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DEPARTMENT OF ENERGY
National Nuclear Security Administration
Los Alamos Site Office
Los Alamos, New Mexico 87544

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Hazardous
Bureau

Mr. James P. Bearzi, Chief
NMED-Hazardous Waste Bureau
2905 Rodeo Park Drive East,
Building 1
Santa Fe, NM 87505-6303

Dear Mr. Bearzi:

Subject: Completion Report for Intermediate Characterization Well LAOI-7

Enclosed are two copies of the Final Completion Report for Intermediate Characterization Well LAOI-7. If you have any questions regarding this report, please contact me at (505)606-0397, or Tom Whitacre at (505)665-5042.

Sincerely,

Edwin L. Wilmot
Manager

ES: 2TW-023

Enclosures

cc w/o enclosures:
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FINAL
COMPLETION REPORT
INTERMEDIATE WELL LAOI-7
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO
PROJECT NO. 49436

Prepared for:

The US Department of Energy and the
National Nuclear Security Administration through the
US Army Corps of Engineers
Sacramento District

Prepared by:

KLEINFELDER

8300 Jefferson NE, Suite B
Albuquerque, New Mexico 87113

January 2006

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LIST OF ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
bgs	below ground surface
BMPs	best management practices
°	degrees
DOE	US Department of Energy
DTW	depth to water
EES-6	Earth and Environmental Sciences Division, Group 6
ft	foot/feet
ft^3	cubic feet
gal.	gallon/gallons
ID	inner diameter
in.	inch/inches
Kleinfelder	Kleinfelder, Inc.
LANL	Los Alamos National Laboratory
NM	not measured
NMED	New Mexico Environment Department
NTU	nephelometric turbidity unit
OD	outer diameter
ppm	parts per million
Qal	Quaternary alluvium
Qbo	Otowi Member of the Bandelier Tuff
Qbog	Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff
RCT	radiation control technician
Spectrum	Spectrum Exploration, Inc.
TA	Technical Area
TD	total depth
TOC	total organic carbon
Tb4	Cerros del Rio basalt/Cerros del Rio maar
Tpf	Puye Formation
μS/cm	microSiemens per centimeter

ABSTRACT

Intermediate Well LAOI-7 was installed in accordance with the "Drilling Work Plan for Intermediate Well LAOI-7, Final" (Kleinfelder 2005a). Drilling activities were funded and directed by the US Department of Energy. Los Alamos National Laboratory personnel provided technical assistance. Kleinfelder, Inc, under contract to the US Army Corps of Engineers, conducted the drilling, installation and sampling at LAOI-7.

LAOI-7 is located in Technical Area 72 in lower Los Alamos Canyon. The well was drilled to identify the western extent of perched intermediate groundwater within the Cerros del Rio basalt found at R-9/R-9i and to help define the eastern extent of contamination in the vadose zone in lower Los Alamos Canyon.

LAOI-7 was drilled to 382.2 feet below ground surface using a track-mounted coring rig and air drilling methods. The stratigraphy encountered during borehole drilling included, in descending order, Quaternary Alluvium, Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed of the Otowi Member, Cerros del Rio basalt, Cerros del Rio maar deposit and the Puye Formation. The well was installed within the Cerros del Rio basalt with a screened interval from 240 to 259.6 feet below ground surface. The depth to water after well installation was 221.48 feet below ground surface.

Six screening groundwater samples were collected during drilling, one from a shallow perched water zone in the Otowi Member and five from perched intermediate groundwater in the Cerros del Rio basalt. A final groundwater sample was collected after the well was installed and developed. Perchlorate was not detected in any samples. Nitrate (as nitrogen) was detected in the shallow aquifer at 0.038 parts per million (ppm), and in four of the six intermediate zone samples at concentrations between 0.003 and 0.37 ppm. Nitrate was not detected in the other two intermediate zone samples with a detection limit of 0.003 ppm. Mercury was detected in both the shallow and perched intermediate zones. Mercury was detected in the shallow aquifer at 0.00101 ppm, and in the perched intermediate zone at concentrations ranging from 0.0023 to 0.025 ppm.

A brief aquifer pumping test was conducted at LAOI-7. The 20-foot-thick perched zone in which the well screen was placed has an average hydraulic conductivity of 16.7 feet per day. During brief pumping and subsequent extended recovery, there was no indication of lateral limits to the saturated perched zone. This, along with correlation to the perched zone in distant well R-9, suggests a laterally extensive perched zone.

1.0 INTRODUCTION

This completion report summarizes the site preparation, drilling, well construction, well development and related activities for Intermediate Well LAOI-7, drilled in August and September 2005 at Los Alamos National Laboratory (LANL). The well was specified in the "Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan" (LANL 2003) and in the Compliance Order on Consent (New Mexico Environmental Department [NMED] 2005).

Drilling activities were funded and directed by the US Department of Energy (DOE). Kleinfelder, Inc. (Kleinfelder), under contract to the US Army Corps of Engineers, was responsible for executing the drilling, installation and sampling activities with technical assistance from LANL. Activities were conducted according to the "Drilling Work Plan for Intermediate Well LAOI-7, Final" (Kleinfelder 2005a).

LAOI-7 is located in lower Los Alamos Canyon within Technical Area 72 (TA-72), as shown in Figure 1.0-1. The well was drilled to identify the western extent of perched intermediate groundwater within the Cerros del Rio basalt found at R-9/R-9i and to help define the eastern extent of contamination in the vadose zone in lower Los Alamos Canyon.

The planning document specified that LAOI-7 would be drilled to 350 feet (ft) below ground surface (bgs), and that a well would be installed if perched intermediate groundwater was encountered. The well was cored to a total depth (TD) of 382.2 ft bgs. Perched intermediate groundwater was encountered within the Cerros del Rio basalt and a well was installed with a single screened interval between 240 and 259.6 ft bgs. Post-installation activities included well development, groundwater sampling, aquifer testing and wellhead surveying.

The information presented in this report was compiled from field reports and activity summaries generated by Kleinfelder, LANL and subcontractor personnel. Original records, including field reports, field logs and survey records, are on file in Kleinfelder's Albuquerque office. Copies have been provided to the LANL Records Processing Facility. This report contains brief descriptions of all activities associated with LAOI-7 as well as supporting figures, tables and appendices. Detailed analysis and interpretation of geologic, geochemical and aquifer data will be included in separate technical documents to be prepared by LANL.

2.0 PRELIMINARY ACTIVITIES

Preliminary activities included preparing administrative planning documents and constructing the drill site.

2.1 Administrative Preparation

Kleinfelder received contractual authorization as a notice to proceed on May 27, 2005. The following documents were prepared to guide the implementation of the scope of work for this well: Drilling Work Plan (Kleinfelder 2005a), Contractor's Quality Management Plan (Kleinfelder 2005b), Site-Specific Health and Safety Plan (Kleinfelder 2005c), and Storm Water Pollution Prevention Plan (Kleinfelder 2005d).

PLACEHOLDER FOR FIGURE 1.0-1

2.2 Site Preparation

Site preparation consisted of clearing the site of vegetation, installing silt fencing to prevent erosion and runoff from the drill site, and setting up the exclusion zone. Best management practices, also known as BMPs, were installed as specified in the Storm Water Pollution Prevention Plan (Kleinfelder 2005d). EnviroWorks, Inc. completed these tasks on July 26, 2005. No cuttings pit was required because LAOI-7 was drilled with a track-mounted core rig without drilling fluids. A radiation control technician (RCT) from LANL's Health, Safety, and Radiation Protection Group-1 screened the site before site preparation activities. A geology trailer, generator, compressor, and safety lighting equipment were moved to the site during the subsequent mobilization of drilling equipment.

3.0 DRILLING ACTIVITIES

LAOI-7 was drilled to a TD of 382.2 ft bgs between August 23 and September 6, 2005. A well was completed with one 20-ft screened interval in the perched intermediate zone from 240 to 259.6 ft bgs. Drilling activities were performed generally in one 12-hour shift per day, 7 days per week, by the drill crew and two site geologists. Depth-to-water (DTW) measurements were taken at the beginning and end of most shifts to check for the presence of groundwater. Recovered core was also inspected for the presence of water. A chronology of drilling and associated activities for LAOI-7 is presented in Table 3.0-1.

Spectrum Exploration, Inc. (Spectrum) drilled LAOI-7 with a Delta Base 540 track-mounted HQ coring rig. LAOI-7 was cored using air; no other fluids were used during coring.

On August 22, 2005, Spectrum mobilized drilling equipment and supplies to the site. On August 23, Spectrum began collecting core with a 2.0-inch (in.) outer diameter (OD) split-spoon sampler, then drilled out the corehole with a 3.9-in. bit. The corehole was then drilled with a 7⅜-in. bit to 45 ft bgs, and temporary 6⅝-in. OD casing was set. Water was noted in the corehole at 26 ft bgs; water sample EU0507LAOI701 was collected from 24.5 ft bgs in the open corehole. On August 24, the corehole was cored/drilled as above and temporary casing was set to 75 ft bgs.

On August 25, water was measured in the casing at 73.40 ft bgs, but the core run from 77.6 to 82.6 ft bgs was dry, indicating that the water-bearing zone was higher in the corehole. The corehole was advanced from 75 to 161.9 ft bgs; no water was observed in the core.

On August 26, the corehole was advanced to 172 ft bgs. The drill pipe separated above the core barrel at approximately 164 ft bgs as the pipe and barrel were being tripped out of the hole.

On August 27, the drill crew attempted to retrieve the core barrel and bit, but was initially unsuccessful. A video log was run that showed the top of the core barrel had been damaged. On August 28, the drill crew successfully retrieved the core barrel and bit from the borehole. No water was measured at 172 ft bgs. Core was collected to a depth of 211.9 ft bgs and no water was observed.

On August 29, core was collected from 211.9 to 272.2 ft bgs. Two water-bearing zones were observed in the basalt: from 237.2 to 242.2 ft bgs, and from 256.8 to 262.2 ft bgs. The water

Table 3.0-1
Chronology of Activities

TASK	DATES																			
	Jul-05	Aug-05				Sep-05				Oct-05		Nov-05		Dec-05				Jan-06	
SITE PREPARATION ACTIVITIES	7/26																		
BOREHOLE DRILLING/SAMPLING																			
Mobilization				8/22															
Coring					8/23-9/6														
Groundwater Screening Sampling				8/23,29,30,31		9/6													
BOREHOLE LOGGING																			
Geophysical Logging							9/7-8												
Video Logging					8/27		9/8												
WELL CONSTRUCTION							9/8-21												
WELL DEVELOPMENT									9/29-30										
GROUNDWATER WELL SAMPLING									9/30										
AQUIFER TESTING														12/6					
PUMP INSTALLATION															12/9				
SITE RESTORATION[a]																			

[a] Site Restoration will begin in the Spring of 2006 after all groundwater analytical results from stored water are received and permission to discharge is obtained.

levels stabilized at approximately 221 ft bgs for both zones and two water samples were collected, EU0507LAOI702 and EU0507LAOI703, respectively.

On the morning of August 30, water was measured in the drill casing at 269.4 ft bgs. Core was collected between 272.2 and 286.8 ft bgs when water was again observed in the core barrel in the 282.2 to 286.8 ft bgs run. Drilling was stopped to measure water levels; the level rose from 264.8 to 237.0 ft bgs over approximately 2.5 hours. Water sample EU0507LAOI704 was collected at 242.3 ft bgs. The corehole was then advanced to 319.8 ft bgs; DTW at the end of the day was 222.2 ft bgs.

On the morning of August 31, DTW was measured at 221.2 ft bgs. Core was collected to a depth of 365.5 ft bgs. After the drill string was removed at the end of the day, a groundwater sample (EU0507LAOI705) was collected from just below the water level of 224.6 ft bgs.

From September 1 to 4, no drilling activities were conducted but DTW was measured either daily or at morning and evening; water levels rose gradually from 223.4 to 222.3 ft bgs in the open corehole over the 3-day period.

On September 6, at a corehole depth of 365.5 ft bgs, a final screening groundwater sample (EU0507LAOI706) was collected from approximately 222.27 ft bgs with a disposable bailer. The corehole was advanced to the final TD of 382.2 ft bgs.

4.0 SAMPLING ACTIVITIES

This section describes the core and groundwater sampling at LAOI-7. Sampling activities were generally conducted in accordance with the Drilling Plan (Kleinfelder 2005a).

4.1 Core Sampling

Lithologic core was continuously collected at LAOI-7 using a 2.0-in. OD split-spoon sampler. The Drilling Plan specified that core samples were to be collected for laboratory analysis every 10 ft to a depth of 100 ft bgs and at 50-ft intervals thereafter. Radiological screening samples were to be collected every 50 ft.

Table 4.1-1 shows the core samples collected and submitted for laboratory analysis. Core recovery was intermittent at LAOI-7; when core recovery was incomplete, samples were collected from core nearest to the specified sampling depth. Core samples from 100, 150 and 200 ft bgs were not submitted for analysis because those intervals consisted of dense lava with such low matrix porosity that contaminants would not be retained. The core from LAOI-7 was labeled and archived in core boxes and submitted to the Field Sampling Facility. LANL RCTs screened all cuttings before they were removed from the site.

4.2 Water Sampling

Six screening groundwater samples were collected from the open borehole with disposable bailers during drilling at LAOI-7. Screening samples were collected from several feet below the DTW measured at the time of collection. A final groundwater sample was collected from 255 ft bgs in the well after development was complete. Table 4.2-1 summarizes dates and collection depths for the water samples. The groundwater samples were submitted to the LANL Earth and Environmental Sciences Division, Group 6 (EES-6) for anions, cations and metals analyses.

Table 4.1-1
Core Samples

Sample ID	Date	Time	Interval (ft bgs)	Radio-logical Screening	Anions, Moisture, $N^{14}N^{15}$[a]	H^{3}[b]	$D^{2}H$ + $O^{18}O^{16}$[c]	Am^{241} + GS + ISO Pu + Sr^{90}[d]
GWi7-05-63255	8/23/05	9:55	7.5-10.7	X	X	X	X	X
GWi7-05-63256	8/23/05	10:44	17.6-20.2	X	X	X	X	X
GWi7-05-63257	8/23/05	11:20	27.6-30.1	X	X	X	X	X
GWi7-05-63258	8/23/05	12:02	40.6-42.0	X	X		X	
GWi7-05-63259	8/24/05	7:58	47.6-49.9	X	X	X	X	X
GWi7-05-63260	8/24/05	8:41	57.6-59.8	X	X	X	X	X
GWi7-05-63261	8/24/05	12:07	70.1-72.0	X	X	X	X	X
GWi7-05-63262	8/25/05	8:25	77.6-78.1	X	X			
GWi7-05-63263	8/25/05	9:05	87.6-88.1	X	X			
GWi7-05-63264	8/30/05	16:45	252.0-253.4	X	X	X	X	X
GWi7-05-63265	8/30/05	15:45	308.3-309.8	X	X	X	X	X
GWi7-05-63266	9/6/05	14:01	377.2-378.8	X	X			

[a] nitrogen 14 and 15 isotopes
[b] tritium
[c] deuterium and oxygen isotopes
[d] americium-241, gamma spectroscopy, plutonium isotopes and strontium-90

Table 4.2-1
Groundwater Samples

Sample Number	Date	DTW (ft bgs)	Corehole Depth (ft bgs)	Water-bearing Unit
EU0507LAOI701	8/23/05	24.5[a]	27.6	Otowi Member
EU0507LAOI702	8/29/05	221.1[a]	242.2	Cerros del Rio basalt
EU0507LAOI703	8/29/05	221.5[a]	262.2	Cerros del Rio basalt
EU0507LAOI704	8/30/05	242.3[a]	286.8	Cerros del Rio basalt
EU0507LAOI705	8/31/05	224.6[a]	364.7	Cerros del Rio basalt/maar
EU0507LAOI706	9/6/05	222.27[a]	363.25	Cerros del Rio basalt/maar
EU0507LAOI707	9/30/05	255[b]	264.9 (well casing depth)	Cerros del Rio basalt

[a] Sample collected with disposable plastic bailer just below water level in open corehole
[b] Sample collected from completed well after well development

5.0 BOREHOLE LOGGING

Video and geophysical logs were run at LAOI-7. Table 5.0-1 summarizes the dates and types of logging. A DVD of the September 8, 2005 video log is presented in Appendix C, and Appendix D contains the geophysical logging spreadsheets and charts.

Table 5.0-1
Borehole Logging

Operator	Date	Tools	Cased Footage (ft bgs)	Open hole Interval (ft bgs)	Logged Interval (ft bgs)	Remarks
Kleinfelder	8/27/05	Video	None	0 – 162	0 – 162	Video camera was used to assist in retrieving core barrel
LANL	9/7/05	Natural Gamma	0 – 230[a]	230 – 382.5	0 – 380	Water level at 221.75 ft bgs
LANL	9/8/05	Video	0 – 230[a]	230 – 382.5	230 – 380.5	None
Kleinfelder	9/8/05	Induction	0 – 230[a]	230 – 382.5	235 – 380.5	None

[a] Drill casing was in the corehole to 230 ft bgs.

6.0 HYDROGEOLOGY

This section contains a brief description of the hydrogeologic features encountered at LAOI-7. The stratigraphy section discusses geologic units at LAOI-7 as identified by the site geologists and LANL's EES-6 staff. The groundwater section describes groundwater encountered at LAOI-7 and is based on drilling observations, open-hole video logging and water level measurements.

6.1 Stratigraphy

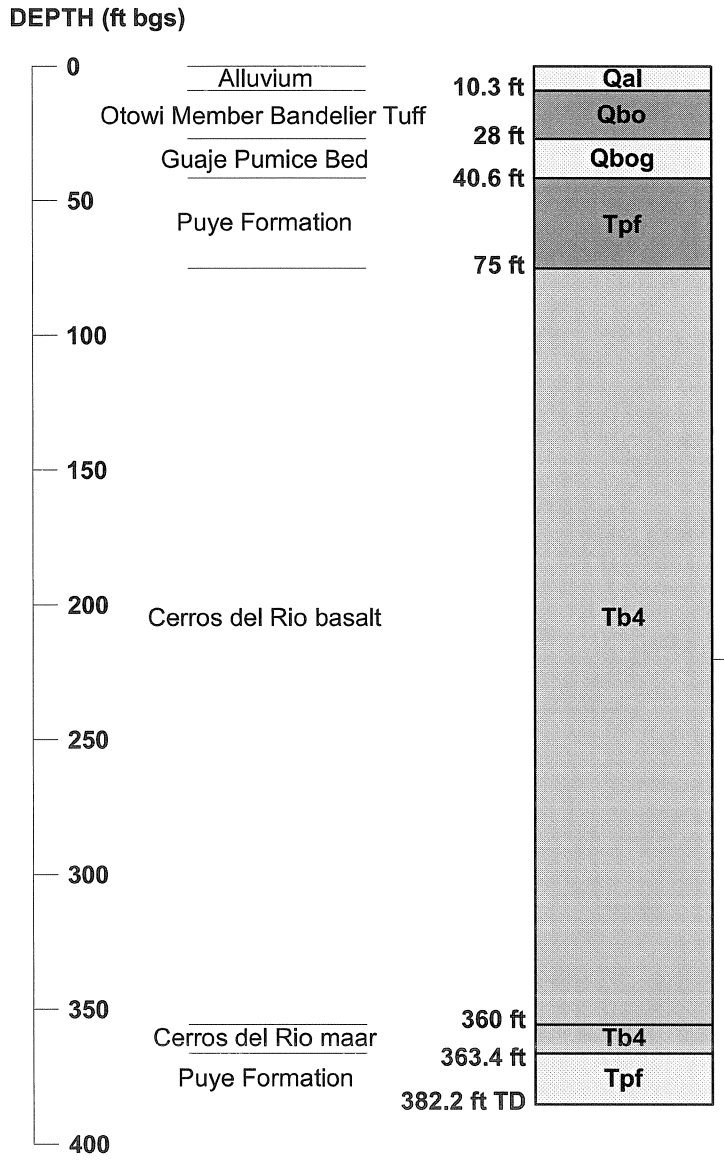
This section presents a brief summary of the lithology encountered at LAOI-7. The following formations were present in order of youngest to oldest: Quaternary Alluvium, Otowi Member ash flows of the Bandelier Tuff, Guaje Pumice Bed of the Otowi Member, Puye Formation, Cerros del Rio basalt, Cerros del Rio maar deposit and the Puye Fanglomerate. Figure 6.1-1 summarizes the local stratigraphy at LAOI-7 and Figure 6.1-2 shows the site stratigraphy plotted with the gamma geophysical log. A detailed lithologic log for LAOI-7 is presented in Appendix A.

Quaternary Alluvium, Qal (0 to 10.3 ft bgs)

The surficial alluvial deposits were primarily unconsolidated silty sand and gravel, ranging in color from yellowish brown to brownish gray. They were poorly sorted, angular to subrounded, felsic to intermediate composition volcanic silt, sand and gravel.

Otowi Member ash flows of the Bandelier Tuff, Qbo (10.3 to 28 ft bgs)

The ash flows of the Otowi Member of the Bandelier Tuff were present from 10.3 to 28 ft bgs. The very pale orange, poorly welded tuff contained 3 to 5% intermediate composition volcanic lithic fragments and 5 to 7% vitric pumice fragments in a fine ash matrix.



DRILLING INFORMATION

DRILLING COMPANY/PERSONNEL

Spectrum Exploration
S. Jager, R. Padillo, B. Husted

DRILL RIG Delta Base 540

DRILLING METHOD

- ☐ HOLLOW-STEM AUGER
- ☐ AIR ROTARY
- ☐ MUD/WATER ROTARY
- ☒ HQ Coring

DRILLING FLUID TYPE

- ☐ BENTONITE
- ☐ WATER
- ☐ POLYMER
- ☒ AIR

DRILLING START / FINISH

DATE 08/23/05 TIME 07:39
DATE 09/06/05 TIME 19:22

221.6 ft bgs
(09/08/05 after logging at TD of 382.2 ft bgs)

Note:
Geologic contacts are preliminary and subject to change.

KLEINFELDER		BOREHOLE SUMMARY DATA SHEET **Intermediate Well LAOI-7** Los Alamos Canyon Los Alamos, New Mexico	FIGURE **6.1-1**
Drawn By: C. Bhongir	Date: January 2006		
Project No.: 49436	Filename: 49436_02_0.dwg		
Scale: not-to-scale	Revision: –		

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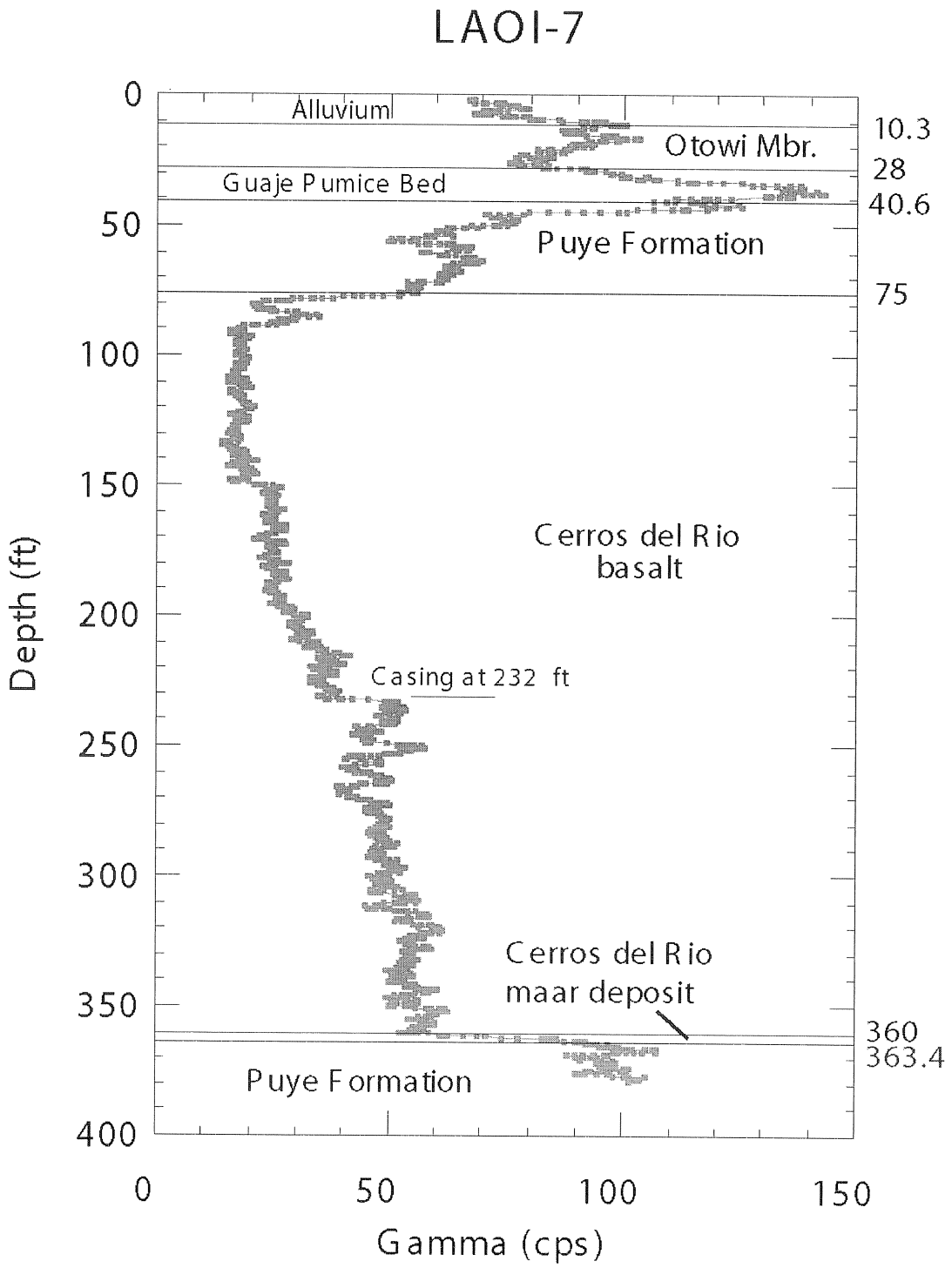


Figure 6.1-2. Gamma Log and LAOI-7 Stratigraphy

Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff, Qbog (28 to 40.6 ft bgs)

The Guaje Pumice Bed was present from 28 to 40.6 ft bgs. The pumice was also very pale orange and contained 45 to 85% white, vitric pumice in a fine ash matrix. It commonly contained anhedral quartz phenocrysts up to 2 millimeters in size.

Puye Formation, Tpf (40.6 to 75 ft bgs)

The sedimentary Puye Formation, from 40.6 to 75 ft bgs, consisted of light brown, sandy silt and silty sand that was angular to subrounded, moderately to well sorted and poorly consolidated. It contained minor amounts of vitric pumice and lithic gravel.

Cerros del Rio basalt, Tb4 (75 to 360 ft bgs)

Lavas of the Cerros del Rio basalt comprised the majority of the corehole at LAOI-7, extending from 75 to 360 ft bgs. The basalt lavas consisted of medium dark gray to brownish gray, highly fractured, vesicular zones alternating with medium dark gray, massive basalt containing few vesicles. Both vesicular and massive basalts contained only 1 to 5% moderate olive brown olivine phenocrysts. Two thin interflow breccia zones were noted at from 234.2 to 236.2 ft bgs and from 333.8 to 336.6 ft bgs. Secondary clay commonly filled vesicles and fractures throughout the formation.

Cerros del Rio maar deposit, Tb4 (360 to 363.4 ft bgs)

The Cerros del Rio maar deposit was present from 360 to 363.4 ft bgs. This hydromagmatic deposit contained fragmented basaltic lava that came in contact with surface or near-surface water. It consisted of darker green, laminated, well sorted, basaltic glass grains in the upper portion with green, finer grained ash containing 3% quartz (entrained detritus) and olivine crystals and basaltic glass grains in the lower portion.

Puye Formation, Tpf (363.4 to 382.2 ft bgs)

The Puye Fanglomerate was present from 363.4 ft bgs to the TD of 382.2 ft bgs and consisted of interbedded sandy siltstone, sandstone and conglomerate. The siltstone and sandstone deposits were dusky to dark yellowish brown and moderately to well sorted. The sand grains were primarily subangular to subrounded intermediate composition volcanics. The conglomerate was light to dark gray, brownish gray and grayish red, containing 70% rounded to subrounded, intermediate composition volcanic gravel and cobbles and 30% felsic, mafic and intermediate composition volcanic sand.

6.2 Groundwater

Shallow and intermediate perched groundwater zones were encountered at LAOI-7. A shallow zone was noted at 26 ft bgs within the Otowi Member of the Bandelier Tuff.

Perched intermediate groundwater was observed in the Cerros del Rio basalt from approximately 237.2 to 242.2 ft bgs in an interval marked by vertical and high-angle fractures. Another interval of perched groundwater occurred from 256.8 to 262.2 ft bgs within a rubble zone. A third zone of perched groundwater was noted in more massive basalt with minor vesicles between 282.2 and 286.8 ft bgs.

At the borehole TD of 382.2 ft bgs on September 8, 2005, standing water was measured in the open borehole at 221.6 ft bgs. After the well was installed, the DTW was 221.48 ft bgs on September 20, 2005.

6.3 Preliminary Groundwater Analytical Results

Analytical data for the seven groundwater samples collected from LAOI-7 are presented and briefly summarized in Appendix B. Perchlorate was not detected in any of the groundwater samples. Nitrate (as nitrogen) was detected in the shallow aquifer at 0.038 parts per million (ppm), and in four of the six intermediate zone samples at concentrations between 0.003 and 0.37 ppm. Nitrate was not detected in the other two intermediate zone samples at an IDL of 0.003 ppm. Mercury was detected in both the shallow and perched intermediate zones. Mercury was detected in the shallow aquifer at 0.00101 ppm, and in the perched intermediate zone at concentrations ranging from 0.0023 to 0.025 ppm.

7.0 WELL INSTALLATION

Data from geophysical logs, core, and water level measurements were evaluated to determine the placement of the screened interval for the well. The well was installed between September 8 and 21, 2005.

7.1 Well Design

The well was designed in accordance with LANL Standard Operating Procedure for Well Construction, Revision 3 (LANL 2001); DOE and LANL provided an approved well design to Kleinfelder. The design called for a single screened interval from 240 to 260 ft bgs to monitor groundwater quality in the intermediate perched zone within the Cerros del Rio basalt. NMED reviewed the well design prior to well installation.

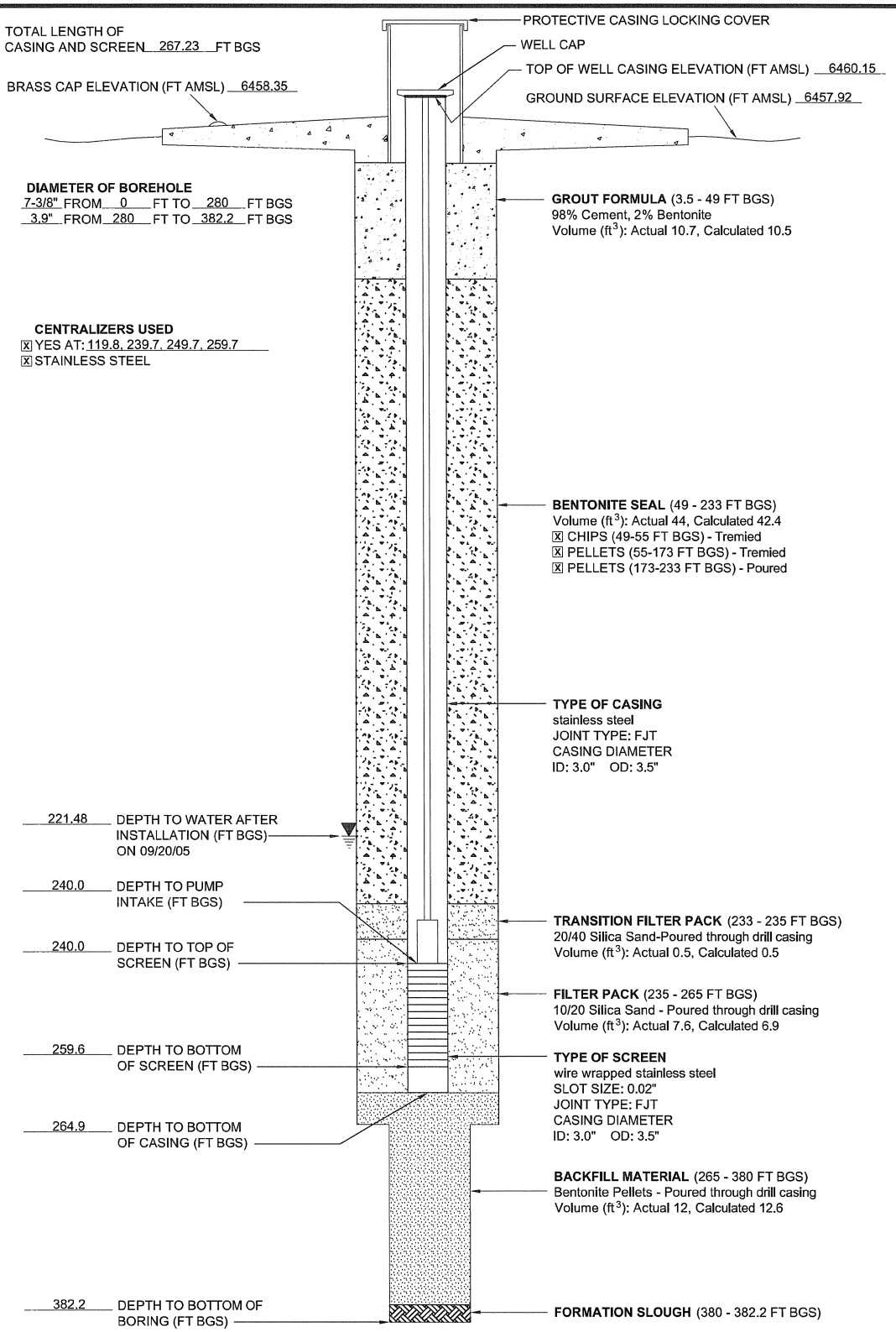
7.2 Well Construction

LAOI-7 was constructed of 3.0-in. inner diameter (ID)/3.5-in. OD, type A304 stainless steel casing fabricated to American Society for Testing and Materials (ASTM) A312 standards. Two nominal 10-ft lengths of 3.5-in. OD, rod-based, 0.020-in. wire-wrapped well screen were used. The casing and screen were factory-cleaned before shipment and delivery to the site.

DOE and LANL personnel decided to backfill the bottom 100-ft of the corehole with bentonite so that the well could be installed to monitor perched intermediate groundwater within the Cerros del Rio basalt. The screened interval chosen for the well was 240 to 260 ft bgs. A 5-ft-deep sump of stainless steel casing was placed below the well screen. Figure 7.2-1 is an as-built schematic showing construction details for LAOI-7.

The drill casing was set at 230 ft bgs and coated bentonite pellets were poured through the drill casing to fill the interval from 380 to 281 ft bgs. Drill casing was then advanced to 280 ft bgs and the bentonite seal was tagged. The casing was pulled up to 260 ft bgs, and bentonite pellets were added to 265 ft bgs.

The well casing, screen and sump were then lowered into the corehole and the annular materials were added between the drill casing and the stainless steel well casing. The primary filter pack of 10/20 silica sand was installed between 265 and 235 ft bgs. After emplacement of the filter pack, the drillers used a swabbing tool to settle the filter pack along the screened interval. A transition filter pack of 20/40 silica sand was then placed from 235 to 233 ft bgs. A bentonite seal was installed above the fine sand collar to a depth of 49 ft bgs. The cement grout surface seal was



WELL DEVELOPMENT INFORMATION

WELL COMPLETION BEGAN
DATE 09/08/05 TIME 16:30
WELL COMPLETION FINISHED
DATE 09/21/05 TIME 08:25

WELL DEVELOPMENT BEGAN
DATE 09/29/05 TIME 09:40
WELL DEVELOPMENT FINISHED
DATE 09/30/05 TIME 17:00

DEVELOPMENT METHOD
X SWABBING X BAILING
X PUMPING
TOTAL PURGE VOLUME 3,594 GALLONS

FINAL PARAMETER MEASUREMENTS
pH 7.12
TEMPERATURE 16.9 °C
SPECIFIC CONDUCTANCE 194 µS
TURBIDITY 0.99 NTU

KLEINFELDER

Drawn By: C. Bhongir	Date: January 2006
Project No.: 49436	Filename: 49436_03_0.dwg
Scale: not-to-scale	Revision: –

WELL SCHEMATIC
Intermediate Well LAOI-7
Los Alamos Canyon
Los Alamos, New Mexico

FIGURE
7.2-1

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emplaced from 49 to 3.5 ft bgs; it consisted of 98% cement and 2% bentonite. Table 7.2-1 summarizes the volumes of annular fill materials used to complete LAOI-7.

Table 7.2-1
Annular Fill Materials

Material	Volume
Surface seal: cement grout seal	10.7 ft^3
Bentonite seal: bentonite chips/pellets	44.0 ft^3
Transition filter pack: 20/40 silica sand	0.5 ft^3
Primary filter: 10/20 silica sand	7.6 ft^3
Backfill material: bentonite pellets	12 ft^3
Potable water	251gallons (gal.)

ft^3 = cubic feet

8.0 POST-INSTALLATION ACTIVITIES

Following well installation, the well was developed and the wellhead was completed and surveyed. Site restoration activities will commence when NMED permission to discharge fluids has been received.

8.1 Well Development

LAOI-7 was developed on September 29 and 30, 2005. The development crew initially bailed and swabbed the screened interval to help remove formation fines and filter pack sand from the well. Approximately 10 gal. of water were removed during swabbing and bailing. A 3-in. Grundfos submersible pump was used for the final stage of well development. The pump intake was set within the screened interval at 255 ft bgs, and 3,584 gal. of water were removed.

Turbidity, pH, temperature, specific conductance, and total organic carbon (TOC) were measured during development; these parameters were required to stabilize before terminating well development. The parameters stabilized over approximately 8 hours. The final turbidity reading was 0.99 and the TOC level was 0.5 ppm, less than the target TOC concentration of 2.0 ppm. Table 8.1-1 shows the volume of water removed during well development and the resultant water quality parameters and TOC levels. Figure 8.1-1 shows the water quality parameters measured during the course of well development.

Table 8.1-1
Final Water Quality Parameters

Method	Water Removed (gal.)	pH	Temper-ature (°Celsius)	Specific Conductance (µS/cm)	Turbidity (NTUs)	Total Organic Carbon (ppm)
Bailing/Swabbing	10	7.99	15.3	238	NM	NM
Pumping	3,584	7.12	16.9	194	0.99	0.5
Aquifer testing	459	NM	NM	NM	NM	NM

µS/cm = microSiemens per centimeter
NM = not measured
NTU = nephelometric turbidity units

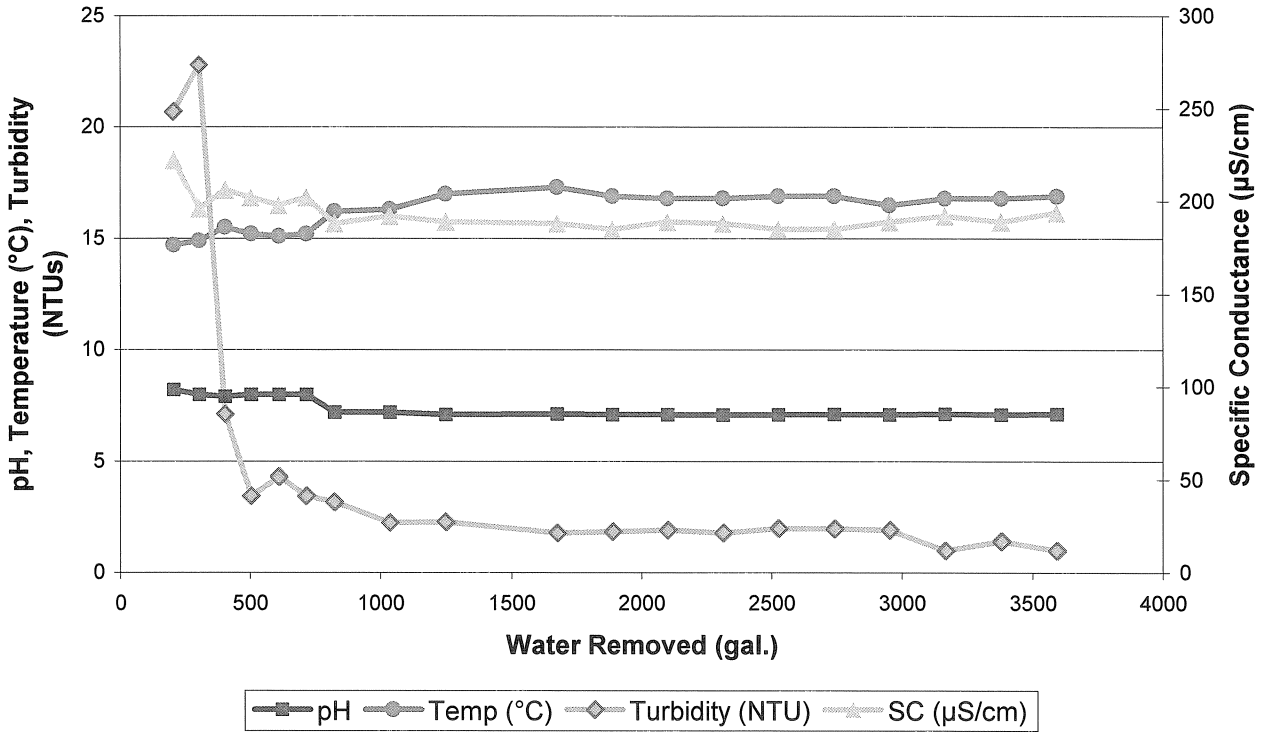

Figure 8.1-1. Water Quality Parameters During Development

8.2 Aquifer Testing

A 2-hour aquifer pumping test was conducted at LAOI-7 on December 6, 2005. The test was terminated after only 2 hours due to limited aboveground water storage capacity. The complete report and associated figures are presented in Appendix E. The key results from the test are as follows:

- In contrast to most of the wells on the Pajarito Plateau, which are nearly 100% barometrically efficient, the barometric efficiency of LAOI-7 was estimated at 18%.
- The background data suggested a background water level decline of a few hundredths of a foot per day.
- While the water level decline that was observed during the testing effort can be explained by the combination of the estimated barometric efficiency of 18% and the presumed background water level trend, it is also possible that it was due solely to barometric pressure changes and a near-zero barometric efficiency. A longer background monitoring period would be required to distinguish between these possibilities.
- Casing storage effects were significant because the inflatable packer could not be employed in the 3-in. well casing.

- The 20-ft-thick perched zone in which the well screen was placed has an average transmissivity of approximately 2,500 gallons per day per foot and an average hydraulic conductivity of 16.7 feet per day.
- The transmissivity appeared to increase away from the well as the cone of depression expanded into a complex array of fracture zones within the Cerros del Rio basalt. The observed flattening of the drawdown and recovery curves could alternatively be explained by leakage from underlying saturated materials.
- Water storage limitations constrained the duration of pumping to just a couple of hours. During brief pumping and subsequent extended recovery, there was no indication of lateral limits to the saturated perched zone. This, along with correlation to the perched zone in distant well R-9, suggests a laterally extensive perched zone.

8.3 Dedicated Sampling System Installation

A dedicated 1.4-in. OD, 0.5 to 0.7 variable horsepower Grundfos submersible pump, Model PI-0126, was installed at LAOI-7 on December 9, 2005. The pump intake was set at 240.0 ft bgs. A ⅞-in. ID PVC transducer tube was installed to 240.3 ft bgs, with a slotted interval from 230.3 to 240.3 ft bgs.

8.4 Wellhead Completion

A reinforced 2,500 pounds per square inch concrete pad, 5 ft by 5 ft by 6 in. thick, was installed around the well casing to provide long-term structural integrity for the well and to prevent surface water from flowing down the outside of the casing. A brass survey pin was embedded in the northwest corner of the pad. A 10.75-in. diameter steel casing with a locking lid was installed to protect the well riser. The concrete pad was elevated slightly above the ground surface, with base-course gravel graded up around the edges.

8.5 Geodetic Survey

Table 8.5-1 presents the geodetic survey data for LAOI-7.

Table 8.5-1
Geodetic Data

Description	Northing	Easting	Elevation[a]
Brass cap in LAOI-7 pad	1771584.11	1644788.53	6458.35
Top of stainless steel casing	1771582.28	1644789.47	6460.15
Ground surface beside pad	1771585.71	1644787.86	6457.92

[a] Measured in feet above mean sea level relative to the National Geodetic Vertical Datum of 1929.

8.6 Site Restoration

Fluids produced during drilling and development were containerized and sampled in accordance with the July 12, 2005 "Waste Characterization Strategy Form" prepared for the 2005 well drilling program at LANL (Appendix C in Kleinfelder 2005a). Fluid sample results will be

compared to the State of New Mexico Water Quality Control Commission Regulation 3103 groundwater standards and applicable Resource Conservation and Recovery Act regulatory limits. Water generated during drilling, development and aquifer testing will be discharged in accordance with the "Workplan Notice of Intent Decision Tree," revised July 15, 2002, and in coordination with NMED. Site restoration will include removing the silt fencing and reseeding the site.

All groundwater samples required by NMED have not been collected because the water in the storage tanks is currently frozen. Once water has been collected and analyzed and permission to discharge has been obtained, a separate memorandum will be issued documenting the results and discharge approval.

9.0 DEVIATIONS FROM PLANNED ACTIVITIES

Appendix F compares the actual drilling and well construction activities at LAOI-7 with the planned activities described in the Drilling Work Plan. In general, drilling, sampling, and well construction were performed as specified in the Drilling Work Plan. The main deviations from planned activities were:

- Planned Borehole Depth – The Drilling Work Plan called for the borehole to be drilled to a target TD of 350 ft bgs; it was drilled to a TD of 382.2 ft bgs.
- Core Sampling – The Drilling Work Plan called for core samples to be submitted for laboratory analysis at 50-ft intervals below 100 ft bgs. However, dense basalt encountered at 100, 150 and 200 ft bgs was not submitted for analysis because contaminants would not be retained in the low porosity matrix.

10.0 ACKNOWLEDGEMENTS

D. Broxton and D. Vaniman of LANL worked with site geologists to identify the geologic contacts.

EnviroWorks, Inc. prepared the drill site.

P. Longmire of LANL evaluated the hydrochemistry.

Spectrum drilled the LAOI-7 corehole and installed the monitoring well.

11.0 REFERENCES

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Kleinfelder, 2005b, Contractor Quality Management Program for the DOE Monitoring Well Installation at Los Alamos National Laboratory, W91238-04-F-0096, Revision 3, May 20, 2005.

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Kleinfelder, 2005d, Storm Water Pollution Prevention Plan for Characterization and Intermediate Wells R-10, R10-a, R16a, R17, R-23i, R-24, R-27, R-3, CdV-16-2(i)r, LADP-5, LAOI-3.2a, and LAOI-7, Los Alamos National Laboratory, Los Alamos New Mexico, July 2005.

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LANL, 2003, Los Alamos Canyon and Pueblo Canyon Intermediate and Regional Aquifer Groundwater Work Plan, Los Alamos National Laboratory, LA-UR-03-9191, Los Alamos, New Mexico.

NMED, 2005, Compliance Order on Consent between New Mexico Environmental Department and Los Alamos National Laboratory and the University of California, March 2005.

Appendix A

Lithologic Log

Geologic Unit	Lithologic Description	Interval (ft bgs)	Elevation (ft amsl)
Quaternary Alluvium (Qal)	Silty sand, dark yellowish brown (10YR 4/2) to grayish brown (5YR 3/7), moderately sorted, non-indurated. Composed of: 60% sand (felsic, angular to subangular) with trace pumice (very light gray (N8), vitric, 2 cm); 40% silt. Rootlets. Damp.	0-2.0	6457.9 – 6455.9
	Silty sand, pale yellowish brown (10YR 6/2) to dark yellowish brown (10YR 4/2), poorly sorted, non-indurated. Composed of: 80% sand, [felsic and intermediate (inter.) composition (comp.) volcanics], angular to subrounded); 15% silt; 5% gravel (inter. comp. volcanics and welded tuff, up to 20 mm, subrounded). Dry.	2.0-6.0	6455.9 – 6451.9
	Gravel, light brownish gray (5YR 6/1), poorly sorted, non-indurated. Composed of: 60% gravel, predominantly inter. comp. volcanics, medium to dark gray (N5-N4), up to 60 mm, angular to subrounded; 40% sand, mixed felsic and varied rock fragments, angular to subrounded. Damp.	6.0-7.5	6451.9 – 6450.4
	Gravelly silty sand, dark yellowish brown (10YR 4/2) to moderate reddish brown (10R 4/6), poorly sorted, non-indurated. Composed of: 80% sand, felsic and inter. comp. volcanics, angular to subrounded; 10% gravel, inter. comp. volcanics, up to 6 cm, subrounded; 10% silt. Damp. • 8.2 feet (ft), gravelly silty sand, as above, with yellowish gray, devitrified pumice. • 8.5-10.3 ft, gravelly silty sand, as above, dry.	7.5-10.3	6450.4 – 6447.6
Otowi Member of the Bandelier Tuff (Qbo)	Tuff, very pale orange (10YR 8/2), poorly welded. Composed of: fine ash matrix; 5-7% pumice, vitric, white to light tan, up to 20 mm, subrounded, minor tan alteration on some pumice edges, minor to common felsic phenocrysts; 3-5% lithics, inter. comp. volcanics, reddish brown and gray to very dark gray, up to 5 mm, generally 1-2 mm, subrounded; 3% felsic phenocrysts, clear, 1 mm, subhedral, common bipyramidal quartz. Dry. Note: The top of the Qbo is 10.3 ft below ground surface (bgs) based on core. • 22.0-28.0 ft, tuff, as above, wet.	10.3-28.0	6447.6 – 6429.9
Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (Qbog)	Pumice Bed, very pale orange (10YR 2/2) to grayish orange (10YR 7/4), poorly welded. Composed of: fine ash matrix; 45-85% pumice, vitric, white (N9) to very light gray (N8), up to 20 mm, rounded to subrounded, common grayish orange alteration on edges; common felsic phenocrysts, predominantly quartz, 1-2 mm anhedral to broken (occasional bipyramidal quartz noted); 1-5% lithics, inter. comp. volcanics, reddish brown to brown and gray to black, 0.5 mm, subhedral to elongate; minor clay lenses, brown with manganese (Mn)-iron (Fe) oxide flecks. Wet. Note: The top of the Qbog is 28.0 ft bgs based on core. • 37.6-40.6 ft, no recovery.	28.0-40.6	6429.9 – 6417.3

Geologic Unit	Lithologic Description	Interval (ft bgs)	Elevation (ft amsl)
Puye Formation (Tpf)	Sandy siltstone/claystone to silty/clayey sandstone, light brown (5YR 5/6), moderately to well sorted, non- to poorly indurated. Composed of: 40-90% silt-clay; 30-60% sand, felsic, subangular; 0-5% gravel, inter. comp. volcanics (gray, up to 5 mm, subangular to rounded) and vitric pumice (white, up to 4 mm, rounded). Dry. Note: The top of the Tpf occurs within an interval with no recovery. It is interpolated to be at 40.6 ft bgs based on geophysical log. • 52.6-55.1 ft, sandy siltstone/claystone, as above, marked increase in clay and induration.	40.6-75.0	6417.3 – 6382.9
Cerros del Rio Basalt (Tb4)	Basalt, medium dark gray (N4) to grayish black (N1), highly fractured/vesicular with decreasing abundance with depth. Composed of: aphanitic groundmass; 3% olivine phenocrysts (moderate olive brown, 1-2 mm, anhedral). Fractures are commonly lined with clay (dark yellowish brown (10YR 5/4)). Dry. Note: No core recovery from 72.6 to 75.0 ft bgs. Note: The top of the Tb4 is interpolated to be 75 ft bgs based on geophysical log. • 75.0-78.1 ft, basalt, as above, with abundant fractures, apertures up to 25 mm, clay-filled, damp. • 82.6-83.3 ft, basalt, as above, near horizontal fractures, 2 mm apertures, clay-filled, damp. • 87.8-88.0 ft, basalt, as above, 20° fracture, 15 mm aperture with clay and basalt fragments, damp. • 88.3-90.3 ft, basalt, as above, high angle fractures, 1 mm apertures, clay-filled, damp. • 94.7ft, basalt, as above, 20° fracture, 2 mm aperture, no clay noted.	75.0-97.6	6382.9 – 6360.3
	Basalt, medium dark gray (N4) to grayish black (N1), massive with minor vesicles. Composed of: aphanitic groundmass; 3% olivine phenocrysts (moderate olive brown, 1-2 mm, anhedral). Trace fractures. Dry.	97.6-116.2	6360.3 – 6341.7
	Basalt, medium dark gray (N4), highly fractured/vesicular with decreasing abundance with depth. Composed of: aphanitic groundmass; 2% olivine phenocrysts (moderate olive brown, 1-2 mm, anhedral). Fractures are commonly clay-lined (dark yellowish brown [10YR 5/4]). Dry. • 116.2-129.0 ft, basalt, as above, dark reddish brown alteration on vesicle surfaces; abundant fractures with apertures up to 5 mm, trace damp clay. • 134.0-142.6 ft, basalt, as above, common low angle fractures, apertures up to 4 mm, trace clay. • 142.6 ft, basalt, as above, marked decrease in vesicle abundance. • 143.2-143.6 ft, basalt, as above, 85° fracture, 3 mm aperture, trace clay. • 146.2-148.2 ft, basalt, as above, common low angle fractures, apertures up to 2 mm, trace clay/clay-filled, damp.	116.2-150.0	6341.7 – 6307.9

Geologic Unit	Lithologic Description	Interval (ft bgs)	Elevation (ft amsl)
	Basalt, medium dark gray (N4), massive with minor vesicles. Composed of: aphanitic groundmass; 5-7% olivine phenocrysts (moderate olive brown, up to 3-4 mm, anhedral). Minor near horizontal fractures, apertures lined with dark yellowish brown (10YR 5/4) dry clay. Dry. • 181.5-182.1ft, basalt, as above, 55° fracture, 2 mm aperture, clay-filled (light brown 5YR 5/6), damp.	150.0-195.3	6307.9 – 6262.6
	Basalt, medium dark gray (N4), vesicular, rubble/highly fractured. Composed of: aphanitic groundmass; 3-10% olivine phenocrysts (moderate olive brown, up to 3 mm, anhedral, rims commonly altered to reddish brown). No clay observed in vesicles or fractures. Dry. • 195.3-198.1ft, basalt, as above, collected as rubble rather than as continuous core. • 209.0-211.9ft, basalt, as above, collected as rubble rather than continuous core. Trace vesicles with grayish orange clay. • 217.0 ft, basalt as above, calcite noted.	195.3-218.6	6262.6 – 6239.3
	Basalt, medium dark gray (N4), massive with minor vesicles (gradational with overlying vesicular basalt). Composed of: aphanitic groundmass with 5-7% olivine phenocrysts (moderate olive brown, up to 5 mm, anhedral, subrounded). Dry. • 231.1-234.2 ft, basalt as above, relative increase in vesicle abundance.	218.6-234.2	6239.3 – 6223.7
	Interflow breccia, medium dark gray (N4), vesicular basalt rubble blocks, generally 30 mm. Basalt composed of: aphanitic groundmass; 3-5% olivine phenocrysts (moderate olive brown, 2 mm, anhedral and subrounded, with reddish brown alteration common on rims); <1% feldspar phenocrysts. Vesicles and rubble lined with light brown (5YR 5/6), waxy clay. Clay lamination noted. Dry to damp.	234.2-236.2	6223.7 – 6221.7
	Basalt, medium dark gray (N4), highly fractured/vesicular. Composed of: aphanitic groundmass; 2-5% olivine phenocrysts (moderate olive brown, 2-3 mm, anhedral, subrounded). Fractures and vesicles lined with light brown, waxy clay. Wet. • 238.6 ft, basalt, as above, vesicle (1 cm by 1.5 cm) with 6 mm laminated clay.	236.2-242.5	6221.7 – 6215.4
	Basalt, medium dark gray (N4), massive with minor vesicles. Composed of: aphanitic groundmass; 3-5% olivine phenocrysts (moderate olive brown, 1-2 mm, anhedral, subrounded, reddish brown alteration along rims). Vesicles and fractures lined with light brown (5Y 5/6), waxy, clay. Wet. • 244.0 ft, basalt, as above, 5° fracture, 1 mm aperture. • 244.1-244.3 ft, basalt, as above, 45° fracture, 2 mm aperture. • 248.1-248.4 ft, basalt, as above, 50° fracture, 1 mm aperture, 40 mm void lined with 2 mm laminated clay. • 248.5-249.0 ft, basalt, as above, marked increase in vesicle abundance.	242.5-249.0	6215.4 – 6208.9

Geologic Unit	Lithologic Description	Interval (ft bgs)	Elevation (ft amsl)
	Basalt, medium gray (N5) to dark greenish gray (5G 4/1), massive with minor vesicles. Composed of: microcrystalline groundmass; 1-5% olivine phenocrysts (moderate olive brown, 2 mm, anhedral, subrounded); 1-3% calcite (clear, up to 20 mm, in voids, vesicles, and freshly exposed surfaces). Vesicles and fractures are filled or lined with light brown (5Y 5/6), waxy clay. Secondary clay-like substance/alteration (grayish yellow green [5GY 7/2]) found filling vesicles and voids. Wet. • 286.6 ft, basalt, as above, calcite in vesicle, 20 mm. • 287.2-287.4 ft, basalt, as above, 55° fracture, 2 mm aperture, trace clay, damp. • 294.8 ft, basalt as above, 20 mm calcite crystals • 296.4-297.2 ft, basalt as above, 80° fracture, 1 mm aperture, trace light brown clay, dry. • 299.0-299.1ft, basalt as above, 30° fracture, 1 mm aperture, trace light brown clay, dry. • 304.7-307.0 ft, basalt as above, abundant fractures, 1-3 mm apertures, trace clay, damp.	282.0-307.0	6175.9 – 6150.9
	Basalt as above, brownish gray (5YR 4/1), rubble to highly fractured, vesicular. Composed of: aphanitic groundmass; 1-2 % olivine phenocrysts (moderate reddish brown to moderate olive brown, 1-2 mm, anhedral). Rubble-zones, fractures and vesicles commonly clay-filled (grayish orange [10YR 7/4], waxy, damp). Wet. • 307.0-312.0 ft, basalt, as above, rubble • 314.2-318.0 ft, basalt, as above, abundant fractures, horizontal to 75°, fracture apertures 1-4 mm, clay-filled to clay-lined.	307.0-318.2	6150.9 – 6139.7
	Basalt, brownish gray (5YR 4/1), massive with minor vesicles. Composed of: aphanitic groundmass; 1% olivine phenocrysts (moderate olive brown, 3 mm, anhedral, subrounded). Trace grayish orange clay in vesicles. Wet. • 320.6-321.0 ft, basalt, as above, 75° fracture, 2 mm aperture, clay filled. • 322.6 ft, basalt, as above, 10° fracture, 2 mm aperture, clay-lined, damp. • 324.7-326.0 ft, basalt, as above, 85° fracture, 2 mm aperture, clay-filled, damp. • 326.2 ft, basalt, as above, 15° fracture, 3 mm aperture, clay filled, damp.	318.2-333.8	6139.7 – 6124.1
	Interflow breccia, medium dark gray (N4), vesicular basalt blocks generally 30 mm. Basalt composed of: aphanitic groundmass; 1-2% olivine phenocrysts (moderate olive brown, 1-2 mm, anhedral, subrounded). Grayish orange (10YR 7/4) to light brown (5YR 5/6) waxy clay lining vesicles and fractures. Wet.	333.8-336.6	6124.1 – 6121.3
	Basalt, medium dark gray (N4), massive with minor vesicles. Composed of: aphanitic groundmass; 1% olivine phenocrysts (moderate olive brown, up to 2 mm, anhedral, subrounded). Wet.	336.6-344.0	6121.3 – 6113.9

Geologic Unit	Lithologic Description	Interval (ft bgs)	Elevation (ft amsl)
	Basalt, medium dark gray (N4), massive with minor vesicles. Composed of: aphanitic groundmass with 2-3% olivine phenocrysts (moderate olive brown, 2-3 mm, anhedral, subrounded). Minor high angle fractures with trace light brown clay (5YR 5/6). Wet. • 348.1-348.3 ft, basalt, as above, 75° fractures, 1 mm aperture, trace clay, damp. • 348.4-348.6 ft, basalt, as above, 50° fracture, 1 mm aperture, trace clay, damp. • 353.1-353.9 ft, basalt, as above, 80° fracture, 10 mm aperture, clay-filled, dry. • 357.7-358.2 ft, basalt, as above, 80° fracture, 2 mm aperture, trace clay, dry. • 359.3-360.0 ft, basalt, as above, marked increase in vesicles and clay.	344.0-360.0	6113.9 – 6097.9
Cerros del Rio Maar (Tb4)	Maar deposit, basaltic glass, medium dark gray (N4), 1-2 mm, rounded to subrounded, well sorted, laminated. Minor loose crystals of quartz and olivine (clear, 1-2 mm, subrounded to rounded). Damp. Note: The top of the Tb4 maar is 360 ft bgs based on core and geophysical log.	360.0-361.2	6097.9 – 6096.7
	Maar deposit, as above, olive gray (5Y 4/1), finer-grained, well sorted, 3% lithics (up to 2 mm, angular). Damp.	361.2-363.4	6096.7 – 6094.5
Puye Formation (Tpf)	Interbedded conglomerate, sandy siltstone/claystone and sandstone: Conglomerate, light gray (N7) to dark gray (N3), brownish gray (5YR 4/1) or grayish red (10R 4/2), poorly sorted, non-indurated. Composed of: 70% gravel to cobbles, inter. comp. volcanics, up to 25cm, rounded to subrounded; 30% sand, inter. comp. volcanics, felsic, and mafic, subangular to rounded. Sandy siltstone/claystone, dark yellowish brown (10YR 4/2) moderately sorted, non-indurated. Composed of: 75% silt/clay; 25% sand, inter. comp. volcanics, subrounded. Sandstone, dusky yellowish brown (10YR 2/2), well sorted, non-indurated. Composed of: 100% sand, inter. comp. volcanics, felsic and mafic, subangular to subrounded. Dry. Note: The top of the Tpf is 363.4 ft based on core. • 363.4-374.5 ft conglomerate, as described above. • 374.5-377.2 ft, sandstone, as described above. • 377.2-377.8 ft, sandy siltstone/claystone, as described above • 377.8-382.2 ft, sandstone, as described above.	363.4-382.2	6094.5 – 6075.7
	TOTAL DEPTH OF COREHOLE WAS 382.2 FT BGS.		6075.7

References

Dutro, J. T., Dietrich, R. V., and Foose, R. M., 1989, American Geological Institute. Data Sheets, 3rd Edition.
Geological Society of America, 1995, Rock-Color Chart, 8th Printing.
Tucker, M.E., 1991, Sedimentary Petrology, An Introduction to the Origin of Sedimentary Rocks, Blackwell Science Limited.

Classification System
Field geologists used principles identified in the AGI Data Sheets (Dutro, J. T, et al., 1989) to describe lithology. Specifically, AGI Data Sheets 32.1, 32.2 and 29.1 (the modified Wentworth scale for grain-size classification) were used for sedimentary units. The AGI approach was augmented by the classification system presented in Sedimentary Petrology, An Introduction to the Origin of Sedimentary Rocks (Tucker, 1991).

Groundwater Occurrence
Please refer to Section 6.2 of the report for a description of groundwater occurrence.

Acronyms and Abbreviations
amsl – above mean sea level
bgs – below ground surface
cm – centimeter
ft – feet/foot
mm – millimeter

Appendix B

Groundwater Analytical Results

1.0 SAMPLING AND ANALYSIS OF GROUNDWATER AT LAOI-7

Shallow groundwater within the Otowi Member of the Bandelier Tuff and perched intermediate zone groundwater within the Cerros del Rio basalt were encountered at LAOI-7. Six screening groundwater samples were collected from the open borehole with disposable bailers during drilling at LAOI-7. A final groundwater sample was collected from 255 feet (ft) below ground surface (bgs) after well development was complete. All of the samples were analyzed for anions, including perchlorate, and metals. During development, water samples were also submitted for total organic carbon (TOC) analysis.

1.1 Analytical Techniques

Groundwater samples were filtered prior to analysis for metals, trace elements, and major cations and anions. Aliquots of the samples were filtered through 0.45-micrometer (μm) Gelman filters. Samples were acidified with analytical grade nitric acid (HNO_3) to a pH of 2.0 or less for metal and major cation analyses. Total carbonate alkalinity was measured at Los Alamos National Laboratory's Environmental and Earth Sciences Group 6 (EES-6) using standard titration techniques. Samples collected for TOC analyses were not filtered.

Groundwater samples were analyzed by EES-6 using techniques specified in the US Environmental Protection Agency SW-846 manual. Ion chromatography (IC) was the analytical method for bromide, chloride, fluoride, nitrate, nitrite, oxalate, perchlorate, phosphate, and sulfate. The instrument detection limits (IDLs) for perchlorate analyses were 0.001 and 0.0005 parts per million (ppm) for LAOI-7 samples.

Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was used for calcium, magnesium, potassium, silica, and sodium. Aluminum, antimony, arsenic, barium, beryllium, cadmium, cesium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, nickel, rubidium, selenium, silver, thallium, thorium, tin, vanadium, uranium, and zinc were analyzed by inductively coupled (argon) plasma mass spectrometry (ICPMS). The precision limits (analytical error) for major ions and trace elements were generally less than ±10% using ICPOES and ICPMS.

1.2 Analytical Results

Analytical results for groundwater samples collected at LAOI-7 are provided in Table 1.2-1. Perchlorate was not detected in the seven groundwater samples collected at LAOI-7. Nitrate (as N) was detected in the shallow aquifer at 0.038 ppm, and in four of the six intermediate zone samples at concentrations between 0.003 and 0.37 ppm. Nitrate was not detected in the other two intermediate zone samples at an IDL of 0.003 ppm. Mercury was detected in both the shallow and perched intermediate zones. Mercury was detected in the shallow aquifer at 0.00101 ppm, and in the perched intermediate zone at concentrations ranging from 0.0023 to 0.025 ppm. TOC was not detected in a groundwater sample collected after well development on September 30, 2005, with an IDL of 0.5 milligrams of carbon per liter.

Table 1.2-1. Hydrochemistry of Groundwater Samples Collected from Shallow and Perched Intermediate Groundwater at LAOI-7 (filtered samples)

SAMPLE ID	**EU0507 LAO1701**	**EU0507 LAOI702**	**EU0507 LAOI703**	**EU0507 LAOI704**	**EU0507 LAO1705**	**EU0507 LAO1706**	**EU0507 LAOI707**
SAMPLE TYPE	During drilling	During drilling	During drilling	During drilling	During drilling	During drilling	After development
DEPTH (ft bgs)	24.48	221.1	221.5	242.3	224.6	222.3	255
GEOLOGIC UNIT	Otowi Member	Cerros del Rio basalt	Cerros del Rio basalt	Cerros del Rio basalt	Cerros del Rio basalt/maar	Cerros del Rio basalt/maar	Cerros del Rio basalt
DATE	08/23/05	08/29/05	08/29/05	08/30/05	8/31/05	09/06/05	9/30/05
Charge Balance (%)	-1.16	-5.16	-4.10	-4.46	+0.50	+2.02	-1.08
pH (Lab)	7.00	8.49	7.06	8.82	7.37	6.84	7.23
Ag (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Al (ppm)	0.17	0.17	0.064	1.07	0.88	0.26	0.010
Alkalinity (ppm $CaCO_3$/L)	33.7	74.0	59.4	81.9	66.2	59.4	52.7
As (ppm)	0.0006	0.0012	0.0006	0.0011	0.0006	0.0002	0.0003
B (ppm)	0.15	0.095	0.090	0.13	0.084	0.073	0.031
Ba (ppm)	0.32	0.34	0.33	0.42	0.38	0.37	0.022
Be (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Br (ppm)	0.34	0.09	0.08	0.08	0.08	0.08	0.07
Ca (ppm)	14.0	9.99	13.3	11.1	13.6	15.5	14.2
Cd (ppm)	U [0.001]	U 0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Cl (ppm)	37.1	20.7	19.7	20.2	19.2	19.6	19.5
ClO_4 (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.0005]
Co (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
CO3 (ppm)	0	7.5	0	11.0	0	0	0
Cr (ppm)	0.0015	0.0026	0.0024	0.0028	0.0015	0.0015	U [0.001]
Cs (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Cu (ppm)	0.0016	0.0019	0.0014	0.0050	0.0027	0.0027	0.0016
F (ppm)	0.38	0.74	0.33	0.69	0.48	0.38	0.16
Fe (ppm)	0.05	0.11	0.03	0.43	0.38	0.10	0.02
HCO_3 (ppm)	41.1	75.0	72.5	77.6	80.8	72.5	64.3
Hg (ppm)	0.00101	0.0166	0.0059	0.0080	0.025	0.0052	0.0023
K (ppm)	5.50	4.70	3.99	5.10	6.62	4.96	4.85
Li (ppm)	0.0061	0.050	0.025	0.021	0.018	0.013	0.0062
Mg (ppm)	3.70	4.72	6.13	5.26	6.51	6.36	6.17
Mn (ppm)	0.034	0.0039	0.050	0.0087	0.041	0.15	0.0026
Mo (ppm)	0.0069	0.0072	0.0025	0.0081	0.015	0.066	0.0018
Na (ppm)	17.6	25.0	12.8	27.1	16.4	13.7	10.2
Ni (ppm)	0.0026	U [0.001]	0.0022	0.0011	0.0011	0.0014	0.0014
NO_2(as N) (ppm)	U [0.002]	U [0.002]	0.003	0.015	U [0.002]	U [0.002]	U [0.002]
NO_3(as N) (ppm)	0.038	0.003	0.33	0.37	U [0.003]	U [0.003]	0.33
C_2O_4 (ppm)(oxalate)	U [0.01]	0.06	0.03	0.05	U [0.01]	U [0.01]	U [0.01]
Pb (ppm)	0.0004	U [0.0002]	U [0.0002]	0.0003	0.0006	0.0005	U [0.0002]
PO_4 (ppm)	U [0.01]	1.45	0.48	1.45	0.13	0.02	0.11
Rb (ppm)	0.018	0.0071	0.0071	0.0059	0.012	0.0077	0.018
Sb (ppm)	U [0.001]	0.0031	0.0011	0.0014	0.001	0.002	U [0.001]
Se (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
SiO_2 (ppm)	67.9	39.3	51.4	40.0	44.7	31.1	55.4
SO_4 (ppm)	10.11	9.52	9.67	9.41	8.62	8.96	8.98
Sn (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Sr (ppm)	0.074	0.048	0.068	0.061	0.084	0.081	0.080
Th (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
Ti (ppm)	0.008	0.009	0.004	0.024	0.024	0.006	U [0.001]
Tl (ppm)	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]	U [0.001]
U (ppm)	U [0.0002]	0.0012	0.0006	0.0011	0.0015	0.0002	0.0005
V (ppm)	U [0.001]	0.032	0.005	0.012	0.004	U [0.001]	0.0022
Zn (ppm)	0.16	0.002	0.027	0.005	0.053	0.12	0.023
TDS (calculated)	198.9	199.6	192.6	213.0	199.1	174.4	185.7

Note: U = Undetected at the IDL shown in brackets. Bicarbonate concentrations (HCO_3) were calculated from measured total carbonate alkalinity.

Appendix C

Borehole Video Log

TO VIEW THE VIDEO THAT ACCOMPANIES THIS DOCUMENT, PLEASE CALL THE HAZARDOUS WASTE BUREAU AT 505-476-6000 TO MAKE AN APPOINTMENT

Appendix D

Geophysical Logging Files

Geophysical logging spreadsheets and charts are located on the final report CD.

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~VERSION INFORMATION
VERS   .2.0             :CWLS LOG ASCII STANDARD-VERSION 2.0
WRAP   .NO              :ONE LINE PER DEPTH STEP
~WELL INFORMATION
STRT   .FT      380.214 :START DEPTH
STOP   .FT      224.279 :STOP DEPTH
STEP   .FT     -0.16363 :STEP
NULL   .        -999.25 :NULL VALUE
COMP   .     Kleinfelder :COMPANY
WELL   .                :WELL
FLD    .                :FIELD
LOC    .     Los Alamo  :LOCATION
PROV   .     N/A        :PROVINCE
SRVC   .     N/A        :SERVICE COMPANY
DATE   .       9/8/2005 :DATE
UWI    .     N/A        :UNIQUE WELL ID
~CURVE INFORMATION
DEPT   .FT              :DEPTH
COND   .MS              :Cond.
I__R   .OHM-M           :I. Res.
~PARAMETER INFORMATION
ELEV   .                :ELEVATION
STE    .                :STE
DENS   .                :DENSITY
CASI   .     150'       :CASING TO1
OPER   .                :OPERATING RIG TIME
WGT1   .                :WGT1
CASI   .     6 58"      :CASING SIZE1
CASI   .     230'       :CASING TO2
WGT2   .                :WGT2
CASI   .     3.895"     :CASING SIZE2
WELL   .     LAOI-7     :WELL ID
CASI   .                :CASING TO3
K.B.   .                :K.B.
WGT3   .                :WGT3
TYPE   .                :TYPE LOG
CASI   .                :CASING SIZE3
CASI   .                :CASING TO4
SALI   .                :SALINITY
TITL   .                :TITLE
WGT4   .                :WGT4
TOP    .                :TOP LOGGED INTERVAL
CASI   .                :CASING SIZE4
WITN   .     David Neic :WITNESSED BY
CASI   .                :CASING TO5
DRIL   .                :DRILLING MEAS. FROM
WGT5   .                :WGT5
CASI   .                :CASING SIZE5
CTY    .                :CTY
WGT6   .                :WGT6
CASI   .                :CASING SIZE6
MAX.   .                :MAX. REC. TEMP.
D.F.   .                :D.F.
CASI   .                :CASING TO6
OTHE   .                :OTHER SERVICES
BIT1   .     7 3/8"     :BIT1
DEPT   .                :DEPTH-DRILLER
BIT2   .     3.895"     :BIT2
RUN    .                :RUN No
RUN1   .                :RUN1
BIT3   .                :BIT3
RUN2   .                :RUN2
PERM   .                :PERMANENT DATUM
TWP    .                :TWP
BIT4   .                :BIT4
LOG    .                :LOG MEAS. FROM
BIT    .     0'         :BIT FROM1
RUN3   .                :RUN3
BIT5   .                :BIT5
CASI   .     0'         :CASING FROM1
TYPE   .                :TYPE FLUID IN HOLE
RUN4   .                :RUN4
FLD    .                :FLD
BIT6   .                :BIT6
BIT    .     150'       :BIT TO1
CASI   .     0'         :CASING FROM2
BIT    .     150'       :BIT FROM2
CO     .                :CO
RGE    .                :RGE
BIT    .     382.5'     :BIT TO2
DEPT   .                :DEPTH-LOGGER
CASI   .                :CASING FROM3
BIT    .                :BIT FROM3
RUN5   .                :RUN5
SEC    .                :SEC
BIT    .                :BIT TO3
G.L.   .                :G.L.
CASI   .                :CASING FROM4
BIT    .                :BIT FROM4
RUN6   .                :RUN6
BIT    .                :BIT TO4
BTM    .                :BTM LOGGED INTERVAL
CASI   .                :CASING FROM5
BIT    .                :BIT FROM5
STAT   .                :STATE
BIT    .                :BIT TO5
LEVE   .                :LEVEL
CASI   .                :CASING FROM6
BIT    .                :BIT FROM6
COUN   .                :COUNTRY
RECO   .     Jordan Va  :RECORDED BY
FILI   .                :FILING No
BIT    .                :BIT TO6
~OTHER
~A
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379.56 8.24567 121.276
379.396 8.26233 121.031
379.232 8.47888 117.94
379.069 8.76206 114.128
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378.741 9.54498 104.767
378.578 9.17851 108.95
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377.76 7.82923 127.727
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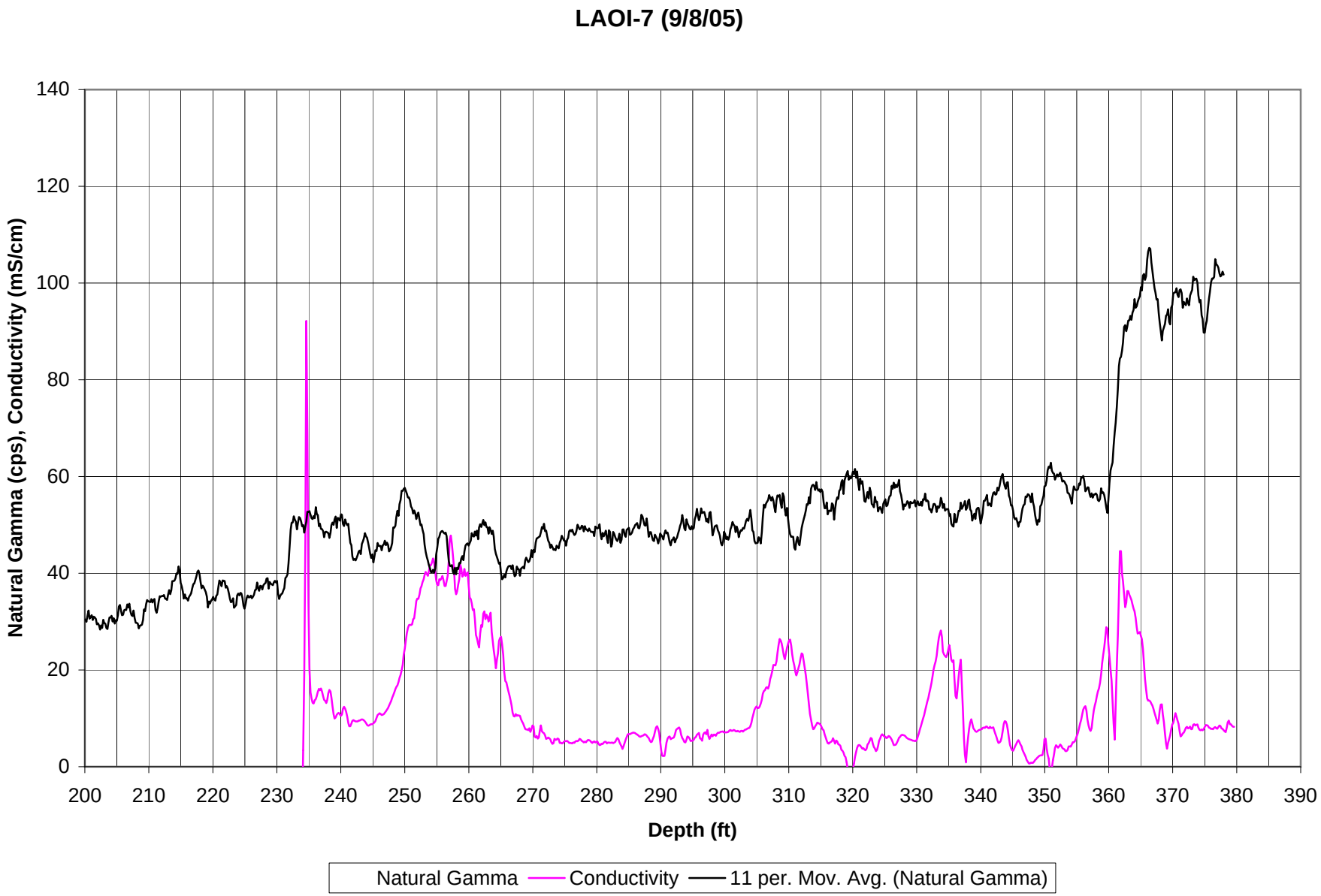
237.533	13.6261	73.3883
237.369	13.8427	72.2403
237.206	14.559	68.6861
237.042	15.5085	64.4809
236.878	16.1748	61.8246
236.715	15.7917	63.3246
236.551	16.1082	62.0804
236.387	15.5085	64.4809
236.224	14.609	68.4512
236.06	13.9926	71.4663
235.897	13.7427	72.7657
235.733	13.0598	76.571
235.569	13.193	75.7975
235.406	14.0259	71.2965
235.242	15.3419	65.181
235.078	20.3059	49.2467
234.915	33.8654	29.5287
234.751	68.8134	14.532
234.588	92.1677	10.8498
234.424	46.7752	21.3789
234.26	19.0899	52.3837
234.097	3.39825	294.269
233.933	-11.0607	-90.41
233.769	-27.8851	-35.8615
233.606	-44.976	-22.2341
233.442	-65.7816	-15.2018
233.279	-87.9531	-11.3697
233.115	-111.174	-8.9949
232.951	-132.629	-7.53981
232.788	-151.086	-6.61874
232.624	-169.526	-5.89879
232.46	-186.801	-5.3533
232.297	-201.135	-4.9718
232.133	-213.761	-4.67812
231.97	-227.512	-4.39537
231.806	-241.038	-4.14872
231.642	-253.973	-3.93743
231.479	-266.425	-3.7534
231.315	-281.334	-3.5545
231.151	-298.599	-3.34897
230.988	-313.808	-3.18666
230.824	-326.813	-3.05985
230.661	-339.199	-2.94813
230.497	-350.967	-2.84927
230.333	-361.641	-2.76517
230.17	-372.135	-2.6872
230.006	-382.167	-2.61665
229.842	-391.39	-2.555
229.679	-398.971	-2.50645
229.515	-403.929	-2.47568
229.352	-406.379	-2.46075


LAOI-7 (9/8/05)
Natural Gamma (cps), Conductivity (mS/cm)
140
120
100
80
60
40
20
0
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350
360
370
380
390
Depth (ft)
Natural Gamma
Conductivity
11 per. Mov. Avg. (Natural Gamma)

Depth	Natural Ga	Conductivity
379.584	99.918	8.24567
379.421	108.363	8.26233
379.257	97.1914	8.47888
379.094	101.918	8.76206
378.93	108.977	8.79538
378.766	104.668	9.54498
378.603	101.59	9.17851
378.439	97.7109	8.09575
378.275	111.871	7.14626
378.112	104.055	7.32949
377.948	82.8789	7.54605
377.785	106.785	7.82923
377.621	99.5313	7.92917
377.457	94.9609	8.42891
377.294	109.129	8.5122
377.13	121.879	8.1957
376.966	110.137	7.86254
376.803	103.125	7.96249
376.639	109.934	8.1957
376.476	71.457	8.07909
376.312	99.957	7.74594
376.148	83.3711	7.86254
375.985	98.2266	7.79591
375.821	78	8.02912
375.657	79.375	8.07909
375.494	85.7852	8.47888
375.33	94.6836	8.59549
375.167	100.199	8.59549
375.003	86.0586	8.21236
374.839	110.363	7.74594
374.676	102.242	7.52939
374.512	108.098	7.71262
374.348	118.695	7.52939
374.185	92.6602	7.66265
374.021	93.6094	8.07909
373.858	108.34	8.74541
373.694	95.1055	8.67878
373.53	93.9453	8.5122
373.367	97.3047	8.79538
373.203	94.2461	8.67878
373.039	79.793	7.81257
372.876	96.8164	7.7626
372.712	101.164	8.29565
372.549	96.5313	7.99581
372.385	98.6172	7.92917
372.221	103.113	8.24567
372.058	93.1914	8.04578
371.894	98.3906	7.49607
371.73	97.918	7.07963
371.567	84.0078	6.87973
371.403	127.797	6.4966
371.24	88.3594	6.26339
371.076	94.6719	7.32949
370.912	85.4688	8.84535
370.749	102.02	9.5783
370.585	113.297	10.3446
370.421	93.8398	11.0775
370.258	92.6523	10.078
370.094	96.3086	9.07856
369.931	71.8984	8.74541
369.767	77.7813	7.7626
369.603	89.5547	6.4966
369.44	93.8281	5.747
369.276	123.773	4.94743
369.112	72.7773	3.73141
368.949	100.152	4.78085
368.785	94.6328	6.87973
368.622	85.418	9.24514
368.458	85.1289	10.8443
368.294	74.5039	12.8932
368.131	93.3633	12.8432
367.967	97.4297	11.6272
367.803	111.078	9.6949
367.64	125.02	8.91198
367.476	122.711	9.74487
367.313	88.7656	10.4778
367.149	110.539	11.1441
366.985	114.242	12.0103
366.822	105.914	12.6766
366.658	102.984	13.0265
366.494	105.734	13.4929
366.331	95.625	13.6928
366.167	88.5938	13.6761
366.004	92.7188	14.1092
365.84	87.7383	15.9416
365.676	114.375	18.1071
365.513	102.266	21.0555
365.349	107.125	24.3038
365.185	79.8516	26.3527
365.022	113.648	27.0357
364.858	82.8164	27.8519
364.695	99.6484	27.6687
364.531	87.9727	27.5187
364.367	79.0078	28.8514
364.204	89.1445	30.7837
364.04	107.891	32.1163
363.876	89.8477	32.666
363.713	95.9375	33.5489
363.549	90.5508	34.4817
363.386	88.8359	35.0481
363.222	103.668	35.5311
363.058	82.1328	36.2974
362.895	85.168	36.3307
362.731	78.1172	33.882
362.567	93.1836	32.9825
362.404	84.9375	35.6644
362.24	72.668	38.313
362.077	71.3086	39.8955
361.913	81.5039	44.5597
361.749	86.7734	44.5763
361.586	71.7656	35.7144
361.422	51.0293	27.019
361.258	40.5527	20.6391
361.095	50.6992	12.61
360.931	56.3945	5.59708
360.768	62.6211	8.92864
360.604	46.7852	13.5762
360.44	64.1445	17.7573
360.277	61.1152	20.156
360.113	53.0605	22.8546
359.949	46.8262	25.4032
359.786	43.9707	28.5515
359.622	62.5547	28.8514
359.459	57.0566	26.5693
359.295	63.0234	24.6869
359.131	63.0566	23.1044
358.968	61.0098	21.322
358.804	57.3633	19.1066
358.64	40.0684	17.3741
358.477	55.8906	16.2081
358.313	55.6699	15.5584
358.15	58.5527	14.6756
357.986	47.2656	13.4596
357.822	60.2891	12.61
357.659	56.7656	11.6439
357.495	56.0313	9.97808
357.331	72.8984	7.97915
357.168	52.7305	7.41278
357.004	64.2578	7.7626
356.841	54.9102	8.57883
356.677	55.9727	9.79485
356.513	50.1074	11.5772
356.35	55.0449	12.5101
356.186	70.9414	12.3102
356.022	71.75	11.8104
355.859	52.6211	10.8609
355.695	57.6172	9.71156
355.531	55.2402	8.91198
355.368	55.6641	8.04578
355.204	52.0293	7.07963
355.041	51.9199	6.42997
354.877	56.1934	5.88027
354.713	51.9453	5.28058
354.55	61.7715	5.08069
354.386	54.9609	5.08069
354.222	48.2715	4.59761
354.059	63.2305	4.14785
353.895	66.4688	4.19783
353.732	59.6738	4.19783
353.568	56.2402	3.44823
353.404	68.7539	3.23167
353.241	56.2617	3.23167
353.077	60.791	3.6148
352.913	54.2285	3.69809
352.75	59.7012	3.89799
352.586	64.9609	4.31443
352.423	58.5449	4.59761
352.259	58.793	4.23114
352.095	62.4512	3.9313
351.932	64.1523	4.19783
351.768	51.1875	4.44769
351.604	61.8984	3.88133
351.441	69.7539	2.49873
351.277	62.3906	1.34934
351.114	60.0254	-0.41638
350.95	77.1914	-2.09882
350.786	52.9844	-0.59962
350.623	61.5938	1.66584
350.459	50.3477	2.49873
350.295	39.7871	3.78138
350.132	52.002	5.81363
349.968	49.8984	5.71369
349.805	40.3555	3.59815
349.641	60.5117	2.39878
349.477	51.4492	2.34881
349.314	56.0059	2.33215
349.15	42.4512	2.26552
348.986	57.6094	2.04897
348.823	49.752	1.83242
348.659	58.9785	1.59921
348.496	53.0977	1.39932
348.332	71.1641	1.0495
348.168	60.5176	0.799636
348.005	60.0117	0.799636
347.841	40.5098	0.832952
347.677	63.9121	0.666374
347.514	60.5313	0.683031
347.35	43.8574	1.0495
347.187	50.9004	1.39932
347.023	51.2578	2.06563
346.859	41.2676	2.49873
346.696	50.6406	2.98181
346.532	63.8848	3.48154
346.368	47.8418	4.23114
346.205	42.2637	4.59761
346.041	40.3809	5.11401
345.878	52.8262	5.48048
345.714	71.1953	5.1973
345.55	53.1055	4.69756
345.387	47.9785	4.28112
345.223	54.7402	3.78138
345.059	57.3164	3.31496
344.896	62.6543	3.43157
344.732	63.9512	3.88133
344.569	63.6836	4.53098
344.405	48.4219	5.93024
344.241	71.1914	7.59602
344.078	52.0879	8.69543
343.914	57.0078	9.34509
343.75	60.0176	9.41172
343.587	57.1895	8.81204
343.423	72.082	7.31284
343.26	52.5176	5.99687
343.096	52.4141	5.24727
342.932	51.4512	5.03072
342.769	53.7051	4.91411
342.605	54.9863	5.49714
342.441	56.4609	6.19676
342.278	50.8242	6.8131
342.114	62.832	7.47941
341.951	58.0586	8.14573
341.787	46.8164	8.04578
341.623	52.4316	7.99581
341.46	56.7461	8.26233
341.296	54.957	7.96249
341.132	46.3105	8.02912
340.969	77.6875	8.29565
340.805	47.5664	8.29565
340.642	50.6602	8.02912
340.478	50.5215	8.09575
340.314	34.7363	8.02912
340.151	46.6953	7.7626
339.987	34.541	7.71262
339.823	71.2578	7.62933
339.66	73.7031	7.54605
339.496	54.6504	7.36281
339.333	42.9004	7.19623
339.169	56.168	7.36281
339.005	59.7832	7.64599
338.842	43.7363	7.97915
338.678	41.3945	8.96196
338.514	56.4102	9.81151
338.351	50.6348	9.17851
338.187	57.0508	7.86254
338.024	68.1406	6.16345
337.86	57.959	3.99793
337.696	50.1094	0.899583
337.533	62.9727	2.48207
337.369	48.4512	5.91358
337.205	54.7871	12.0103
337.042	38.6465	17.1743
336.878	55.4375	22.1383
336.715	37.4941	20.8057
336.551	51.0742	18.6568
336.387	44.125	16.1581
336.224	55.6309	14.1092
336.06	57.543	14.6256
335.896	69.2148	18.1071
335.733	33.5977	22.0217
335.569	50.5176	21.6552
335.406	59.2539	22.105
335.242	60.8047	23.904
335.078	51.6465	25.1533
334.915	52.2383	24.1206
334.751	51.4629	23.1377
334.587	43.7656	22.6547
334.424	52.3867	22.8712
334.26	72.7109	23.2377
334.097	60.1348	23.7707
333.933	47.4668	26.7858
333.769	59.8418	28.1851
333.606	40.8984	27.4688
333.442	56.1055	26.6359
333.278	55.0859	24.9701
333.115	39.6172	22.9212
332.951	65.5391	21.7218
332.788	47.7715	21.0389
332.624	52.1797	20.0561
332.46	62.0176	18.5569
332.297	51.7422	17.3408
332.133	55.2676	16.2248
331.969	58.7988	15.2253
331.806	58.627	14.2258
331.642	59.2266	13.4596
331.479	52.9492	12.5101
331.315	57.0801	11.5939
331.151	51.5859	10.6777
330.988	48.959	9.96143
330.824	37.166	9.19517
330.66	71.1016	8.47888
330.497	43.6543	7.74594
330.333	55.918	6.91305
330.17	67.3281	6.21342
330.006	54.9082	5.58042
329.842	51.2324	5.3139
329.679	67.4766	5.3139
329.515	51.2695	5.38053
329.351	50.791	5.38053
329.188	48.3828	5.53045
329.024	40.5898	5.58042
328.861	57.1797	5.66371
328.697	55.6504	5.747
328.533	59.2637	5.88027
328.37	60.9961	6.04684
328.206	50.1797	6.33003
328.042	54.6914	6.4966
327.879	55.8262	6.54658
327.715	69.9258	6.59655
327.552	65.5391	6.47995
327.388	56.6387	6.16345
327.224	66.4336	5.98021
327.061	45.7129	5.41385
326.897	50.3672	4.94743
326.733	65.3086	4.5643
326.57	53.7246	4.49767
326.406	61.8223	4.48101
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325.752	64.2969	6.26339
325.588	48.5488	6.36334
325.424	54.0352	6.04684
325.261	43.2559	5.91358
325.097	66.3242	6.21342
324.934	60.7402	6.24674
324.77	47.6816	6.47995
324.606	41.3105	6.6965
324.443	47.1641	6.47995
324.279	69.6406	5.83029
324.115	44.9375	5.36387
323.952	56.791	4.33109
323.788	70.9609	3.48154
323.625	52.918	3.23167
323.461	55.4375	3.76472
323.297	42.4316	4.06456
323.134	66.0781	4.78085
322.97	49.875	5.81363
322.806	68.9063	5.93024
322.643	56.5527	5.36387
322.479	45.3281	4.86414
322.316	59.5332	4.5643
322.152	47.3613	3.71475
321.988	58.0449	3.39825
321.825	54.6699	3.56483
321.661	78.8711	3.8147
321.497	64.0469	3.71475
321.334	60.4648	4.04791
321.17	61.6973	4.38106
321.007	42.6484	4.49767
320.843	73.7031	4.43104
320.679	70.5547	3.86467
320.516	45.1035	3.0651
320.352	67.4141	2.04897
320.188	46.3203	0.683031
320.025	60.0195	-0.64959
319.861	68.3086	-1.69903
319.697	59.2246	-2.19877
319.534	65.8594	-1.99887
319.37	53.3477	-1.54911
319.207	62.6914	-0.54965
319.043	67.207	0.949556
318.879	63.0332	1.999
318.716	37.9941	2.23221
318.552	36.2441	2.93183
318.388	77.9688	3.33162
318.225	55.5391	3.48154
318.061	51.582	4.31443
317.898	56.0996	4.5643
317.734	47.3457	4.61427
317.57	56.6816	5.24727
317.407	53.709	5.41385
317.243	49.4395	4.76419
317.079	39.3594	5.33056
316.916	71.6211	5.88027
316.752	39.584	5.28058
316.589	60.2949	5.14732
316.425	56.5723	5.03072
316.261	51.334	4.76419
316.098	47.9805	4.8808
315.934	74.4336	5.36387
315.77	43.666	6.03019
315.607	53.4375	6.71316
315.443	62.5508	7.52939
315.28	63.9375	7.7626
315.116	76.8711	8.24567
314.952	33.7656	8.74541
314.789	66.1367	8.86201
314.625	53.6465	9.02859
314.461	57.4629	9.12854
314.298	61.6387	8.69543
314.134	56.2148	8.37894
313.971	52.5371	7.8792
313.807	56.7031	7.7626
313.643	60.5508	8.54551
313.48	56.4414	9.76153
313.316	44.0039	10.9276
313.152	47.7246	12.8099
312.989	48.7715	15.0254
312.825	55.2227	17.1076
312.662	43.1523	18.8733
312.498	50.4453	20.3726
312.334	47.2324	21.8551
312.171	42.5605	23.2544
312.007	46.3945	23.4209
311.843	41.2559	22.4048
311.68	36.8789	21.1388
311.516	49.4375	20.4392
311.353	61.1152	19.5563
311.189	39.1094	18.8733
311.025	36.0449	19.6729
310.862	47.5254	20.9223
310.698	75.3164	21.8884
310.534	47.8125	23.3043
310.371	41.8027	25.0867
310.207	52.6543	26.2861
310.044	54.7949	26.0862
309.88	58.1172	25.4199
309.716	74.2617	24.537
309.553	43.8652	23.371
309.389	53.7422	22.2382
309.225	64.4414	22.9379
309.062	55.3184	24.3038
308.898	41.7871	25.4698
308.735	58.0508	26.0862
308.571	61.1992	26.4027
308.407	48.791	25.1533
308.244	57.6445	23.5209
308.08	47.2539	21.8051
307.916	46.6484	20.9389
307.753	55.5449	21.0222
307.589	69.0703	21.0389
307.426	72.2344	19.8228
307.262	47.0723	18.84
307.098	48.5957	18.1237
306.935	63.8398	16.8411
306.771	49.6406	16.1581
306.607	45.0059	16.4413
306.444	53.7227	16.3414
306.28	37.7344	15.825
306.117	53.5352	15.6584
305.953	26.9824	15.0754
305.789	35.4824	13.8927
305.626	46.2578	13.0598
305.462	58.0078	12.4434
305.298	51.7441	12.1436
305.135	51.0762	12.1269
304.971	49.3105	12.4601
304.808	44.0781	12.2269
304.644	58.9902	11.7938
304.48	58.627	10.9109
304.317	57.1094	10.0614
304.153	53.4004	9.07856
303.989	55.4941	8.37894
303.826	31.6865	7.99581
303.662	47.627	7.97915
303.499	56.4219	7.86254
303.335	46.832	7.71262
303.171	38.9688	7.66265
303.008	36.3086	7.47941
302.844	60.4668	7.2462
302.68	52.8027	7.42944
302.517	58.0039	7.41278
302.353	47.6367	7.21289
302.19	45.1484	7.29618
302.026	49.1348	7.42944
301.862	54.6582	7.31284
301.699	43.4395	7.32949
301.535	61.4863	7.54605
301.371	41.3184	7.59602
301.208	42.5684	7.42944
301.044	49.7891	7.42944
300.881	47.2051	7.59602
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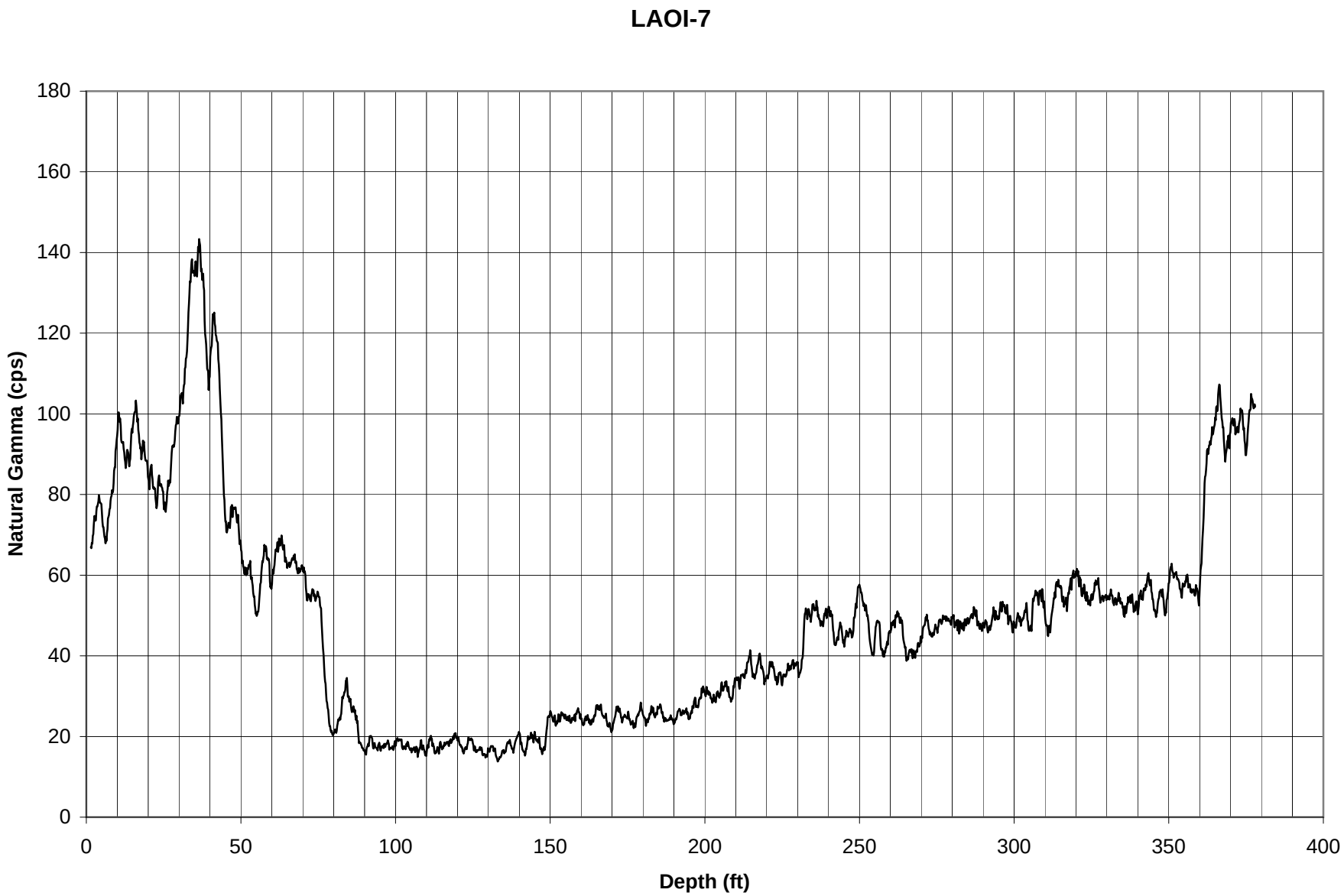
300.39	51.709	7.1296
300.226	44.0645	7.09628
300.062	65.75	7.09628
299.899	48.9277	7.07963
299.735	39.5098	7.29618
299.572	32.4219	7.2462
299.408	47.9941	7.2462
299.244	66.3828	7.09628
299.081	54.2695	6.99634
298.917	46.5469	7.02965
298.753	51.582	6.76313
298.59	50.6855	6.38
298.426	42.3574	6.62987
298.263	54.4707	6.62987
298.099	39.8887	6.28005
297.935	66.4609	6.64652
297.772	58.6172	6.19676
297.608	46.0859	5.747
297.444	44.1426	6.28005
297.281	62.5703	7.62933
297.117	40.8203	6.71316
296.954	63.7637	7.09628
296.79	60.123	6.99634
296.626	41.959	6.62987
296.463	52.3555	5.36387
296.299	50.6035	5.76366
296.135	48.7539	5.83029
295.972	49.3633	6.97968
295.808	55.7285	6.79644


LAOI-7
Natural Gamma (cps)
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
350
400
Depth (ft)

```
~VERSION INFORMATION
VERS    .2.0                :CWLS LOG ASCII STANDARD-VERSION 2.0
WRAP    .NO                 :ONE LINE PER DEPTH STEP
~WELL INFORMATION
STRT    .FT        379.584  :START DEPTH
STOP    .FT        1.44577  :STOP DEPTH
STEP    .FT       -0.16363  :STEP
NULL    .          -999.25  :NULL VALUE
COMP    .       Kleinfelder :COMPANY
WELL    .                   :WELL
FLD     .                   :FIELD
LOC     .       Los Alamo   :LOCATION
PROV    .       N/A         :PROVINCE
SRVC    .       N/A         :SERVICE COMPANY
DATE    .       09/07/200   :DATE
UWI     .       N/A         :UNIQUE WELL ID
~CURVE INFORMATION
DEPT    .FT                 :DEPTH
GAMM    .CPS                :Gamma
~PARAMETER INFORMATION
ELEV    .                   :ELEVATION
STE     .                   :STE
DENS    .                   :DENSITY
CASI    .       150'        :CASING TO1
OPER    .                   :OPERATING RIG TIME
WGT1    .                   :WGT1
CASI    .       6 5/8"      :CASING SIZE1
CASI    .       230'        :CASING TO2
WGT2    .                   :WGT2
CASI    .       3.9"        :CASING SIZE2
WELL    .       LAOI-7      :WELL ID
CASI    .                   :CASING TO3
K.B.    .                   :K.B.
WGT3    .                   :WGT3
TYPE    .                   :TYPE LOG
CASI    .                   :CASING SIZE3
CASI    .                   :CASING TO4
SALI    .                   :SALINITY
TITL    .                   :TITLE
WGT4    .                   :WGT4
TOP     .                   :TOP LOGGED INTERVAL
CASI    .                   :CASING SIZE4
WITN    .       Mark Ever   :WITNESSED BY
CASI    .                   :CASING TO5
DRIL    .                   :DRILLING MEAS. FROM
WGT5    .                   :WGT5
CASI    .                   :CASING SIZE5
CTY     .                   :CTY
WGT6    .                   :WGT6
CASI    .                   :CASING SIZE6
MAX.    .                   :MAX. REC. TEMP.
D.F.    .                   :D.F.
CASI    .                   :CASING TO6
OTHE    .                   :OTHER SERVICES
BIT1    .       7 3/8"      :BIT1
DEPT    .                   :DEPTH-DRILLER
BIT2    .       3.9"        :BIT2
RUN     .                   :RUN No
RUN1    .                   :RUN1
BIT3    .                   :BIT3
RUN2    .                   :RUN2
PERM    .                   :PERMANENT DATUM
TWP     .                   :TWP
BIT4    .                   :BIT4
LOG     .                   :LOG MEAS. FROM
BIT     .                 0 :BIT FROM1
RUN3    .                   :RUN3
BIT5    .                   :BIT5
CASI    .                 0 :CASING FROM1
TYPE    .                   :TYPE FLUID IN HOLE
RUN4    .                   :RUN4
FLD     .                   :FLD
BIT6    .                   :BIT6
BIT     .       150'        :BIT TO1
CASI    .                 0 :CASING FROM2
BIT     .       150'        :BIT FROM2
CO      .                   :CO
RGE     .                   :RGE
BIT     .       382.55'     :BIT TO2
DEPT    .                   :DEPTH-LOGGER
CASI    .                   :CASING FROM3
BIT     .                   :BIT FROM3
RUN5    .                   :RUN5
SEC     .                   :SEC
BIT     .                   :BIT TO3
G.L.    .                   :G.L.
CASI    .                   :CASING FROM4
BIT     .                   :BIT FROM4
RUN6    .                   :RUN6
BIT     .                   :BIT TO4
BTM     .                   :BTM LOGGED INTERVAL
CASI    .                   :CASING FROM5
BIT     .                   :BIT FROM5
STAT    .                   :STATE
BIT     .                   :BIT TO5
LEVE    .                   :LEVEL
CASI    .                   :CASING FROM6
BIT     .                   :BIT FROM6
COUN    .                   :COUNTRY
RECO    .       Jordann V   :RECORDED BY
FILI    .                   :FILING No
BIT     .                   :BIT TO6
~OTHER
~A
 379.584    99.918
 379.421   108.363
 379.257   97.1914
 379.094   101.918
  378.93   108.977
 378.766   104.668
 378.603    101.59
 378.439   97.7109
 378.275   111.871
 378.112   104.055
 377.948   82.8789
 377.785   106.785
 377.621   99.5313
 377.457   94.9609
 377.294   109.129
  377.13   121.879
 376.966   110.137
 376.803   103.125
 376.639   109.934
 376.476    71.457
 376.312    99.957
 376.148   83.3711
 375.985   98.2266
 375.821        78
 375.657    79.375
 375.494   85.7852
  375.33   94.6836
 375.167   100.199
 375.003   86.0586
 374.839   110.363
 374.676   102.242
 374.512   108.098
 374.348   118.695
 374.185   92.6602
 374.021   93.6094
 373.858    108.34
 373.694   95.1055
  373.53   93.9453
 373.367   97.3047
 373.203   94.2461
 373.039    79.793
 372.876   96.8164
 372.712   101.164
 372.549   96.5313
 372.385   98.6172
 372.221   103.113
 372.058   93.1914
 371.894   98.3906
  371.73    97.918
 371.567   84.0078
 371.403   127.797
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 371.076   94.6719
 370.912   85.4688
 370.749    102.02
 370.585   113.297
 370.421   93.8398
 370.258   92.6523
 370.094   96.3086
 369.931   71.8984
 369.767   77.7813
 369.603   89.5547
  369.44   93.8281
 369.276   123.773
 369.112   72.7773
 368.949   100.152
 368.785   94.6328
 368.622    85.418
 368.458   85.1289
 368.294   74.5039
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 367.967   97.4297
 367.803   111.078
  367.64    125.02
 367.476   122.711
 367.313   88.7656
 367.149   110.539
 366.985   114.242
 366.822   105.914
 366.658   102.984
 366.494   105.734
 366.331    95.625
 366.167   88.5938
 366.004   92.7188
  365.84   87.7383
 365.676   114.375
 365.513   102.266
 365.349   107.125
 365.185   79.8516
 365.022   113.648
 364.858   82.8164
 364.695   99.6484
 364.531   87.9727
 364.367   79.0078
 364.204   89.1445
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 363.713   95.9375
 363.549   90.5508
 363.386   88.8359
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 363.058   82.1328
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 360.277   61.1152
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 346.368   47.8418
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 345.714   71.1953
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 343.587   57.1895
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 342.441   56.4609
 342.278   50.8242
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 340.314   34.7363
 340.151   46.6953
 339.987    34.541
 339.823   71.2578
  339.66   73.7031
 339.496   54.6504
 339.333   42.9004
 339.169    56.168
 339.005   59.7832
 338.842   43.7363
 338.678   41.3945
 338.514   56.4102
 338.351   50.6348
 338.187   57.0508
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 337.533   62.9727
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 336.715   37.4941
 336.551   51.0742
 336.387    44.125
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  334.26   72.7109
 334.097   60.1348
 333.933   47.4668
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 327.552   65.5391
 327.388   56.6387
 327.224   66.4336
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 325.424   54.0352
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 322.643   56.5527
 322.479   45.3281
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 322.152   47.3613
 321.988   58.0449
 321.825   54.6699
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 321.334   60.4648
  321.17   61.6973
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 320.025   60.0195
 319.861   68.3086
 319.697   59.2246
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  319.37   53.3477
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 319.043    67.207
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 317.898   56.0996
 317.734   47.3457
  317.57   56.6816
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 317.079   39.3594
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 316.752    39.584
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  315.77    43.666
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 313.316   44.0039
 313.152   47.7246
 312.989   48.7715
 312.825   55.2227
 312.662   43.1523
```

Appendix E

Aquifer Test Report

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LAOI-7 PUMPING TEST ANALYSIS

INTRODUCTION

This section describes the analysis of constant-rate test pumping conducted in December 2005 on LAOI-7, located in Los Alamos Canyon. The primary objective of the analysis was to determine the hydraulic properties of the screened interval in LAOI-7. LAOI-7 is a 3-inch well completed with a 20-foot-long screen between the depths of 240 and 260 feet below land surface, in a perched zone within the Cerros del Rio basalt. Because of the casing diameter constraint, it was not possible to utilize an inflatable packer during the testing, as has been done in most of the previous pumping tests.

The Cerros del Rio basalt in which the well was completed extends from 77 feet to 360 feet below land surface. The screened interval is apparently confined, as dry core was observed until the 237 to 242 foot interval was sampled, after which the water level in the borehole rose to 221 feet below land surface. Additional permeable zones within the Cerros del Rio basalt were encountered at greater depths, with static water levels near or at the elevation of that of the screened interval. This suggested hydraulic interconnection of a number of fractured zones, implying a complex three-dimensional saturated perched zone configuration. The water in the permeable Cerros del Rio intervals is perched well above the regional aquifer – perhaps by tight sediments within the underlying Puye Formation or possibly by the lower section of the Cerros del Rio basalt itself, if it is sufficiently tight.

Because mercury levels had been measured in groundwater samples from LAOI-7, original plans called for slug testing of the well, to avoid producing large volumes of contaminated water. However, at the time of testing, the onsite storage tanks used to contain development water had a remaining storage capacity of around 600 gallons. Therefore, a testing plan was devised to take advantage of the additional storage volume and conduct an abbreviated constant-rate pumping test. It was judged that better estimates of formation parameters could be obtained in this manner than would have been possible based on simple slug testing.

Testing consisted of brief trial pumping on December 5, followed by a short constant-rate pumping test on December 6. Trial pumping was conducted at a discharge rate of 4.0 gallons per minute (gpm) for 18 minutes from 5:50 pm until 6:08 pm on December 5 and was followed by 1072 minutes of recovery until noon December 6.

At that time, the constant-rate pumping test was started at a discharge rate of 3.5 gpm. Pumping continued for 130 minutes until 2:10 pm on December 6. Then, the pump was shut down and recovery measurements were recorded for 1090 minutes until 8:20 am on December 7.

BACKGROUND DATA

The background water level data collected in conjunction with running the pumping tests allow the analyst to see what water level fluctuations occur naturally in the aquifer and help distinguish between water level changes caused by conducting the pumping test and changes associated with other causes.

Background water level fluctuations have several causes, among them barometric pressure changes, operation of other wells in the aquifer, earth tides and long-term trends related to

weather patterns. The background data hydrograph from the LAOI-7 testing was compared to barometric pressure data from the area to determine if a correlation existed.

Previous pumping tests have demonstrated a barometric efficiency for most wells of between 90 and 100%. Barometric efficiency is defined as the ratio of water level change divided by barometric pressure change, expressed as a percentage. In the initial pumping tests conducted as part of this project, down hole pressure was monitored using a *vented* transducer. This equipment measures the *difference* between the total pressure applied to the transducer and the barometric pressure, this difference being the true height of water above the transducer.

Subsequent pumping tests, including LAOI-7, have utilized *non-vented* transducers. These devices simply record the total pressure on the transducer, that is, the sum of the water height plus the barometric pressure. This results in an attenuated "apparent" hydrograph in a barometrically efficient well. Take as an example a 90% barometrically efficient well. When monitored using a vented transducer, an *increase* in barometric pressure of 1 unit causes a *decrease* in recorded down-hole pressure of 0.9 units, because the water level is forced downward 0.9 units by the barometric pressure change. However, using a non-vented transducer, the total measured pressure *increases* by 0.1 units (the combination of the barometric pressure increase and the water level decrease). Thus, the resulting apparent hydrograph changes by a factor of 100 minus the barometric efficiency, and in the same direction as the barometric pressure change, rather than in the opposite direction.

Barometric pressure data were obtained from the Los Alamos National Laboratory TA-54 tower site from ENV-Meteorology and Air Quality. The TA-54 measurement location is at an elevation of 6548 feet above mean sea level (amsl), whereas the wellhead elevation is 6362 feet amsl. The static water level in LAOI-7 was about 221 feet below land surface, making the water table elevation approximately 6141 feet amsl. Therefore, the measured barometric pressure data from TA-54 had to be adjusted to reflect the pressure at the elevation of the water table within LAOI-7.

The following formula was used to adjust the measured barometric pressure data:

$$P_{WT} = P_{TA54} \exp\left[-\frac{g}{3.281R} \left(\frac{E_{LAOi-7} - E_{TA54}}{T_{TA54}} + \frac{E_{WT} - E_{LAOi-7}}{T_{WELL}} \right) \right] \tag{1}$$

where,

P_{WT} = barometric pressure at the water table inside LAOI-7
P_{TA54} = barometric pressure measured at TA-54
g = acceleration of gravity, in m/sec^2 (9.80665 m/sec^2)
R = gas constant, in J/Kg/degree Kelvin (287.04 J/Kg/degree Kelvin)
E_{LAOI-7} = land surface elevation at LAOI-7, in feet (6362 feet)
E_{TA54} = elevation of barometric pressure measuring point at TA-54, in feet (6548 feet)
E_{WT} = elevation of the water level in LAOI-7, in feet (approximately 6141 feet)
T_{TA54} = air temperature near TA-54, in degrees Kelvin (assigned a value of 19.0 degrees Fahrenheit, or 265.9 degrees Kelvin)

T_{WELL} = air temperature inside LAOI-7, in degrees Kelvin (assigned a value of 56.8 degrees Fahrenheit, or 286.9 degrees Kelvin)

This formula is an adaptation of an equation provided by ENV-Meteorology and Air Quality. It can be derived from the ideal gas law and standard physics principles. An inherent assumption in the derivation of the equation is that the air temperature between TA-54 and the well is temporally and spatially constant, and that the temperature of the air column in the well is similarly constant.

The corrected barometric pressure data reflecting pressure conditions at the water table were compared to the water level hydrograph to discern the correlation between the two.

IMPORTANCE OF EARLY DATA

When pumping or recovery first begins, the vertical extent of the cone of depression is limited to approximately the well screen length, the filter pack length or, the aquifer thickness in relatively thin permeable strata. For many Pajarito Plateau pumping tests, the early pumping period is the only time that the effective height of the cone of depression is known with certainty. Thus, the early data often offer the best opportunity to obtain hydraulic conductivity information, because conductivity would equal the earliest-time transmissivity divided by the well screen length.

Unfortunately, in the Plateau wells, casing storage effects dominate the early-time data, often hindering the effort to determine the transmissivity of the screened interval. The duration of casing storage effects can be estimated using the following equation (Schafer, 1978).

$$t_c = \frac{0.6\left(D^2 - d^2\right)}{\frac{Q}{s}} \tag{2}$$

where,

t_c = duration of casing storage effect, in minutes
D = inside diameter of well casing, in inches
d = outside diameter of column pipe, in inches
Q = discharge rate, in gpm
s = drawdown observed in pumped well at time t_c, in feet

In some instances, it may be possible to eliminate casing storage effects by setting an inflatable packer above the tested screen interval prior to conducting the test. This approach has been used consistently in the 4.5-inch wells on the Plateau. However, the diameter constraint of the 3-inch completion in LAOI-7 precluded using the available inflatable packer. Therefore, the above casing storage time calculation was used to screen out unusable data and guide the interpretation.

TIME-DRAWDOWN METHODS

Time-drawdown data can be analyzed using a variety of methods. Among them is the Cooper-Jacob method (1946), a simplification of the Theis equation (1935) that is mathematically equivalent to the Theis equation for pumped well data. The Cooper-Jacob equation describes drawdown around a pumping well as follows:

(3)

$$s = \frac{264Q}{T} \log \frac{0.3Tt}{r^2 S}$$

where,

s = drawdown, in feet
Q = discharge rate, in gpm
T = transmissivity, in gallons per day per foot (gpd/ft)
t = pumping time, in days
r = distance from center of pumpage, in feet
S = storage coefficient (dimensionless)

The Cooper-Jacob equation is a simplified approximation of the Theis equation and is valid whenever the u value is less than about 0.05, where u is defined as follows:

(4)

$$u = \frac{1.87r^2 S}{Tt}$$

For small radius values (e.g., corresponding to borehole radii), u is less than 0.05 at very early pumping times and, therefore, is less than 0.05 for all measured drawdown values. Thus, for the pumped well, the Cooper-Jacob equation can be considered a valid approximation of the Theis equation.

According to the Cooper-Jacob method, the time-drawdown data are plotted on a semilog graph, with time plotted on the logarithmic scale. Then a straight line of best fit is constructed through the data points and transmissivity is calculated using:

(5)

$$T = \frac{264Q}{\Delta s}$$

where,

T = transmissivity, in gpd/ft
Q = discharge rate, in gpm
Δs = change in head over one log cycle of the graph, in feet

RECOVERY METHODS

Recovery data were analyzed using the Theis Recovery Method. This is a semi-log analysis method similar to the Cooper-Jacob procedure.

In this method, residual drawdown is plotted on a semi-log graph versus the ratio t/t', where t is the time since pumping began and t' is the time since pumping stopped. A straight line of best fit is constructed through the data points and T is calculated from the slope of the line as follows:

$$T = \frac{264Q}{\Delta s} \tag{6}$$

The recovery data are particularly useful compared to time-drawdown data. Because the pump is not running, spurious data responses associated with dynamic discharge rate fluctuations are eliminated. The result is that the data set is generally "smoother" and easier to analyze.

SPECIFIC CAPACITY METHOD

The specific capacity of the pumped well can be used to obtain a lower-bound value of hydraulic conductivity. The hydraulic conductivity is computed using formulas that are based on the assumption that the pumped well is 100% efficient. The resulting hydraulic conductivity is the value required to sustain the observed specific capacity. If the actual well is less than 100% efficient, it follows that the actual hydraulic conductivity would have to be greater than calculated to compensate for well inefficiency. Thus, because the efficiency is unknown, the computed hydraulic conductivity value represents a lower bound. The actual conductivity is known to be greater than or equal to the computed value.

For fully penetrating wells, the Cooper-Jacob equation can be iterated to solve for the lower-bound transmissivity as follows:

$$T = \frac{264Q}{s} \log \frac{0.3Tt}{r^2 S} \tag{7}$$

Note that because transmissivity appears on both sides of the equation, an iterative approach is required to find a solution.

To apply this procedure, a storage coefficient value must be assigned. Storage coefficient values for confined conditions, as observed in LAOI-7, can be expected to range from about 10^{-5} to 10^{-3}, depending on aquifer thickness (the thicker the aquifer, the greater the storage coefficient). Typically, a value of 5×10^{-4} may be assigned for calculation purposes. The calculation result is not particularly sensitive to the choice of storage coefficient value, so a rough estimate of the storage coefficient is adequate to support the calculations. In the calculations used for the LAOI-7 test, the "typical" value of 5×10^{-4} was used. In addition, a lower-end value of 10^{-5} was used to account for the possibility of a much lower storage coefficient for the fractured basalt formation.

It is also necessary to assign an aquifer thickness value, *b*. In the calculations presented in this report, the aquifer thickness was assigned a value of 20 feet – equal to the well screen length.

Computing the lower-bound estimate of hydraulic conductivity can provide a useful frame of reference for evaluating the other pumping test calculations.

LAOI-7 DATA ANALYSIS

This section presents the data obtained from the LAOI-7 pump testing and the results of the analytical interpretations. Analyses were applied to recovery data following the trial test, and the pumping and recovery data from the constant-rate pumping test. There also is a discussion of the background data recorded before and after the constant-rate pumping test.

Background Data

Formation pressure data were plotted along with barometric pressure data for comparison purposes. Figure 1 shows the resulting data plot. Because of the scatter in the hydrograph record, a rolling average plot was prepared as shown on Figure 2. Superficially, the plots seem to coincide, suggesting a low (near zero) barometric efficiency for the screened interval. This occurs when barometric pressure changes effectively penetrate to the depth of the saturated formation in question. In fact, this interpretation may be correct. Note that this is in stark contrast to most wells on the Pajarito Plateau which have exceedingly high barometric efficiencies. Exceptions to this have included R-10, R-10a, R-16 and R16a, which have moderate to low barometric efficiencies. LAOI-7 has the lowest barometric efficiency yet measured.

In addition to the above explanation, alternate interpretations of the hydrograph data were considered. It was noticed that although the overall hydrograph shape matched the barometric pressure trace fairly well, the small sinusoidal perturbations in the barometric signal were more attenuated in the hydrograph, potentially consistent with a greater barometric efficiency. Also, the hydrograph level seemed to "step" downward following each pumping event – about 0.02 feet after the trial test and about 0.1 feet after the constant-rate test – consistent with possible dewatering of an areally limited perched zone (although "steps" in the barometric signal occurred at the same times). To account for multiple hydraulic influences, the hydrograph and barometric pressure data were corrected for three factors – (1) barometric efficiency, (2) a linear background trend (water level decline), and (3) dewatering of a limited perched zone.

Figure 3 shows a correlation developed for (1) a barometric efficiency of 59%, (2) a background water level decline of 0.035 feet per day, and (3) assumed dewatering of 0.05 feet during the 130-minute constant-rate pumping test. The resulting match is quite good – better than that shown on Figure 2.

While the analysis shown on Figure 3 was consistent with dewatering of an areally limited perched zone, subsequent analysis showed that the pumping test data did not bear this out (described below). Therefore, the dewatering scenario was rejected. It was apparently just a coincidence that abrupt barometrically induced formation pressure declines coincided with the timing of the two pumping events.

A final barometric pressure/hydrograph correlation was developed for a scenario in which dewatering was excluded. Figure 4 shows a comparison based on (1) a barometric efficiency of 18%, (2) a background water level decline of 0.03 feet per day, and (3) no dewatering. For a couple of reasons, this was a reasonable scenario. First, rejecting the hypothesis of dewatering of a limited perched zone was appropriate because (a) the pumping test data (described below) refuted this idea, and (b) the observed perched zone seemed to correlate hydrogeologically with perched groundwater at R-9, almost a mile away. Second, manual water level measurements made 3.8 days apart – the afternoon of December 5 and the morning of December 9 – showed a static water level decline of 0.13 feet, from 220.85 feet to 220.98 feet below land surface. The corresponding barometric pressure increased by 0.08 feet over this same period. Based on a barometric efficiency of 18%, the barometric pressure change would have caused about 0.014 feet of the observed water level change. The balance of 0.116 feet over 3.8 days is approximately 0.03 feet per day, in good agreement with the assumption used in generating Figure 4.

Although this last scenario is reasonable based on visual inspection of Figure 4, it is still possible that a near-zero barometric efficiency consistent with Figure 2 could explain most of the observed response. To distinguish between the possible options would have required a more extensive background water level monitoring period – perhaps two or three days.

Trial Testing

Following pump installation, LAOI-7 was pumped briefly (trial testing) to evaluate capacity, fill the drop pipe in preparation for the constant-rate test, and generate some useful data. Trial pumping was begun at 4.0 gpm at 5:50 pm on December 5 and lasted 18 minutes until 6:08 pm. Following pump shutoff, recovery was recorded until noon December 6.

Figure 5 shows the trial recovery data. Calculations showed that casing storage effects could be expected to persist for nearly 17 minutes, so data prior to that could not be analyzed. This corresponded to a t/t' value of about 2.1. Subsequent data shown on the expanded-scale plot on Figure 6 suggested a transmissivity of 2640 gpd/ft and a hydraulic conductivity of 131 gallons per day per foot squared (gpd/ft$^{2)}$, or 17.5 feet per day.

The late data showed flattening and even water level reversal. The reversal was likely attributable to a combination of the background trend showing a slight water level decline as well as barometric pressure changes during the recovery period.

The very late data showed perturbations associated with starting the pump against shut-in head. This was a false start attempt at initiating the constant-rate pumping test on the morning of December 6. Unfortunately, cold weather had caused water in the drop pipe below ground to freeze overnight, making it impossible to pump water. Pumping was attempted briefly until the problem was diagnosed, resulting in the water level perturbations shown on the graph.

Constant-Rate Pumping Test

After the false start described above, the ice in the drop pipe was melted and the constant-rate pumping test was started at noon on December 6 at a discharge rate of 3.5 gpm. Pumping continued for 130 minutes until 2:10 pm. At that time, the pump was shut down and recovery measurements were recorded for 1090 minutes until 8:20 am on December 7.

Time-Drawdown Analysis

Figure 7 shows the time-drawdown data for the constant-rate pumping test. Again, calculations showed a casing storage duration of approximately 17 minutes, precluding use of the early data for determining formation properties. Note also on the graph that manual valve adjustments that were intended to stabilize the discharge rate actually caused significant flow rate fluctuations early on.

As shown on the expanded-scale plot on Figure 8, the data following casing storage yielded a transmissivity of only 1070 gpd/ft – about half that obtained from the trial recovery data. Recovery data generally provide superior reliability, whereas drawdown data can be affected by dynamic influences such as a gradually changing discharge rate, aquifer dewatering, or declining well efficiency (caused, for example, by gradual hydraulic packing of the filter media or formation materials during pumping). It is possible that the LAOI-7 drawdown data were affected in such a way. Once the discharge rate was stabilized, it remained nearly constant

throughout the remainder of the test, so it was unlikely that a changing pumping rate could have caused the observed drawdown response. The most likely explanation was a gradually declining well efficiency during pumping.

During the last hour or so, the data trace flattened slightly. This effect could have been caused by an increase in transmissivity away from the well or the barometric pressure reductions observed during pumping, or a combination of both. An alternate possibility is vertical leakage from underlying saturated materials. Note that there was no evidence whatsoever of negative boundaries (curve steepening) commonly indicative of laterally limited perched zones.

Recovery Analysis

After pump shutoff, recovery data were recorded from 2:10 pm on December 6 until 8:20 am on December 7. Figure 9 shows the corresponding recovery plot. The first 17 minutes of recovery, corresponding to a t/t' value of 8.7, were affected by casing storage and were not analyzable.

The usable data were re-plotted on the expanded-scale graph shown on Figure 10, yielding a transmissivity of 2400 gpd/ft and a hydraulic conductivity of 120 gpd/ft^2, or 16.0 feet per day.

The late recovery data (flat portion of the plot) confirmed a transmissivity increase away from the well or possible leakage from below. Different from the drawdown phase, the barometric pressure did not change significantly during recovery and couldn't have contributed to the observed flattening. There was no indication of a steepening of the recovery curve, as would have occurred if the lateral extent of the perched zone were severely limited. Finally, the shortfall of the recovered water level with respect to the original static level was consistent with the combination of overall barometric pressure change since the onset of data collection and the hypothesized background water level decline.

Specific Capacity Data

Specific capacity data were used along with well geometry to estimate a lower-bound transmissivity value for the screened interval, as a reality check on the conventionally calculated values. In addition to specific capacity, other input values used in the calculations included storage coefficient and borehole radius. A borehole radius of 0.51 feet was assigned in the calculations. Two storage coefficients were used – a medium value of 5×10^{-4} and a lower value of 10^{-5}, possibly more representative of fractured basalt.

LAOI-7 produced 3.5 gpm with 6.0 feet of drawdown after 130 minutes during the constant-rate test. Applying the Cooper-Jacob equation yielded lower-bound transmissivity values of 800 and 1100 gpd/ft for assumed storage coefficient values of 5×10^{-4} and 10^{-5}, respectively. These values were not inconsistent with the average transmissivity of about 2500 gpd/ft determined from the recovery analyses presented earlier, and suggested a well efficiency around 32 to 44% – a plausible range of values.

SUMMARY

The following information summarizes the results of the pumping and recovery tests on LAOI-7:

1. In stark contrast to most of the wells on the Pajarito Plateau, which are nearly 100% barometrically efficient, the barometric efficiency of LAOI-7 was estimated at 18%.

2. The background data suggested a background water level decline of a few hundredths of a foot per day.

3. While the water level decline that was observed during the testing effort can be explained by the combination of the estimated barometric efficiency of 18% and the presumed background water level trend, it is also possible that it was due solely to barometric pressure changes and a near-zero barometric efficiency. A longer background monitoring period would have been required to distinguish between these options.

4. Casing storage effects were significant because the inflatable packer could not be employed in the 3-inch well casing.

5. The 20-foot-thick perched zone in which the well screen was placed has an average transmissivity of approximately 2500 gpd/ft and an average hydraulic conductivity of 125 gpd/ft^2, or 16.7 feet per day.

6. Specific capacity data predicted a lower-bound transmissivity of about 800 to 1100 gpd/ft, just 32 to 44% of that calculated using conventional analysis techniques. The result was not inconsistent with the conventional results and suggested a well efficiency of about 32 to 44% – a plausible range of values.

7. The transmissivity appeared to increase away from the well as the cone of depression expanded into a complex array of fracture zones within the Cerros del Rio basalt. The observed flattening of the drawdown and recovery curves alternatively could be explained by leakage from underlying saturated materials.

8. Water storage limitations constrained the duration of pumping to just a couple of hours. During brief pumping and subsequent extended recovery, there was no indication of lateral limits to the saturated perched zone. This, along with correlation to the perched zone in distant well R-9, suggested a laterally extensive perched zone.

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Figure 1. Comparison of LAOi-7 Apparent Hydrograph and Adjusted TA-54 Barometric Pressure

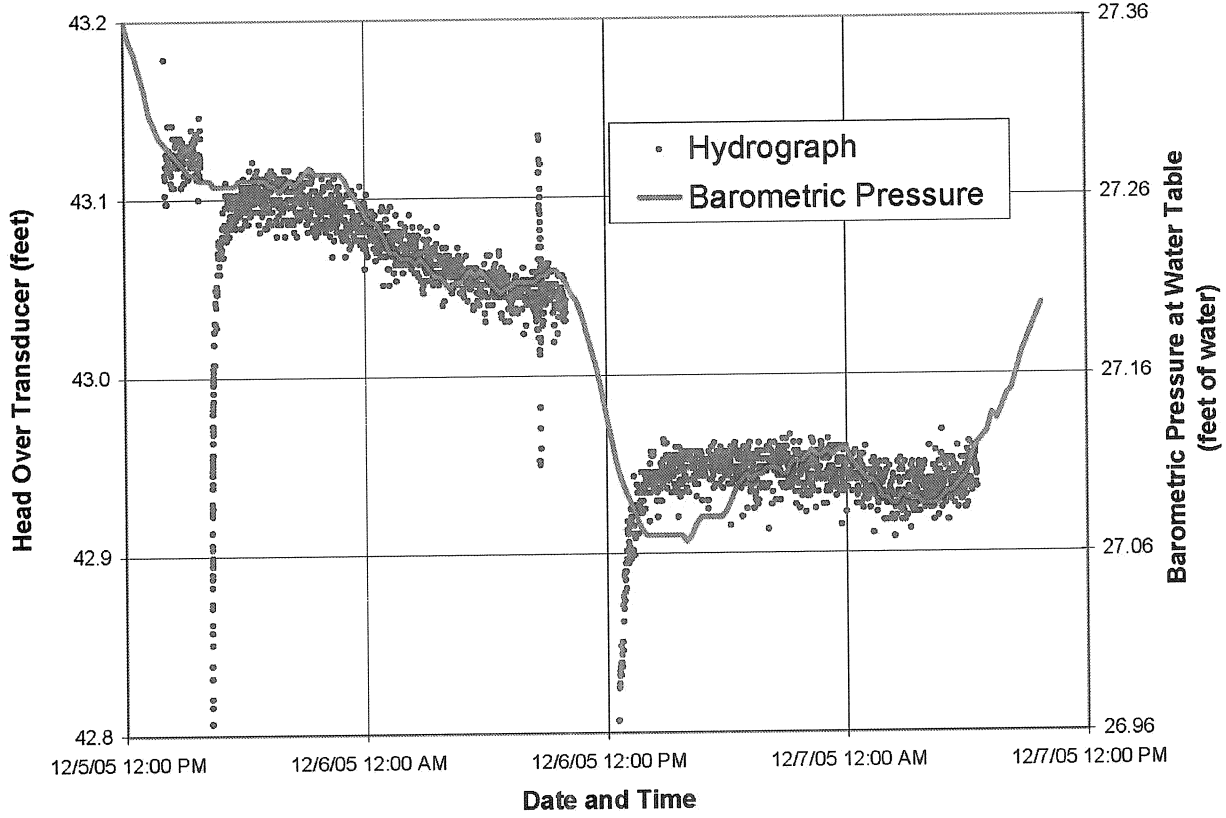


Figure 2. Comparison of LAOi-7 Rolling Average Hydrograph and Adjusted TA 54 Barometric Pressure

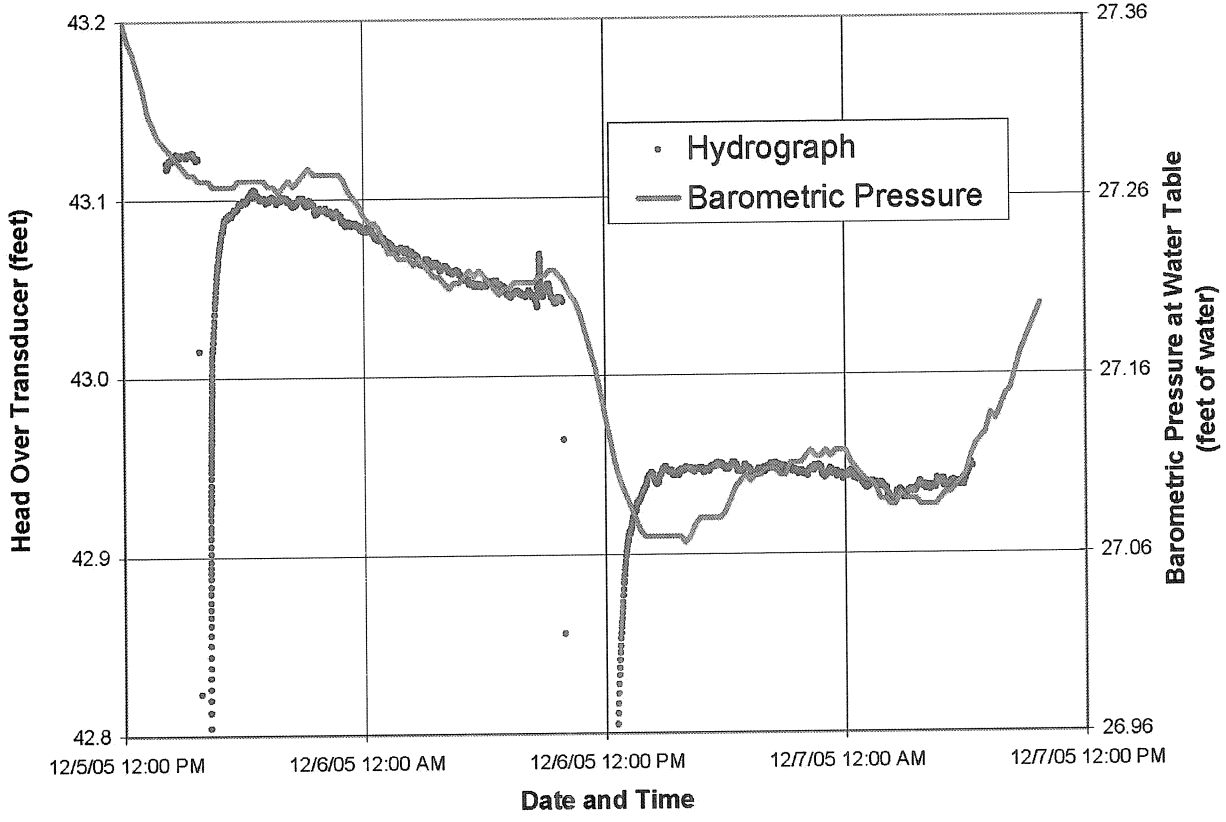


Figure 3. Comparison of LAOi-7 Rolling Average Hydrograph and TA-54 Barometric Pressure Change Corrected For Barometric Efficiency, Water Level Trend and Dewatering

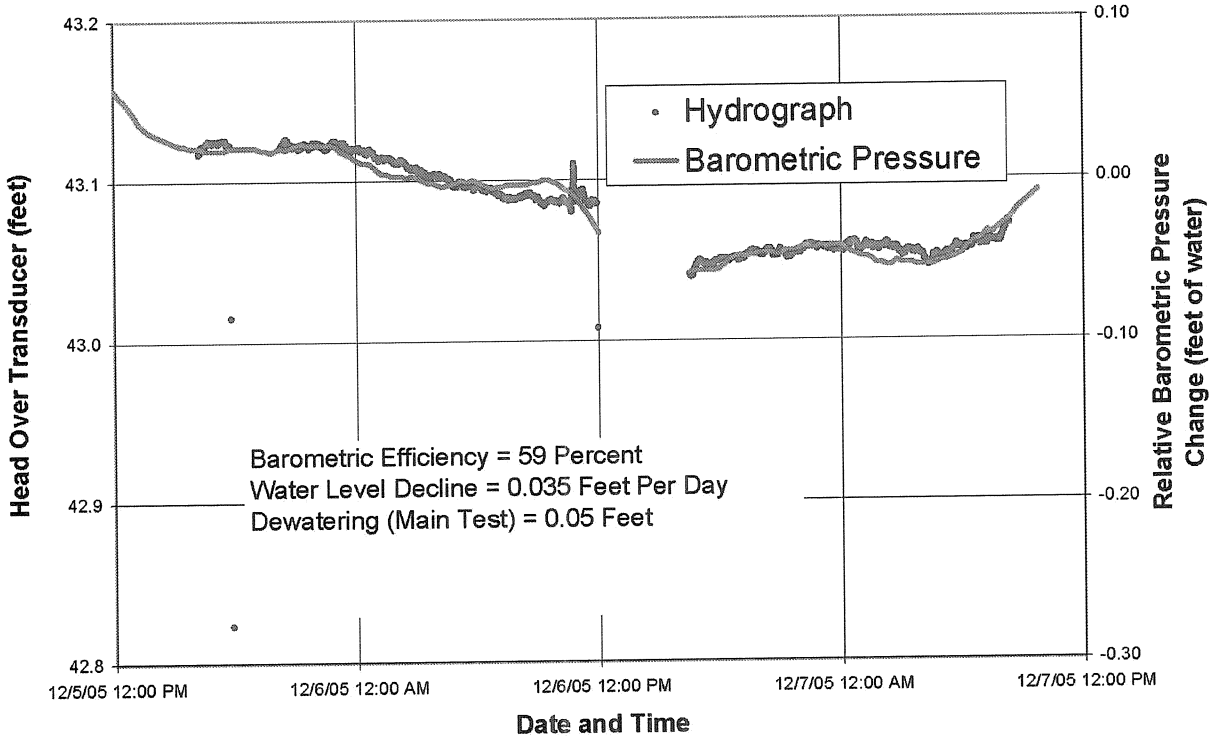


Figure 4. Comparison of LAOi-7 Rolling Average Hydrograph and TA-54 Barometric Pressure Change Corrected For Barometric Efficiency and Water Level Trend, But Not Dewatering

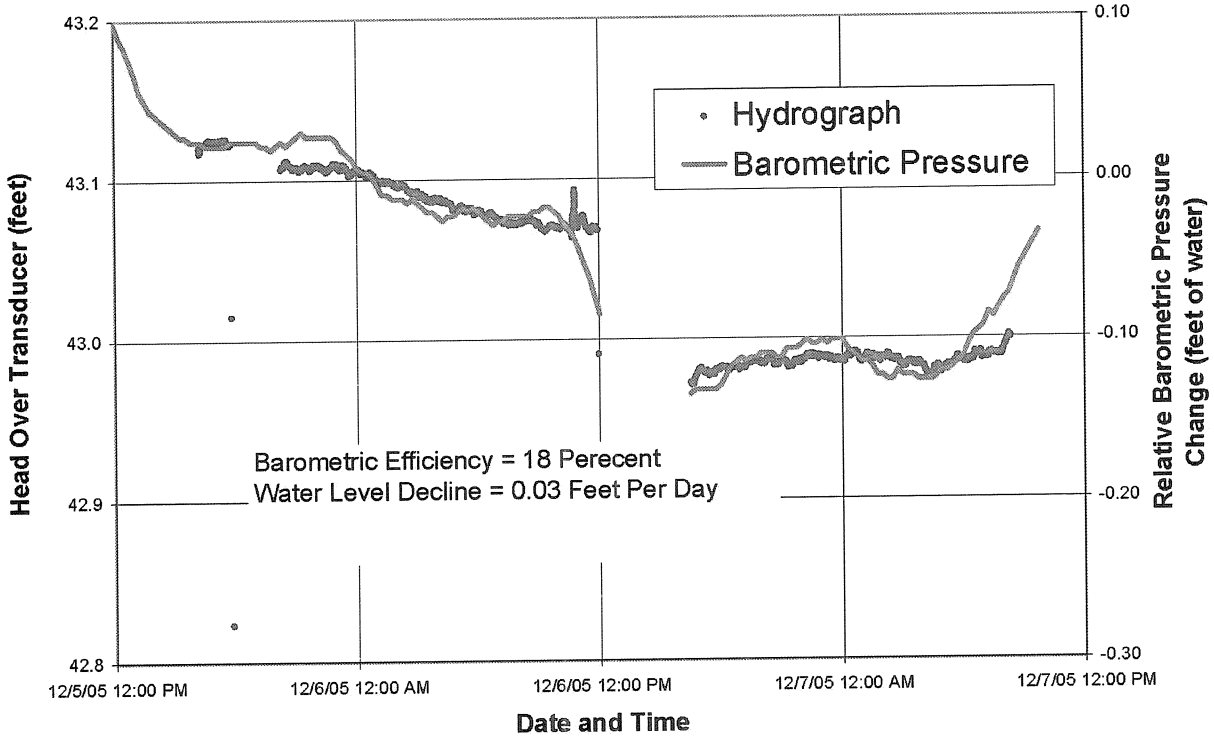


Figure 5. Well LAOi-7 Trial Recovery

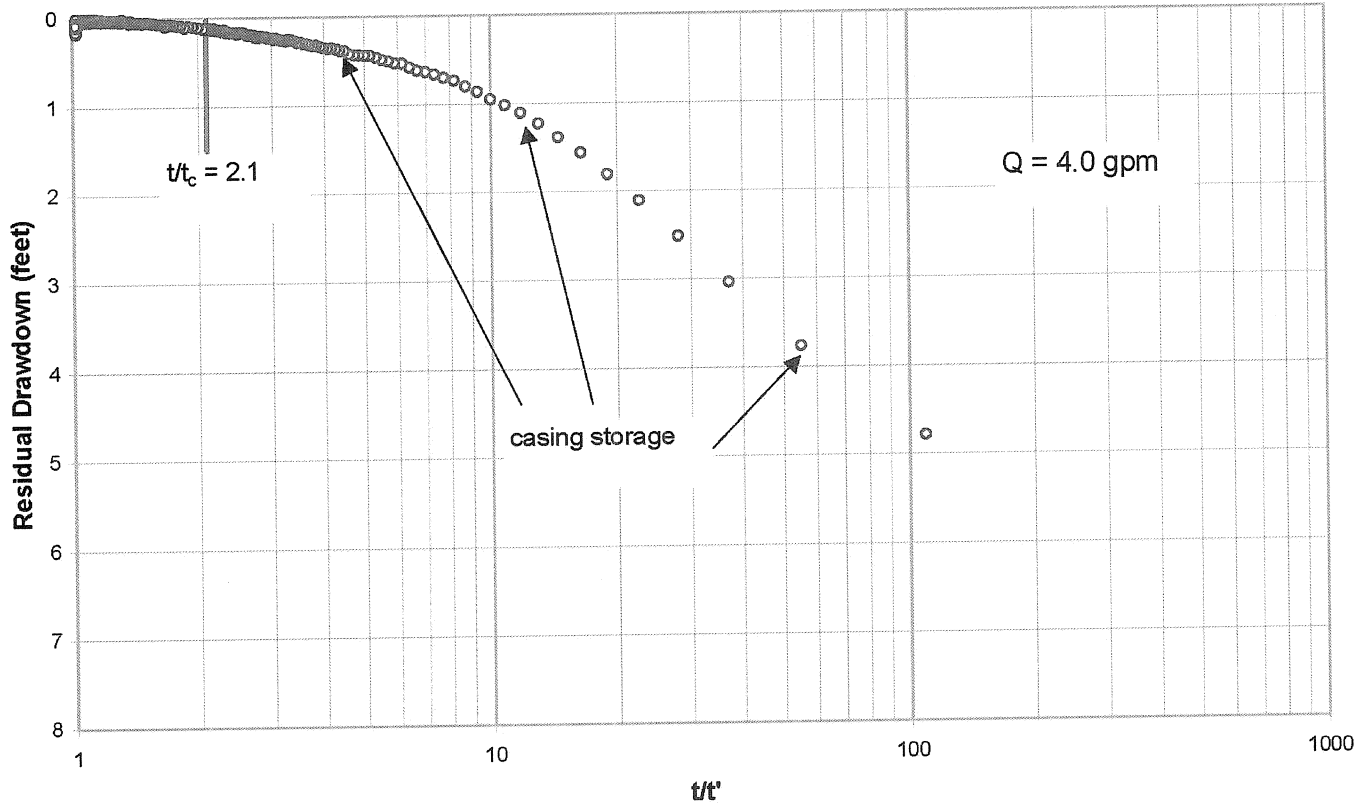


Figure 6. Well LAOi-7 Trial Recovery - Expanded Scale

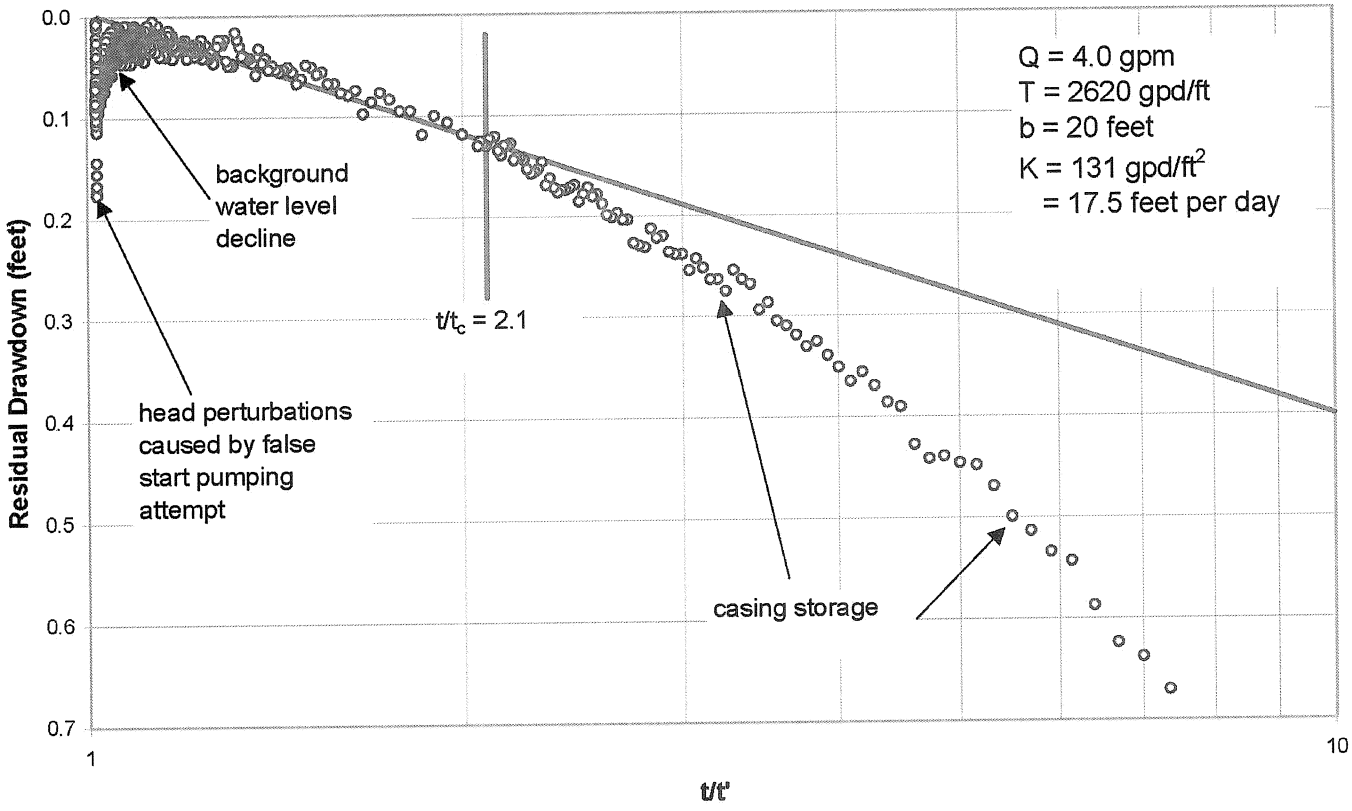


Figure 7. Well LAOi-7 Drawdown

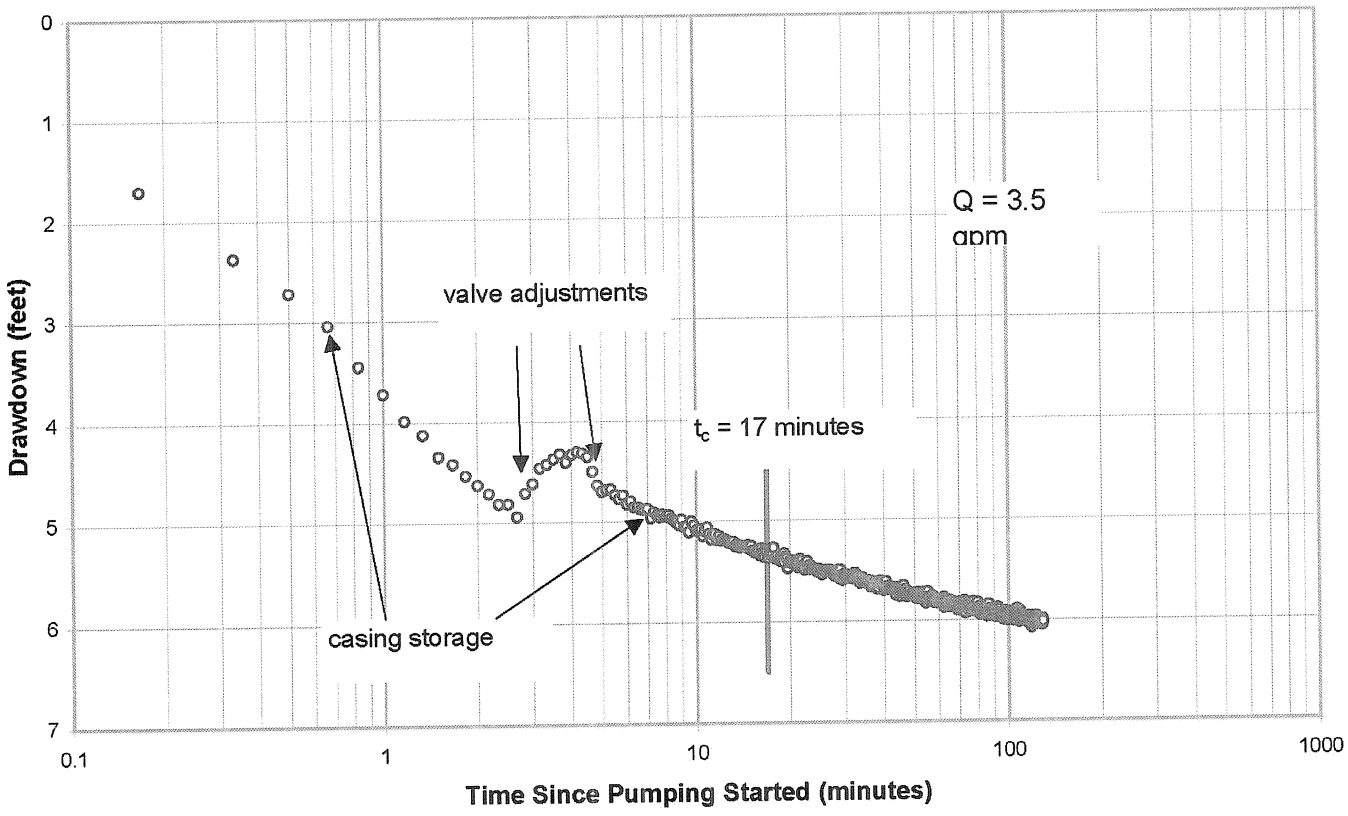


Figure 8. Well LAOi-7 Drawdown - Expanded Scale

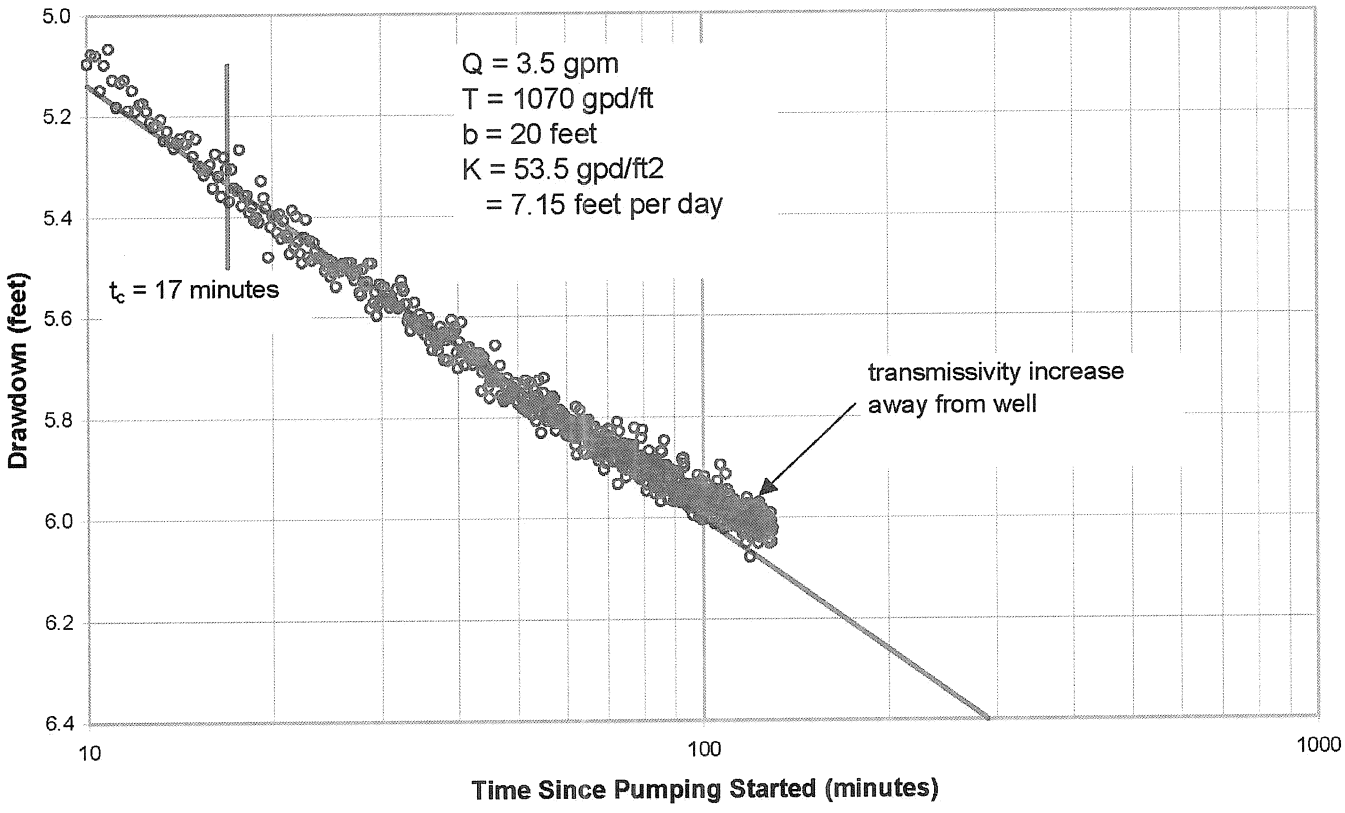


Figure 9. Well LAOi-7 Recovery

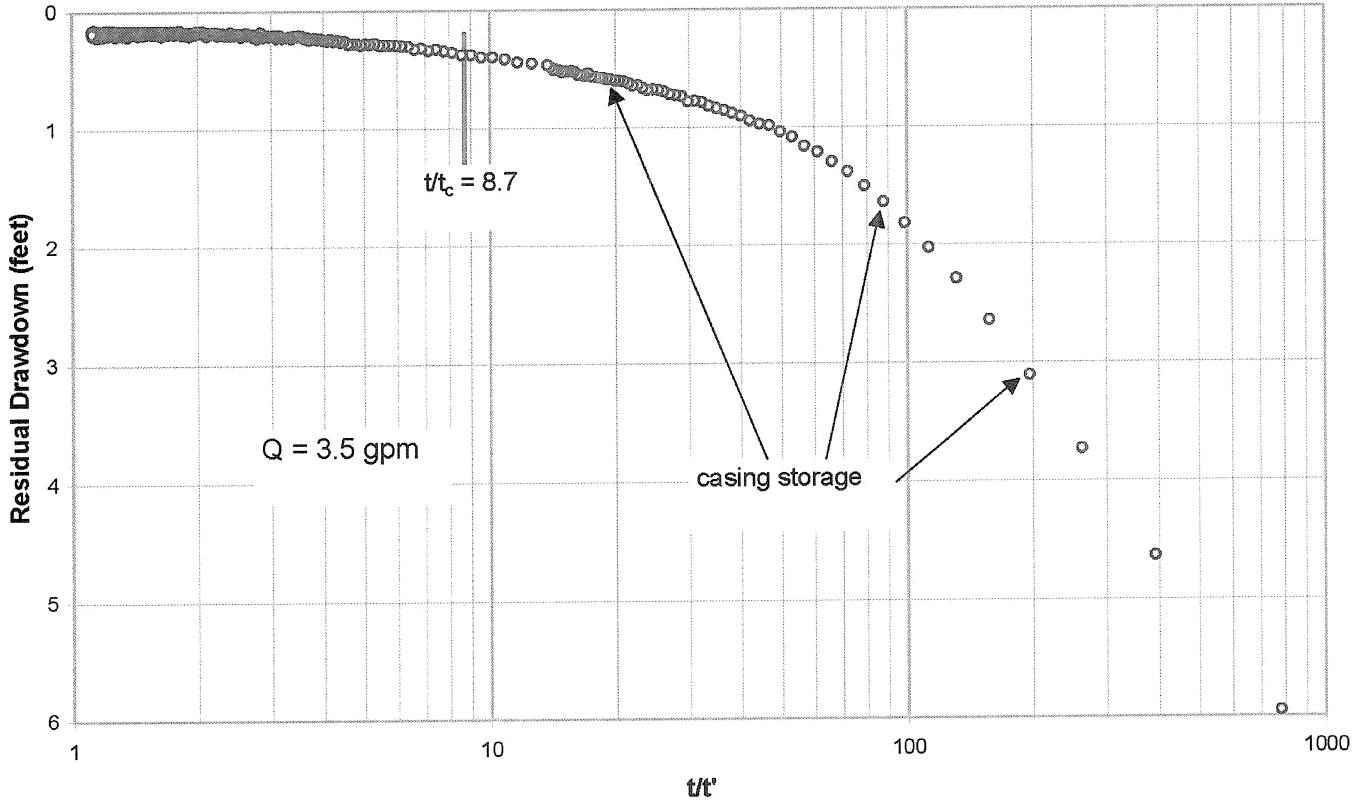
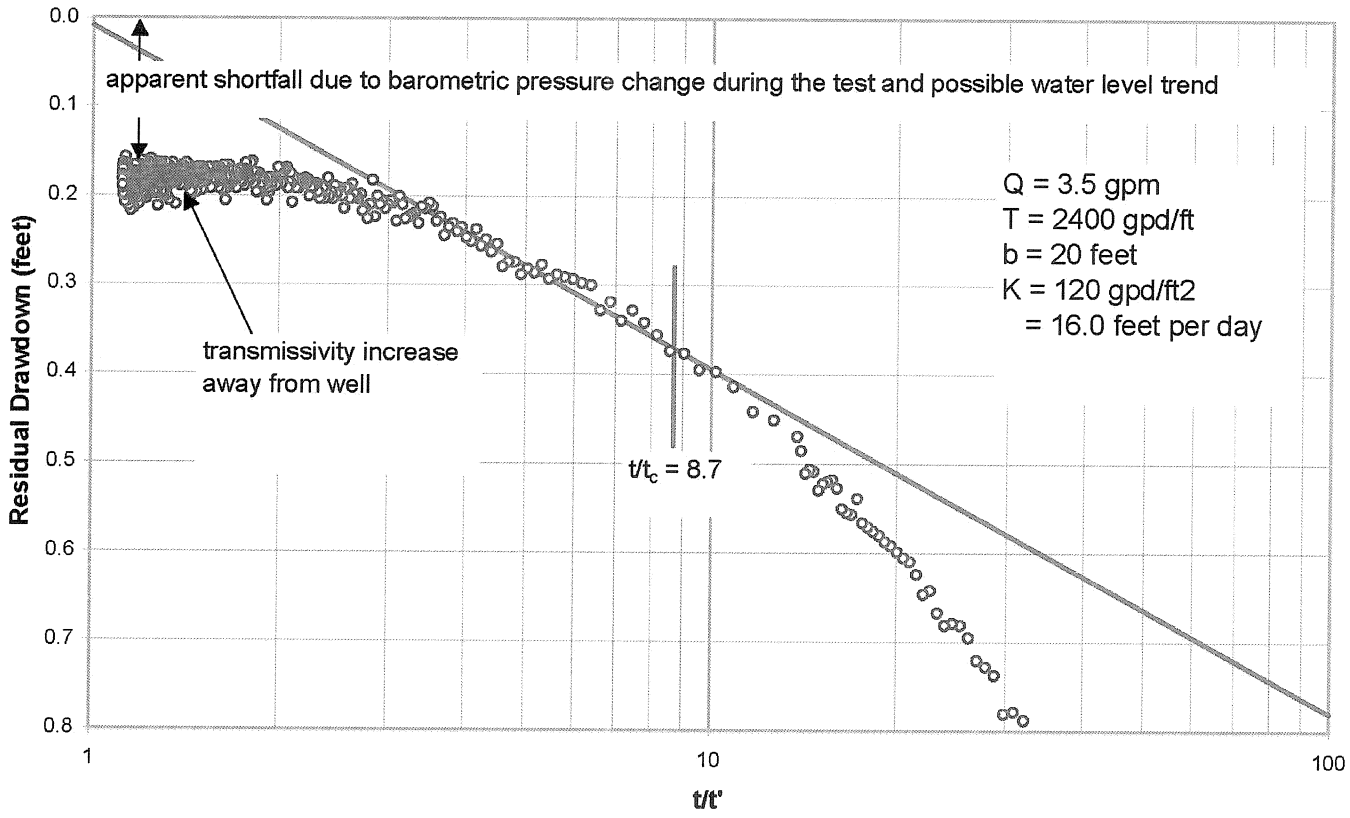


Figure 10. Well LAOi-7 Recovery - Expanded Scale



Appendix F

Deviations from Planned Activities

Activity	Drilling Work Plan for LAOI-7 (Kleinfelder 2005a)	LAOI-7 Actual Work
Planned Depth	Target total depth (TD) of 350 feet (ft) below ground surface (bgs).	LAOI-7 was drilled to 382.2 ft bgs.
Drilling Method	Air coring rig.	Drilled with an air coring rig.
Amount of Core	Coring to be collected continuously.	Continuous core was collected.
Screening Water Samples for Contaminant Analysis	If perched water is encountered in the unsaturated zone, groundwater samples are to be collected from each perched zone for screening analysis.	Six screening groundwater samples were collected during drilling.
Groundwater Samples Collected During Well Development	Samples to be collected daily during well development and submitted for Total Organic Carbon (TOC) analysis.	One TOC sample was analyzed during the pumping phase of well development, which took 1 day.
Post-Well Development Groundwater Sample	One groundwater sample to be collected following well development	A final water sample was collected immediately after well development was complete.
Water Sample Analysis	Groundwater samples to be analyzed for anions, cations (including perchlorate).	Screening and final groundwater samples were submitted for analysis of anions, cations (including perchlorate) and metals.
Core Samples to be Collected for Contaminant Analysis	Core samples to be collected every 10 ft to 100 ft bgs, at 50-ft intervals thereafter.	Core samples were collected for contaminant analysis as specified, except no basalt core from 100, 150 or 200 ft bgs was submitted for analysis because the low matrix porosity would not retain contaminants.
Geophysics	Natural gamma and array induction to be conducted.	Logged as specified.
Water Level Measurements	Water levels to be determined for each saturated zone by water level meter or video camera.	Electric water level meter and video camera used to identify zones of perched saturation.
Field Hydraulic-Property Tests	Constant rate pumping test or slug test.	A 2-hour constant rate pumping test was conducted.