NEWCASTLE, UTAH SMALL-SCALE GEOTHERMAL POWER DEVELOPMENT PROJECT – EXPLORATORY DRILLING

by

Robert E. Blackett

REPORT OF INVESTIGATION 252
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Department of Energy, National Renewable Energy Lab

March 2004

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ABSTRACT

As part of a U.S. Department of Energy-sponsored program to assist locating a production well to supply a proposed, small-scale geothermal power plant, two exploratory (thermal-gradient) boreholes were drilled in the fall of 2001 on private lands belonging to Milgro Newcastle, Inc., a floral greenhouse operator, near Newcastle, Utah. Newcastle is the site of a moderate- to high-temperature (> 120ºC [248ºF]) geothermal system. Temperature-depth measurements recorded in exploratory drill holes MN-6 and MN-7 were about 10 percent below the anticipated results for this part of the geothermal field. The maximum temperatures recorded were:

- 115.0°C (239.0°F) in drill hole MN-6 at 102 m (335 ft), and
- 117.3°C (243.1°F) in drill hole MN-7 at 102 m (335 ft).

MN-6 was an offset to the original UNOCAL hole. Drill hole MN-7 was located near the eastern boundary of Milgro's property, about 152 m (500 ft) southeast of MN-6.

Drill cuttings were examined to attempt to determine relative porosity and permeability of the valley-fill alluvial units. Lithologic logs based upon examination of the drill cuttings and drillers' reports, however, give only a very generalized view of the stratigraphy of MN-6 and MN-7. Moreover, because samples were collected at about 3-m (10-ft) intervals, there is always some mixing of lithologies throughout the sample interval. Because of the depositional environment of the valley-fill units in the Escalante Valley, lithologic breaks are subtle and difficult to identify in cuttings.

Temperature-depth profiles for MN-6 and MN-7 are similar, as maximum temperatures in each hole are within about 4ºC (7.2ºF). Based on previous geothermal studies coupled with results from this exploratory drilling, the best location for a new production well, with respect to Milgro's existing property boundary, would be just south of drill hole MN-7. The exact location for a production well would be influenced by other considerations such as the layout of permanent surface facilities.

INTRODUCTION

Milgro Newcastle, Inc. operates several geothermally heated, commercial greenhouses at Newcastle, Utah. As part of an anticipated expansion of their operations, including possible geothermal electric power generation, Milgro proposed a cooperative project to the National Renewable Energy Laboratory (NREL) as part of NREL's program for "Field Verification of Small-Scale Geothermal Power Plants." As part of the cooperative project, Milgro and NREL enlisted the help of the Utah Geological Survey (UGS) to assist with better defining the geothermal resource potential on Milgro's eastward property extension.

At Newcastle, geothermal production wells tap an unconfined, alluvial aquifer beneath the Escalante Valley. The aquifer contains hot water and covers an area of several square miles. Thermal water originates from a buried point source near a range-front fault (located about 1.2

km [0.75 mile] southeast of the main production area), enters the aquifer, and moves northwest (figure 1). The fluids cool by conduction and probably mix with shallow ground water at the margin of the system. Although a number of studies have addressed the geothermal resources of the area (Blackett and Shubat, 1992; Blackett and others, 1997), fluids having temperatures high enough to generate electricity have not yet been produced from the geothermal field.

One task of the project, "Preliminary Well Development," included an electrical resistivity survey (Ross and Mackelprang, 2001) to better characterize the outflow plume in the subsurface, and drilling of two wells to investigate lithology and thermal gradient reported here. This report describes the results of the drilling phase of this task. The UGS responsibility with respect to the drilling phase was to measure the temperature profiles of the boreholes, describe and log cutting samples, and report the findings. Exploratory holes MN-6 and MN-7, located by Milgro based on UGS past findings, were drilled to determine the temperature profile and lithologies within the geothermal plume on Milgro's eastward property extension. In 1981, UNOCAL drilled an exploratory well (CHR-1) in this area, which revealed a maximum temperature of 130°C (266°F). This high temperature and other information led to speculation that temperatures hot enough to generate electricity using binary technology could be achieved by drilling a production well in this area.

EXPLORATORY DRILLING

Methods and Purpose

Two exploratory, thermal-gradient holes were drilled by Gardner Brothers Drilling, Inc. of Enterprise, Utah using a conventional, truck-mounted drill rig. Each hole was approximately 25 cm (10 inches) in diameter and drilled to a depth of 152 m (500 ft). The drill crew collected cutting samples at 3-m (10-ft) intervals from 9.1 m (30 ft) to total depth for later, visual inspection. Because the cutting samples contained much clay and drilling mud, the author washed and screened the samples using a #40 sieve (425 micrometer opening [0.0165 in], Tyler equivalent 35 mesh). This retained cuttings ranging in size from medium sand through pebbles. Visual estimates of the amount of fine-grained material were made for each sample prior to washing and screening. Following this, the author examined each of the washed samples with a magnifying (20X hand held) lens and binocular microscope to estimate clast lithology and grain size.

The main focus of this task was measuring temperature profiles in the exploratory holes. The author made temperature-depth measurements using an NP Instruments-brand, high-precision thermistor probe and temperature logging equipment. Instrument characteristics and periodic calibrations (at least monthly) result in a temperature measurement precision of 0.01°C. The author also measured depth to water level using a Soiltest Water Level Indicator. A "rule of thumb" applied to measuring temperature profiles within geothermal temperature-gradient boreholes is to allow the borehole about double the amount of time of drilling and completion to thermally equilibrate with the surrounding geologic material. MN-6 and MN-7 required 16 and

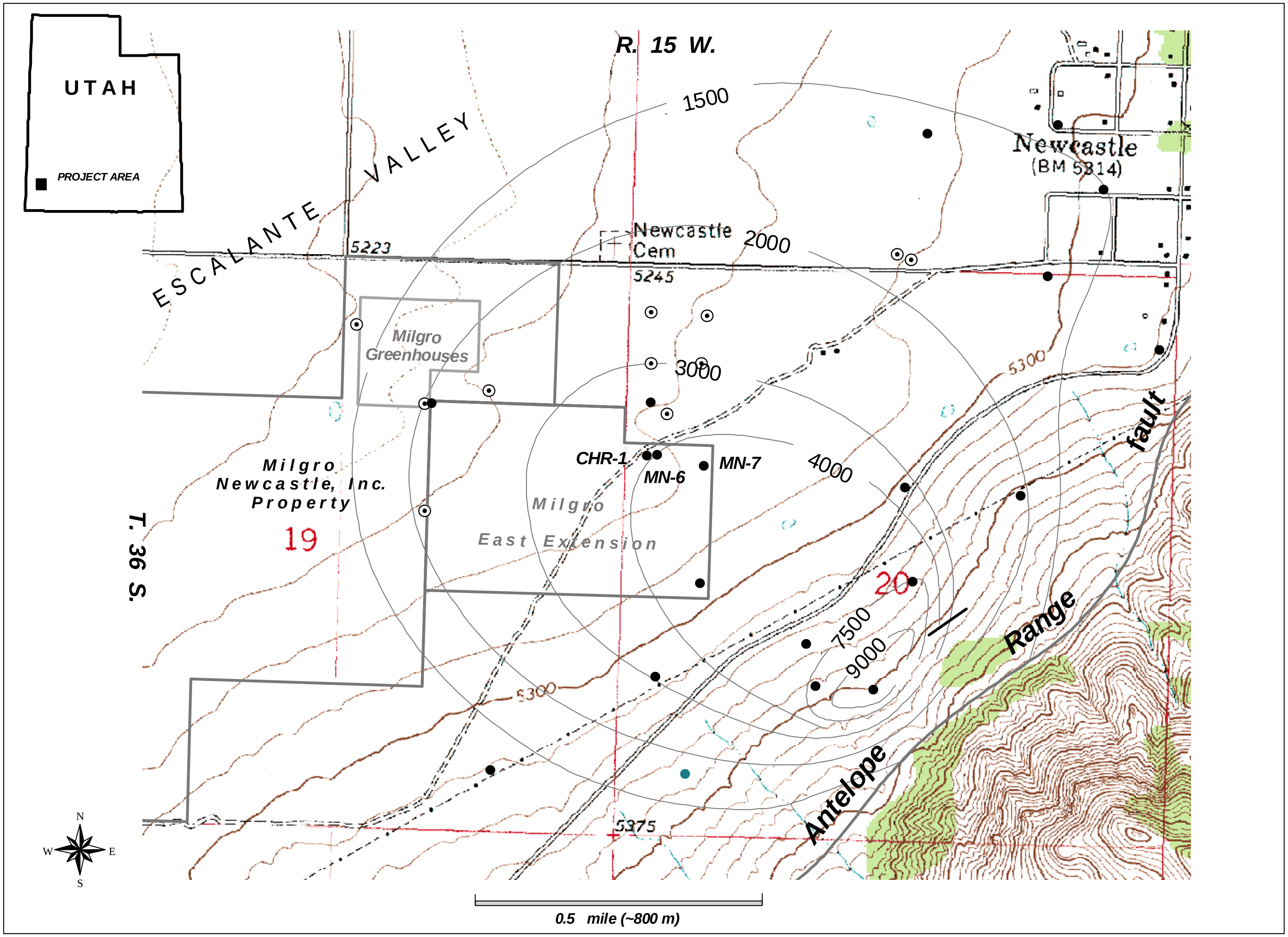

Figure 1. Location of drill holes in the Newcastle geothermal area, Utah. Heat flow contour lines are from previous studies (values reported in milliwatts per square meter). Milgro property boundries and greenhouses are also shown. Production and injection wells are shown as bullseye symbols. Exploratory drill holes are shown as smaller dots. Exploratory holes MN-6 and MN-7 are the focus of this report. Drill hole CHR-1 (Unocal) is shown for reference. Base map from USGS Newcastle 7.5 minute quadrangle (1:24,000).

8 days to complete, respectively. Although the rule of thumb for equilibration generally seems to hold in an exploration sense, the author noted that borehole temperatures seemed to actually stabilize only after several months following completion of drilling.

Drill Hole MN-6

Gardner Brothers spudded exploratory drill hole MN-6 on June 8, 2001, and completed the borehole to a total depth of 152 m (500 ft) on June 23, 2001. They initially completed MN-6 by installing two parallel strings of 2.5-cm (1-inch) diameter steel pipe. They installed one string to total depth and sealed at the bottom for temperature-depth measurements. The second string was installed to 107 m (350 ft) and perforated. The annulus of the drill hole was filled with pea gravel to allow ground water to flow into the perforated string for water-level monitoring. This completion method failed as isothermal (no change in temperature with depth) conditions measured in the unperforated string indicated downward flow of shallow cool water through the gravel pack. This condition dictated that the drillers pump cement into the perforated string, thereby grouting the pea gravel. This fix successfully sealed the gravel pack, preventing the vertical movement of water, and allowing for accurate temperature-depth measurements. Appendix A contains temperature-depth data for MN-6, logged on October 9, 2001, and on April 21, 2003.

The Well Driller's Report (appendix B) describes encountering a variety of alluvial valley-fill deposits ranging in grain size from clay to gravel. Particular note was made of the amount of clay material encountered; suggesting that the drill bit penetrated abundant fine-grained layers. The author confirmed this from hand-specimen and microscopic examination of the drill cuttings. The cuttings contained abundant fine-grained material that prompted washing and screening (described above). A lithology log for drill hole MN-6 is shown in appendix C.

A composite of the temperature-depth information and general lithology is illustrated in figure 2. Cutting samples appear typical for the generally alluvial environment of the Escalante Valley. No beds could be clearly correlated between drill holes. The deposits appear to be mostly debris/mud flows, where materials of a range of grain sizes are deposited as a single mass during a mudflow event. Some beds, containing mostly sand and granules, suggest fluvial (stream-channel) or eolian (wind-deposited) conditions probably existed occasionally.

Temperature gradients are high (1,500°C/km [82.3°F/100 ft]) at depths between 20 and 60 m (66 and 197 ft), becoming less so (600°C/km [32.9°F/100 ft]) between 60 and 90 m (197 and 295 ft). A maximum temperature of 115.0°C (239.0°F) was recorded at 102 m (335 ft). Below this depth the temperature gradient was negative, with a bottom-hole temperature of 109.3°C (228.7°F) recorded.

Drill Hole MN-7

Exploratory drill hole MN-7 was spudded June 28, 2001 and completed to a total depth of 152 m (500 ft) on July 05, 2001. The drillers completed MN-7 by cementing a sealed, 2.5-cm

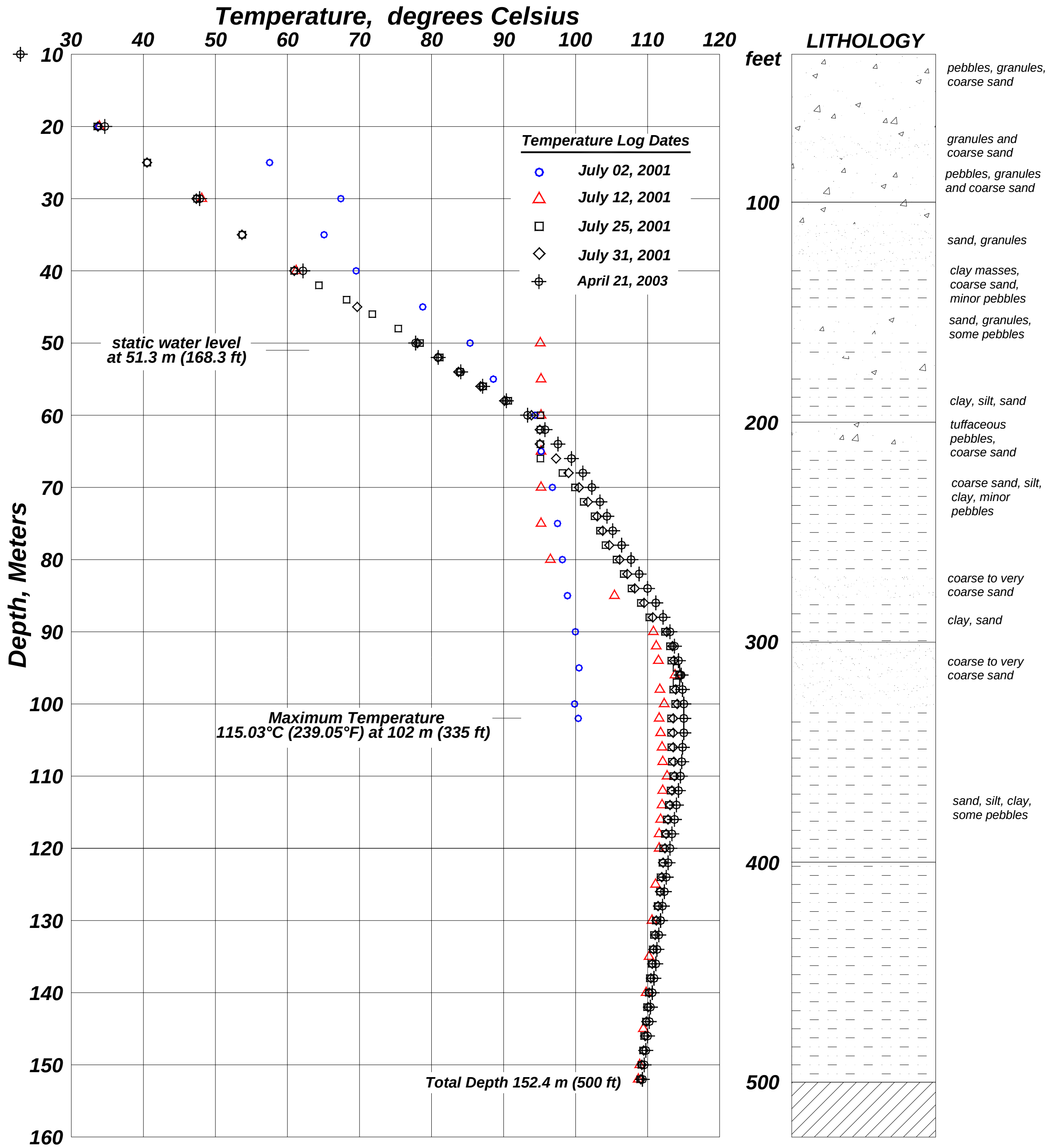

Figure 2. Temperature-depth plots and graphic lithology log of drill hole MN-6, located 1809 ft South, 305 ft East of NW Corner, Sec. 20, T. 36 S., R. 15 W. Salt Lake Base Line and Meridian.

(1-inch) diameter string from surface to total depth. Appendix D contains temperature-depth data for MN-7, logged on August 13, 2002, and on April 21, 2003.

Similar to drill hole MN-6, the Well Driller's Report (appendix E) described encountering a variety of alluvial valley-fill deposits ranging in grain size from clay to gravel. Note was also made of the amount of clay material encountered, suggesting that the drill bit penetrated abundant fine-grained layers. Hand-specimen and microscopic examination of the drill cuttings also suggested this. The cuttings contained abundant fine-grained material that required washing and screening (described above). A lithology log for drill hole MN-7 is shown in appendix F.

A composite of the temperature-depth information and general lithology is illustrated on figure 3. Cutting samples appear typical for the generally alluvial environment dominating the Escalante Valley. No beds could be clearly correlated between drill holes. As in drill hole MN-6, the deposits appear to be mostly debris/mud flows. Some beds suggesting fluvial (stream-channel) or eolian (wind-deposited) conditions probably existed occasionally. Temperature gradients are high (1,250°C/km [68.6°F/100 ft]) at depths between 20 and 66 m (66 and 217 ft), becoming less so (611°C/km [33.5°F/100 ft]) between 66 and 84 m (217 and 276 ft). A maximum temperature of 117.3°C (242.6°F) was recorded at 102 m (335 ft). Below this depth, the temperature gradient is nearly isothermal. We recorded a bottom-hole temperature of 113.2°C (235.7°F). Initially, the 2.5-cm (1-inch) pipe was inadvertently not filled with water. The result was that early temperature-depth measurements showed almost completely isothermal conditions (figure 3). The drill hole achieved a temperature of 95°C (203°F) at about 16 m (53 ft) and remained at that temperature to nearly total depth. This condition, caused by hot water vapor in the pipe, was corrected after filling the pipe string with water and allowing enough time for thermal equilibration.

CONCLUSIONS AND RECOMMENDATIONS

Initial results for maximum temperature (~117ºC [243ºF]) from the thermal-gradient drilling were roughly 13ºC (23ºF) cooler than anticipated for this part of the geothermal field. The higher expected temperatures were based on temperature logs obtained from UNOCAL from an exploratory hole drilled in the vicinity in 1981. The temperature logs from UNOCAL's Christiansen #1 (CHR-1, appendix G) geothermal well indicated that the well penetrated the geothermal outflow plume with a maximum temperature of 130°C (266°F) at a depth of 105 m (346 ft). The reasons for the lower temperatures encountered in drill hole MN-6 (essentially an offset to UNOCAL's CHR-1 well) are not known. Possibly geothermal production from nearby wells over the past 20 years reduced the temperature of the outflow plume in this area, or the hotter zone of the plume has shifted due to geothermal fluid withdraw. It is also possible that the original temperature probe and logging gear were not properly calibrated prior to logging, or a scale shift on the original strip chart record was not noted.

Based upon the reported characteristics of production wells drilled over the past decade elsewhere in the field, a production well drilled in this area could produce water at temperatures above the static readings observed in MN-6 and MN-7. The pumped well drawing hotter zones of the geothermal plume toward the well could cause this increase in production fluid tempera-

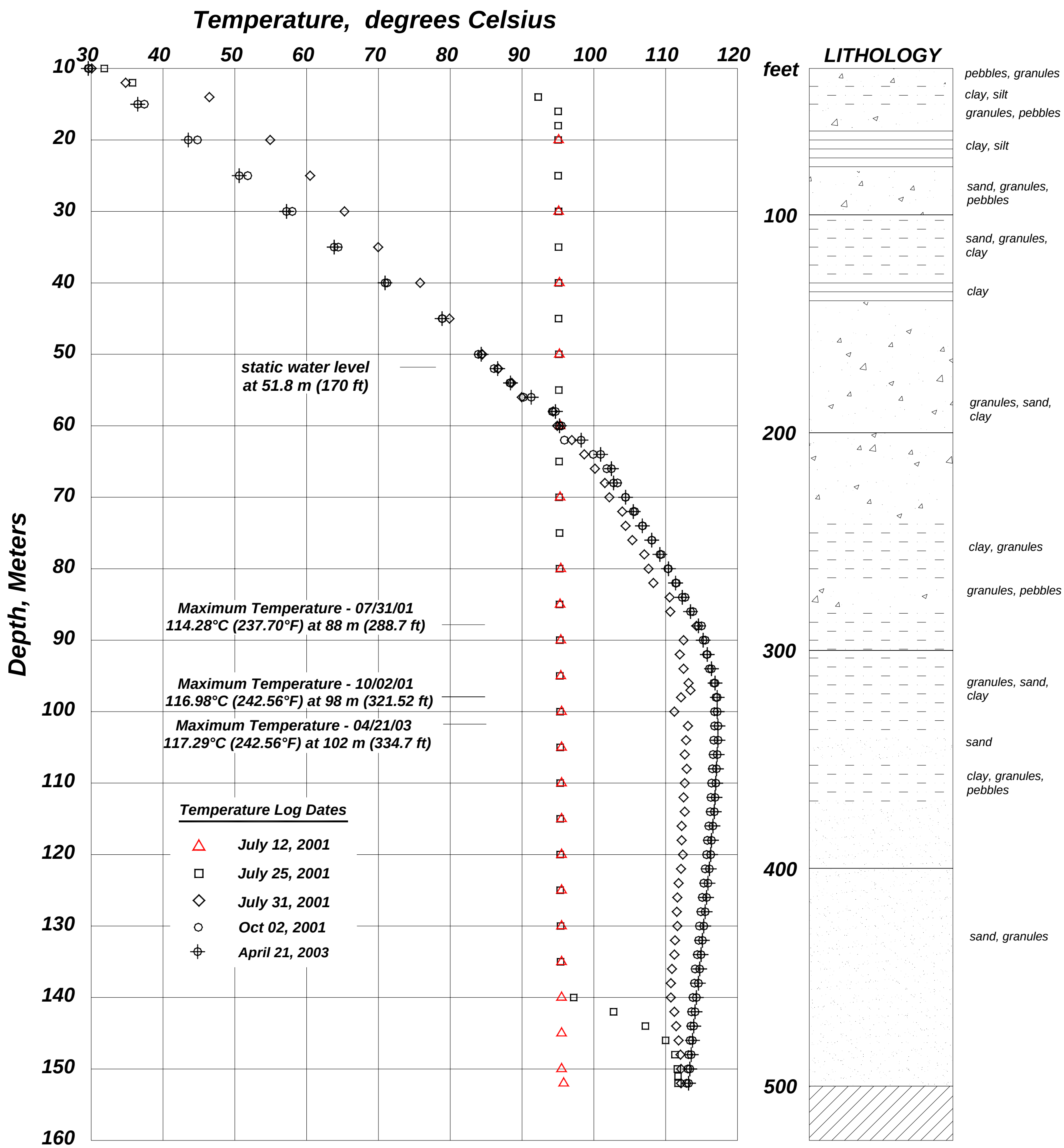

Figure 3. Temperature-depth plots and graphic lithology log of drill hole MN-7, located 1926 ft South, 760 ft East of NW corner, Sec. 20, T. 36 S., R. 15 W. Salt Lake Base Line and Meridian.

ture over time. Because only anecdotal evidence of increasing production temperature is available, the amount of production temperature increase versus static temperature cannot be known prior to well testing.

Temperature-depth profiles for MN-6 and MN-7 are similar, as maximum temperatures in each hole are within about 4ºC (7.2ºF). Based on previous geothermal studies coupled with results from this exploratory drilling, the best location for a new production well, with respect to Milgro's existing property boundary, would be just south of drill hole MN-7. The exact location for a production well would be influenced by other considerations such as the layout of permanent surface facilities.

ACKNOWLEDGMENTS

The University of Utah Energy and Geoscience Institute allowed use of their high-precision, temperature probe and logging equipment for this project. The U.S. Department of Energy, National Renewable Energy Laboratory, helped support this work under a cost-share agreement with Milgro Newcastle, Inc. Such support does not constitute an endorsement by the U.S. Department of Energy of the views expressed in this document.

REFERENCES

Blackett, R.E., Ross, H.P., and Forster, C.B., 1997, Effect of geothermal drawdown on sustainable development, Newcastle area, Iron County, Utah: Utah Geological Survey Circular 97, 31 p.

Blackett, R.E., and Shubat, M.A., 1992, A case study of the Newcastle geothermal system, Iron County, Utah: Utah Geological Survey Special Study 81, 30 p.

Ross, H.P., and Mackelprang, C.E., 2001, Electrical resistivity profiles – Newcastle geothermal area, Utah: Unpublished report prepared for Milgro Newcastle, Inc. and the National Renewable Energy Lab., 5 p

APPENDIX A

Temperature-Depth Data for Drill Hole MN-6

DRILL HOLE MN-6

Total Depth: 152.4 m (500 ft)

		Oct. 9, 2001			***Apr. 21, 2003***		
Depth (m)	**Depth (ft)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**
10	32.81	91.12	22.28	72.10	88.98	22.92	73.26
20	65.62	59.06	33.87	92.97	57.35	34.64	94.35
30	98.43	35.67	47.22	117.00	34.90	47.81	118.06
40	131.23	21.15	61.45	142.61	20.62	62.15	143.87
50	164.04	12.06	77.59	171.66	11.98	77.79	172.02
52	170.60	10.91	80.60	177.08	10.79	80.93	177.67
54	177.17	9.86	83.68	182.62	9.74	84.05	183.29
56	183.73	8.95	86.67	188.01	8.83	87.09	188.76
58	190.29	8.04	90.03	194.05	7.95	90.39	194.70
60	196.85	7.17	93.69	200.64	7.25	93.33	199.99
62	203.41	6.71	95.84	204.51	6.73	95.75	204.35
64	209.97	6.40	97.39	207.30	6.37	97.55	207.59
66	216.54	6.08	99.08	210.34	6.02	99.42	210.96
68	223.10	5.78	100.77	213.39	5.74	101.01	213.82
70	229.66	5.56	102.08	215.74	5.53	102.26	216.07
72	236.22	5.37	103.25	217.85	5.35	103.38	218.08
74	242.78	5.23	104.15	219.47	5.20	104.35	219.83
76	249.34	5.12	104.88	220.78	5.08	105.15	221.27
78	255.91	4.95	106.04	222.87	4.90	106.39	223.50
80	262.47	4.77	107.33	225.19	4.72	107.69	225.84
82	269.03	4.62	108.44	227.19	4.57	108.82	227.88
84	275.59	4.47	109.60	229.28	4.42	109.99	229.98
86	282.15	4.33	110.72	231.30	4.28	111.13	232.03
88	288.71	4.18	111.97	233.55	4.16	112.14	233.85
90	295.28	4.05	113.10	235.58	4.05	113.10	235.58
92	301.84	3.96	113.91	237.04	3.98	113.73	236.71
94	308.40	3.91	114.37	237.87	3.92	114.28	237.70
96	314.96	3.86	114.84	238.71	3.88	114.65	238.37
98	321.52	3.86	114.84	238.71	3.86	114.84	238.71
100	328.08	3.86	114.84	238.71	3.84	115.03	239.05
102	334.65	3.88	114.65	238.37	3.84	115.03	239.05
104	341.21	3.89	114.56	238.21	3.84	115.03	239.05
106	347.77	3.90	114.46	238.03	3.86	114.84	238.71
108	354.33	3.90	114.46	238.03	3.87	114.74	238.53
110	360.89	3.92	114.28	237.70	3.89	114.56	238.21
112	367.45	3.95	114.00	237.20	3.92	114.28	237.70
114	374.02	3.99	113.64	236.55	3.95	114.00	237.20
116	380.58	4.02	113.37	236.07	3.98	113.73	236.71
118	387.14	4.05	113.10	235.58	4.02	113.37	236.07

DRILL HOLE MN-6 Cont.

		Oct. 9, 2001			*Apr. 21, 2003*		
Depth (m)	**Depth (ft)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**
120	393.70	4.08	112.84	235.11	4.05	113.10	235.58
122	400.26	4.11	112.58	234.64	4.08	112.84	235.11
124	406.82	4.14	112.32	234.18	4.11	112.58	234.64
126	413.39	4.17	112.06	233.71	4.14	112.32	234.18
128	419.95	4.19	111.89	233.40	4.17	112.06	233.71
130	426.51	4.22	111.63	232.93	4.20	111.80	233.24
132	433.07	4.25	111.38	232.48	4.23	111.55	232.79
134	439.63	4.28	111.13	232.03	4.26	111.30	232.34
136	446.19	4.30	110.96	231.73	4.28	111.13	232.03
138	452.76	4.33	110.72	231.30	4.31	110.88	231.58
140	459.32	4.36	110.48	230.86	4.34	110.64	231.15
142	465.88	4.38	110.31	230.56	4.37	110.39	230.70
144	472.44	4.41	110.07	230.13	4.39	110.23	230.41
146	479.00	4.44	109.83	229.69	4.42	109.99	229.98
148	485.56	4.46	109.67	229.41	4.45	109.75	229.55
150	492.13	4.49	109.44	228.99	4.48	109.52	229.14
152	498.69	4.52	109.21	228.58	4.51	109.28	228.70

APPENDIX B

Well Driller's Report for Drill Hole MN-6

WELL DRILLER'S REPORT

State of Utah

Division of Water Rights

For additional space, use "Additional Well Data Form" and attach

Well Identification PROVISIONAL WELL: 01-71-002-P-01

Owner *Note any changes*

Milgro Newcastle Inc.
P.O. Box 153
Newcastle, UT 84756

Contact Person/Engineer: ______

Well Location *Note any changes*

SOUTH 1800 feet EAST 300 feet from the NW Corner of SECTION 20, TOWNSHIP 36S, RANGE 15W, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #) ______

Drillers Activity Start Date: 6-8-01 Completion Date: 6-23-01

Check all that apply: [X] New [ ] Repair [ ] Deepen [ ] Clean [ ] Replace [ ] Public Nature of Use: Test well for Heat

If a replacement well, provide the location of the new well. ____ feet north/south and ____ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	35	13	Rotary	mud
35	500	7 7/8	"	"

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition, density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
0	20			X	X	X								
20	25				X		X	X						20% Clay
25	94			X			X	X						
94	100				X	X	X	X						10% Clay
100	170			X	X									5% sand
170	212				X	X	X							10% Clay
212	223				X									
223	268			X		X	X							Cemented sand & gravel
268	284				X									
284	317			X		X	X							Cemented sand & gravel

Static Water Level

Date 6-28-01 Water Level 120 feet Flowing? [ ] Yes [X] No

Method of Water Level Measurement probe If Flowing, Capped Pressure ____ PSI

Point to Which Water Level Measurement was Referenced ground Ground Elevation (If known) ____

Height of Water Level reference point above ground surface - feet Temperature 26° [ ] °C [ ] °F

ADDITIONAL WELL DATA FORM

3

Water Right #______________

OWNER NAME

Page____ of ____

Well Log DEPTH (feet) FROM	TO	WATER	PERMEABILITY high	PERMEABILITY low	UNCONSOLIDATED CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDER	OTHER	CONSOLIDATED ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (e.g. relative %, grain size, sorting, angularity, bedding, grain composistion, density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)
317	348			X	X		X	X						Clay 10%
348	500				X		X	X						Clay 10%

Depth Feet	Degrees of F mud
25'	71°
94'	72°
100'	73°
130'	76°
145'	80°
160'	84°
180'	84°
215'	86°
240'	89°
260'	94°
280'	96°
300'	100°
315'	108°
330'	113°
345'	117°
360'	117°
385'	120°
410	126°
440	127°
465	131°
500	133°

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM (in)	DEPTH (feet) FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
18"	33?	Steel	.250	8"	100	350	1/16 x 2	20	4
12"	500"	Steel	SCH 40	1"					
12"	100"	Steel	SCH 40	1"					

☐ SCREEN ☒ PERFORATIONS ☐ OPEN BOTTOM

Well Head Configuration: Cap Access Port Provided? ☐ Yes ☐ No
Casing Joint Type: ____ Perforator Used: Yes
Was a Surface Seal installed? ☒ Yes ☐ No Depth of Surface Seal: 35 feet Drive Shoe? ☐ Yes ☒ No
Surface Seal Material Placement Method: ground

Provide Seal Material description below:

DEPTH (feet) FROM	TO	SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION: SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal., # bag mix, gal./sack etc.)
0	35	Cement Grout	1 1/4 yards	6 bag mix
0	35	Bentonite hole plug	22	bags
35	500	pea gravel	3 yards	
0	500	pump cement	6 yards	

Well Development and Well Yield Test Information

Date	Method	Yield	Units Check One GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
	N/A					

Pump (Permanent)

Pump Description: N/A Horsepower: ____ Pump Intake Depth: ____ feet
Approximate maximum pumping rate: ____ Well disinfected upon completion? ☒ Yes ☐ No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment procedures. *Use additional well data form for more space.*

This well is a heat monitoring and water level monitoring only there are two 1" steel casing in this bore hole one two 500' with no perforations and the other 350' with 250' of perforations after testing find that cold water hot were mix to give one temp. So the well [illegible]

Well Driller Statement This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name: Gardner Drilling License No. 492

APPENDIX C

LITHOLOGIC LOG
Milgro Newcastle, Inc. Drill Hole MN-6
1809 ft south, 305 ft east, NW corner, Sec. 20, T. 36 S., R. 15 W. SLB&M[1]
UTM Zone +12 Coordinate (m) E273745; N4170643

Logged by: Robert Blackett, Utah Geological Survey, SUU Box 9053, Cedar City, Utah 84720, (435) 865-8139, Email: blackett@suu.edu

General Comments: Drilling period June 08, 2001, to June 23, 2001, using conventional, truck-mounted rotary drilling rig. Hole diameter approx. 10 inches. Heavy mud used to stabilize wellbore. Samples washed and screened using No. 40 sieve (425 micrometer opening [0.0165 in], Tyler equivalent 35 mesh). Notes on fine-grained (< 0.425 mm) material reflect hand-specimen estimates before washing and screening. Minus #40 fraction includes medium sand through clay-size material.

Depth Interval (ft)	Description
30 – 40	Pebbles/sand: subround pebble fragments (50 %) and very coarse sand (50%); mostly volcanic rock fragments (VRF) w/angular edges due to drill bit. No estimate for minus #40 fraction for this sample.
40 – 50	Pebbles/sand: subround pebble fragments (60 %) and very coarse sand (40%); mostly VRF w/angular edges due to drill bit. No estimate for minus #40 fraction for this sample.
50 – 60	Pebbles/sand: Estimate 50% minus #40 fraction before screening. Subround pebble fragments (60 %) and very coarse sand (40%); mostly VRF w/angular edges due to drill bit.
60 – 70	Sand/pebbles: Estimate 25% minus #40 fraction before screening. Very coarse sand (60%), angular-subround and pebble fragments (40%) w/angular edges.
70 – 80	Sand: Estimate 10% minus #40 fraction before screening. Very coarse sand (80%), angular-subround; subround pebbles (20%), consist of VRF and quartzite
80 – 90	Sand/pebbles: Estimate 15% minus #40 fraction before screening. Very coarse sand (70%), angular; pebbles (30%) mostly subrounded Isom Fm. (?) w/subangular to angular VRFs.

[1] Salt Lake Base Line and Meridian

90 – 100	Sand/pebbles: Estimate 20% pebbles and 10% minus #40 fraction prior to screening. Very coarse sand (70%), angular; pebbles (30%), subangular, mostly gray-brown Isom Fm. (?) and light-gray tuffaceous sediments.
100 – 110	Sand/pebbles: Estimate 10% minus #40 fraction before screening. Very coarse sand to granules (70%), angular; pebbles (30%) subangular to round, mixed VRF lithologies; some clay masses.
110 – 120	Sand/granules: Estimate 20% minus #40 fraction before screening. Very coarse sand and granules (90%), angular to subangular; pebbles (10%).
120 – 130	Sand/granules: Estimate 20 – 30% minus #40 fraction before screening. Very coarse sand and granules (95%), angular to subangular; pebbles (5%).
130 – 140	Clay/sand/pebbles: Estimate 50% minus #40 fraction as mainly clay masses before screening. Very coarse sand and granules (90%); < 10% pebbles.
140 – 150	Clay/sand/pebbles: Estimate 50% minus #40 fraction as mainly clay masses before screening. Very coarse sand and granules (90%); < 10% pebbles, mixed VRF lithologies.
150 – 160	Clay/sand/granules: Estimate 50-60% minus #40 fraction before screening. Very coarse sand and granules (90%) dominated by Isom Fm. (?) fragments; pebbles (10%), mixed VRF lithologies.
160 – 170	Clay/pebbles/sand: Approx. 40 – 50% minus #40 fraction before screening. Sand, very coarse to granules, mixed lithologies. Pebbles, dominated by Isom Fm. clasts with other VRFs.
170 – 180	Pebbles/clay/sand: Approx. 30% minus #40 fraction before screening. Pebbles comprise about 40% of sample after screening comprising mostly Isom Fm. clasts with large light-colored volcanics. Remaining clasts are coarse sand and granules of mixed lithologies.
180 – 190	Clay/sand/pebbles: Approx. 50% minus #40 fraction before screening. Sample mostly coarse sand and granules. Pebbles consist of light colored VRFs. About 40% granules are Isom Fm. clasts.
190 – 200	Pebbles/clay/sand: Approx. 40% minus #40 fraction before screening. Screened sample mostly (50%) angular pebbles of light colored sandstone. Coarse sand and granules dominantly Isom Fm. and VRF clasts.

200 – 210	Pebbles/clay/sand: Approx. 30% minus #40 fraction before screening. Screened sample contains about 50% tuffaceous, clastic pebbles; about 50% very coarse sand and granules.
210 – 220	Coarse sand/clay/pebbles: Approx. 30% minus #40 fraction before screening. Screened sample contains about 20% pebbles of various types and a few clay masses. Approx. 80% very coarse sand and granules.
220 – 230	Coarse sand/clay/pebbles: Approx. 20% minus #40 fraction before screening. Screened sample contains about 20% pebbles of various types and a few clay masses. Approx. 80% very coarse sand and granules.
230 – 240	Coarse sand/clay/pebbles: Approx. 30% minus #40 fraction before screening. Screened sample contains less than 10% pebbles of various types and a few clay masses. Approx. 90% very coarse sand and granules.
240 – 250	Clay/pebbles/coarse sand: Approx. 60% minus #40 fraction before screening. Screened sample contains about 20% pebbles, mostly Isom Fm. clasts, and a few clay masses. Approx. 80% very coarse sand and granules.
250 – 260	Clay/pebbles/coarse sand: Approx. 50% clay/clay masses/mud before screening. Screened sample contains less than 10% pebbles, mostly Isom Fm. clasts, and clay masses.
260 – 270	Coarse sand/clay: Approx. 30% clay/clay masses/mud before screening. Screened sample contains less than 10% pebbles, mostly Isom Fm. clasts, and clay masses.
270 – 280	Sand: Approx. 20% minus #40 fraction before screening. Coarse to very coarse sand; screened sample contains less than 10% pebbles, mostly Isom Fm. clasts, and clay masses.
280 – 290	Sand/clay: Approx. 40% minus #40 fraction before screening. Screened sample primarily coarse-very coarse VRFs of various lithologies.
290 – 300	Clay/sand: Approx. 40 – 50% minus #40 fraction before screening. Screened sample primarily very coarse VRFs of various lithologies.
300 – 310	Sand: Approx. 20% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/40%) and minor pebbles (10%).
310 – 320	Sand: Approx. 15% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/40%) and minor pebbles (10%).

320 – 330	Sand: Approx.15% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/40%).
330 – 340	Sand/clay: Approx. 30-40% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/45%) and minor pebbles (< 5%).
340 – 350	Clay/sand: More than 50% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/40%) and some clay masses (< 10%).
350 – 360	Sand/clay: Approx. 40-50% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%) and clay masses (15%).
360 – 370	Sand/clay: Approx. 30% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/45%) and clay masses (< 5%).
370 – 380	Sand/clay: Approx. 40% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/45%) and pebbles (< 5%).
380 – 390	Sand/clay: Approx. 25% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/45%) and pebbles (approx. 10%).
390 – 400	Sand/clay: Approx. 25% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%). Contains clay masses (10%) and pebbles (5%).
400 – 410	Sand/clay: Approx. 30% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%). Contains clay masses (10%) and pebbles (5%).
410 – 420	Same as above. Pebbles are a mixture of sandstone, quartz, and Isom Fm. clasts.
420 – 430	Sand/clay: Approx. 20% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%). Contains clay masses (10%) and pebbles (5%).
430 – 440	Sand/clay: Approx. 30% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%). Contains clay masses (10%) and pebbles (5%). Pebbles appear mostly as Isom Fm. clasts and reddish chert.

440 – 450 Sand/clay: Approx. 15-20% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (40/40%). Contains clay masses (15%) and pebbles (5%). Pebbles mostly quartz and reddish chert.

450 – 460 Sand/clay: Approx. 20-25% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (45/40%). Contains clay masses (15%).

460 – 470 Sand/clay: Approx. 20-25% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (40/40%). Contains clay masses (15%) and pebbles (5%). Pebbles mostly quartz, reddish chert, and Isom Fm. clasts.

470 – 480 Sand/clay: Approx. 20% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/45%). Contains clay masses (5%) and occasional pebbles.

480 – 490 Sand/clay: Approx. 30% minus #40 fraction before screening. Screened sample mostly coarse – very coarse sand (50/45%). Contains clay masses (5%) and occasional pebbles.

490 – 500 Same as above.

APPENDIX D

Temperature-Depth Data for Drill Hole MN-7

DRILL HOLE MN-7

Total Depth: 152.4 m (500 ft)

		Aug. 13, 2002			***Apr. 21, 2003***		
Depth (m)	**Depth (ft)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**
10	32.8	70.14	29.31	84.76	69.40	29.59	85.26
15	49.2	53.93	36.27	97.29	53.50	36.48	97.66
20	65.6	41.64	43.10	109.58	41.00	43.52	110.34
25	82.0	31.85	50.26	122.47	31.43	50.61	123.10
30	98.4	25.16	56.65	133.97	24.66	57.20	134.96
35	114.8	19.81	63.27	145.89	19.42	63.83	146.89
40	131.2	15.46	70.32	158.58	15.14	70.92	159.66
45	147.6	11.73	78.42	173.16	11.56	78.86	173.95
50	164.0	9.81	83.83	182.89	9.66	84.31	183.76
52	170.6	9.18	85.88	186.58	8.97	86.60	187.88
54	177.2	8.63	87.81	190.06	8.47	88.39	191.10
56	183.7	8.12	89.72	193.50	7.73	91.28	196.30
58	190.3	7.18	93.65	200.57	6.96	94.65	202.37
60	196.8	6.85	95.17	203.31	6.84	95.22	203.40
62	203.4	6.77	95.55	203.99	6.24	98.23	208.81
64	210.0	5.93	99.92	211.86	5.75	100.95	213.71
66	216.5	5.65	101.54	214.77	5.50	102.44	216.39
68	223.1	5.39	103.13	217.63	5.45	102.75	216.95
70	229.7	5.20	104.35	219.83	5.19	104.42	219.96
72	236.2	5.02	105.56	222.01	5.03	105.49	221.88
74	242.8	4.82	106.96	224.53	4.85	106.75	224.15
76	249.3	4.72	107.69	225.84	4.67	108.06	226.51
78	255.9	4.52	109.20	228.56	4.52	109.20	228.56
80	262.5	4.37	110.39	230.70	4.37	110.39	230.70
82	269.0	4.24	111.46	232.63	4.25	111.38	232.48
84	275.6	4.12	112.49	234.48	4.14	112.32	234.18
86	282.2	4.01	113.46	236.23	4.01	113.46	236.23
88	288.7	3.88	114.65	238.37	3.89	114.56	238.21
90	295.3	3.80	115.41	239.74	3.82	115.22	239.40
92	301.8	3.74	115.99	240.78	3.76	115.79	240.42
94	308.4	3.69	116.48	241.66	3.70	116.38	241.48
96	315.0	3.65	116.88	242.38	3.65	116.88	242.38
98	321.5	3.61	117.29	243.12	3.62	117.18	242.92
100	328.1	3.61	117.29	243.12	3.62	117.18	242.92
102	334.6	3.60	117.39	243.30	3.61	117.29	243.12
104	341.2	3.61	117.29	243.12	3.61	117.29	243.12
106	347.8	3.62	117.18	242.92	3.62	117.18	242.92
108	354.3	3.62	117.18	242.92	3.63	117.08	242.74
110	360.9	3.64	116.98	242.56	3.64	116.98	242.56

DRILL HOLE MN-7 Cont.

		Aug. 13, 2002			***Apr. 21, 2003***		
Depth (m)	**Depth (ft)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**	**Resistance (kohms)**	**Temp. (°C)**	**Temp. (°F)**
112	367.5	3.65	116.88	242.38	3.65	116.88	242.38
114	374.0	3.66	116.78	242.20	3.66	116.78	242.20
116	380.6	3.68	116.58	241.84	3.68	116.58	241.84
118	387.1	3.70	116.38	241.48	3.70	116.38	241.48
120	393.7	3.72	116.18	241.12	3.71	116.28	241.30
122	400.3	3.73	116.09	240.96	3.73	116.09	240.96
124	406.8	3.75	115.89	240.60	3.75	115.89	240.60
126	413.4	3.77	115.70	240.26	3.77	115.70	240.26
128	419.9	3.79	115.50	239.90	3.79	115.50	239.90
130	426.5	3.81	115.31	239.56	3.81	115.31	239.56
132	433.1	3.83	115.12	239.22	3.83	115.12	239.22
134	439.6	3.85	114.93	238.87	3.85	114.93	238.87
136	446.2	3.87	114.74	238.53	3.87	114.74	238.53
138	452.8	3.90	114.46	238.03	3.89	114.56	238.21
140	459.3	3.92	114.28	237.70	3.92	114.28	237.70
142	465.9	3.94	114.09	237.36	3.94	114.09	237.36
144	472.4	3.96	113.91	237.04	3.96	113.91	237.04
146	479.0	3.98	113.73	236.71	3.98	113.73	236.71
148	485.6	4.00	113.55	236.39	4.00	113.55	236.39
150	492.1	4.02	113.37	236.07	4.02	113.37	236.07
152	498.7	4.04	113.19	235.74	4.04	113.19	235.74

APPENDIX E
Well Driller's Report for Drill Hole MN-7

Sent By: GARDNER DRILLING; 435 439 5771; Jul-10-01 9:02; Page 2

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WELL DRILLER'S REPORT

State of Utah
Division of Water Rights
For additional space, use "Additional Well Data Form" and attach

Well Identification PROVISIONAL WELL: 01-71-003-P-01

Owner *Note any changes*
Milgro Newcastle Inc.
P.O. Box 153
Newcastle, UT 84756

Contact Person/Engineer: ______

Well Location *Note any changes*

SOUTH 1926 feet EAST 760 feet fróm the NW Corner of
SECTION 20, TOWNSHIP 36S, RANGE 15W, SLB&M.

Location Description: (address, proximity to buildings, landmarks, ground elevation, local well #) ______

Drillers Activity Start Date: 6-28-01 Completion Date: 7-5-01

Check all that apply: [X] New [ ] Repair [ ] Deepen [ ] Clean [ ] Replace [ ] Public Nature of Use:

If a replacement well, provide the location of the new well. ____ feet north/south and ____ feet east/west of the existing well.

DEPTH (feet) FROM	TO	BOREHOLE DIAMETER (in)	DRILLING METHOD	DRILLING FLUID
0	30	13"	Rotary	mud
30	120	7 7/8	"	"

Well Log

DEPTH (feet) FROM	TO	WATER	PERMEABLE high	PERMEABLE low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDERS	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (e.g., relative %, grain size, sorting, angularity, bedding, grain composition, density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)	Temp
0	30			X	X		X	X					Br blk Tan	Sand ¾ gravel ¼	50
30	46		X				X	X					"	" "	50
46	52				X								Brown		65
52	68			X	X		X	X					Br blk Tan	60 % Clay	70
68	74		X				X	X					"	1/8 to ¾	70
74	80			X	X		X	X					"	50 % Clay	80
80	88			X	X		X						Brown	50 % Clay	82
88	94			X	X		X	X					Br blk Tan	40 % Clay	86
94	110		X				X	X					"		86
110	118			X	X		X	X					"	30 % Clay	86

Static Water Level

Date 6-25-01 Water Level 120 feet Flowing? [ ] Yes [X] No

Method of Water Level Measurement probe If Flowing, Capped Pressure ______ PSI

Construction Information

DEPTH (feet) FROM	TO	CASING TYPE AND MATERIAL/GRADE	WALL THICK (in)	NOMINAL DIAM (in)	DEPTH (feet) FROM	TO	SCREEN SLOT SIZE OR PERF SIZE (in)	SCREEN DIAM OR PERF LENGTH (in)	SCREEN TYPE OR NUMBER PERF (per round/interval)
2+	30	Steel	.250	8					
2+	500	Steel	sch 40	1"					

☐ SCREEN ☐ PERFORATIONS ☐ OPEN BOTTOM

Well Head Configuration: Cap Access Port Provided? ☐ Yes ☒ No

Casing Joint Type: ____ Perforator Used: ____

Was a Surface Seal installed? ☒ Yes ☐ No Depth of Surface Seal: 30 feet Drive Shoe? ☐ Yes ☒ No

Surface Seal Material Placement Method: poured, & pump the inside of well Bore

Provide Seal Material description below:

SURFACE SEAL / INTERVAL SEAL / FILTER PACK / PACKER INFORMATION

DEPTH (feet) FROM	TO	SEAL MATERIAL, FILTER PACK and PACKER TYPE and DESCRIPTION	Quantity of Material Used (if applicable)	GROUT DENSITY (lbs./gal.,# bag mix, gal./sack etc.)
0	500	Cement Grout	7 yds	6 bag mix

Well Development and Well Yield Test Information

Date	Method	Yield	Units Check One GPM	CFS	DRAWDOWN (ft)	TIME PUMPED (hrs & min)
	N/A					

Pump (Permanent)

Pump Description: N/A Horsepower: ____ Pump Intake Depth: ____ feet

Approximate maximum pumping rate: ____ Well disinfected upon completion? ☒ Yes ☐ No

Comments Description of construction activity, additional materials used, problems encountered, extraordinary circumstances, abandonment procedures. *Use additional well data form for more space.*

This is a heat monitoring only well

Well Driller Statement This well was drilled and constructed under my supervision, according to applicable rules and regulations, and this report is complete and correct to the best of my knowledge and belief.

Name Gardner Brother Drilling License No. 492

(Person, Firm, or Corporation - Print or Type)

Signature [signature] Date 7-6-01

(Licensed Well Driller)

ADDITIONAL WELL DATA FORM

Water Right #________________

OWNER NAME

Page ____ of ____

Well Log

DEPTH (feet) FROM	TO	WATER	high	low	CLAY	SILT	SAND	GRAVEL	COBBLES	BOULDERS	OTHER	ROCK TYPE	COLOR	DESCRIPTIONS AND REMARKS (e.g. relative %, grain size, sorting, angularity, bedding, grain composistion, density, plasticity, shape, cementation, consistancy, water bearing, odor, fracturing, minerology, texture, degree of weathering, hardness, water quality, etc.)	Temp.
118	126			x	X		X	X					Tan Blk Br	60 % Clay	87°
126	142			X	X								Br		89
142	158			x	X		X	X					Tan Blk Br	50 % Clay	88°
158	176	.	X				X	X					"		92°
176	192		x				X	X					"		98
192	208	x	x				X	X					"		100
208	224			c	Y		X	X					"	60 % Clay	[illegible]
224	240			Y	X		X	X					"	" "	103
240	248			x	X								Br		106°
248	256			X	X		X						"		109°
256	264			Y	Y		X	X					Tan Blk Br	40 % Clay	109°
264	272			x	X		X							"	110°
272	288			x	X		x	X					"	"	111°
288	298			X	X								Br		112°
298	304			X	X		X	X					Tan Blk Br	60 % Clay	112°
304	354			X	X		x	X					"	"	122°
354	356			x	x		X						"	"	120°
356	379			X	X		X	X					"	80% Clay	120°
379	404		X				X	X					Tan Blk Br		140°
404	435		•	X	X								Br		140°
435	440				X		X	X					Tan Blk Br	Clay 60 %	120°
440	465		X				X	X					"		145°
465	500		X				X	X					"		150°

APPENDIX F

LITHOLOGIC LOG
Milgro Newcastle, Inc. Drill Hole MN-7
1926 ft south, 760 ft east, NW Corner, Sec. 20, T. 36 S., R. 15 W. SLB&M[1]
UTM Zone +12 Coordinate (m) E273877; N4170613

Logged by: Robert Blackett, Utah Geological Survey, SUU Box 9053, Cedar City, Utah 84720, (435) 865-8139, Email: blackett@suu.edu

General Comments: Drilling period June 28, 2001 to July 05, 2001 using conventional, truck-mounted rotary drilling rig. Hole diameter approx. 10 inches. Heavy mud used to stabilize wellbore. Samples washed and screened using No. 40 sieve (425 micrometer opening [0.0165 in], Tyler equivalent 35 mesh). Notes on clay-sized material reflect hand-specimen estimates before washing and screening. Minus #40 fraction includes medium sand through clay-size material.

Depth Interval (ft)	Description
30 – 40	Pebbles/granules: Estimate 10% mud/clay before screening/washing. Very coarse mixed lithologies, with clasts consist of quartzite, chert, VRFs.
40 – 50	Clay/silt: Approx. 60-70% of sample minus #40 fraction before screening. Remainder coarse-grained sand with small pebbles. Clasts as above.
50 – 60	Granules/pebbles: Approx. 10-20% minus #40 fraction before screening/washing. Mostly granules (40%) and pebbles (20%), with coarse sand (20%).
60 – 70	Clay/silt: Approx. 90% of sample minus #40 fraction. Dark red-brown, No screening/washing.
70 – 80	Clay/silt: Approx. 90% of sample minus #40 fraction. Dark red-brown, No screening/washing.
80 – 90	Granules/pebbles: Granules (60%) comprise most of screened sample. Pebbles (40%) often round to subround.
90 – 100	Sand/granules/pebbles: Sand (40%) coarse-grained; granules (40%): pebbles (20%) angular to subround.

[1] Salt Lake Base Line and Meridian.

100 - 110	Clay/sand/granules: Approx. 40 to 50% of sample minus #40 fraction before screening. Screened portion includes coarse sand and granules (70%), subrounded pebbles (20%), and clay masses (10%).
110 - 120	Sand/granules/clay: Approx. 20 to 30% of sample minus #40 fraction before screening. After screening, sample consists of mostly granules and coarse sand (80%), and subround to angular pebbles. Mixed lithologies.
120 - 130	Sand/granules/clay: Approx. 20 to 30% of sample minus #40 fraction before screening. After screening, sample consists of mostly granules and coarse sand (80%), and subround to angular pebbles. Mixed lithologies.
130 - 140	Clay: Approx. 70% of sample is minus #40 fraction with abundant plant fibers (soil sample?).
140 - 150	Granules/sand/clay: Approx. 20 to 30% of sample minus #40 fraction before screening. After screening, sample contains mostly dark gray (Isom Fm?) granules (70%) and coarse sand (30%).
150 - 160	Granules/sand/clay: Approx. 20 to 30% of sample minus #40 fraction before screening. After screening, sample contains granules (70%) and coarse sand (30%). Approx. 50% of granules consist of light tan tuffaceous clasts. Remaining clasts are a variety of dark gray VRFs.
160 - 170	Granules/sand/clay: Approx. 10 to 20% of sample minus #40 fraction before screening. After screening, sample contains granules (70%) and coarse sand (20%), with some subangular to subround pebbles (10%). Granules mostly dark (Isom ?) clasts.
170 - 180	Granules/sand/clay: Approx. 10 to 20% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%) and coarse sand (30%). Mixed VRFs with approx. 40% Isom (?) clasts.
180 - 190	Same as above.
190 - 200	Granules/sand/clay: Approx. 20 to 30% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%), coarse sand (20%), and approx. 10% clay masses. Mixed VRFs with approx. 40% dark gray Isom (?) clasts.
200 - 210	Clay/granules/sand: Approx. 30 to 40% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (50%) and coarse sand (50%). Mixed lithologies with approx. 30% dark gray (Isom ?) clasts.

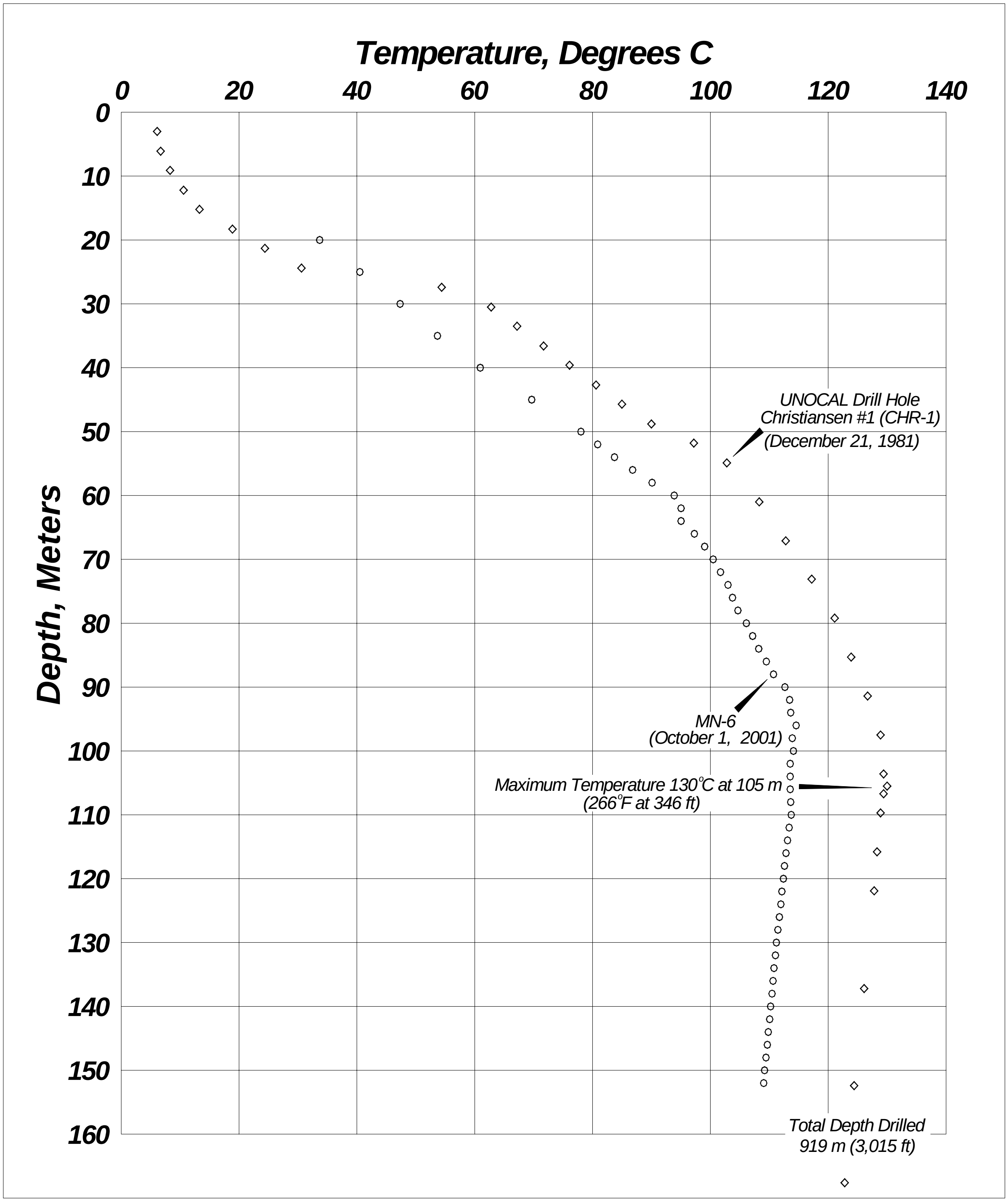
210 - 220	Clay/granules/sand: Approx. 40% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (50%), coarse sand (40%), and clay masses (10%).
220 - 230	Granules/sand/clay: Approx.20% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%), coarse sand (25%), and clay masses (5%).
230 - 240	Same as above.
240 - 250	Clay/granules: Approx. 30 to 40% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%), coarse sand (25%), and clay masses (5%).
250 - 260	Clay/granules: Approx. 40% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%), coarse sand (15%), and clay masses (15%).
260 - 270	Granules/clay: Approx. 30% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (70%), coarse sand (15%), and clay masses (15%).
270 - 280	Granules/pebbles: Approx. 20% of sample minus #40 fraction before screening. After screening, sample contains granules to small pebbles (80%), coarse sand (15%), and some clay masses (5%). Abundant dark gray (Isom?) clasts.
280 - 290	Granules/pebbles/clay: Approx. 30% of sample minus #40 fraction before screening. After screening, sample contains small pebbles to granules (80%), coarse sand (15%), and some clay masses (5%). Abundant dark gray (Isom?) clasts.
290 - 300	Sand/granules: Approx. 20% of sample minus #40 fraction before screening. After screening, sample contains abundant coarse sand to granules (60%), small pebbles (20%), and clay masses (20%). Larger clasts mostly dark gray (Isom?) fragments.
300 - 310	Granules/sand/clay: Approx. 30% minus #40 fraction before screening. After screening, sample contains granules (60%) coarse sand (25%), with some pebbles (10%) and clay masses (5%). Abundant dark gray VRFs (Isom?).
310 - 320	Granules/sand/clay: Approx. 30% minus #40 fraction before screening. After screening, sample contains granules (60%) coarse sand (25%), with some pebbles (10%) and clay masses (5%). Abundant dark gray VRFs (Isom?).

320 - 330	Granules/sand/clay: Approx. 30% minus #40 fraction before screening. After screening, sample contains granules (60%), coarse sand (20%), clay masses (15%), and some pebbles (5%). Abundant dark gray VRFs (Isom?).
330 - 340	Granules/sand/clay: Approx. 20% minus #40 fraction before screening. After screening, sample contains granules (60%), coarse sand (20%), clay masses (15%), and some pebbles (5%). Abundant dark gray VRFs (Isom?).
340 - 350	Sand: Estimate less than 5% minus #40 fraction before screening. After screening sample contains coarse to very coarse sand (80%), granules (15%), and clay masses (5%). Mixed lithologies.
350 - 360	Clay/granules/pebbles: Approx. 60 - 65% minus #40 fraction before screening. After screening sample dominantly granules (80%) and pebbles (20%). Mixed lithologies. Sample gives off moderate sulfur smell.
360 - 370	As above. No sulfur smell.
370 - 380	Sand/granules: Approx. 10 to 20% minus #40 fraction before screening. After screening sample contains very coarse sand (70%), granules (20%), and clay masses (10%).
380 - 390	As above.
390 - 400	Sand/granules/clay: Approx. 20 to 30% minus #40 fraction before screening. After screening, sample contains coarse to very coarse sand (60%), granules (20%), and clay masses (20%). Mixed lithologies.
400 - 410	Granules/sand: Approx. 10 to 20% minus #40 fraction before screening. After screening, sample contains coarse to very coarse sand and granules (70%), pebbles (20%), and clay masses (10%). Mixed lithologies.
410 - 420	Granules/sand: Approx. 10 to 20% minus #40 fraction before screening. After screening, sample contains coarse to very coarse sand and granules (70%), pebbles (10%), and clay masses (20%). Mixed lithologies.
420 - 430	Granules/sand: Approx. 10 to 20% minus #40 fraction before screening. After screening, sample contains coarse to very coarse sand and granules (70%), pebbles (10%), and clay masses (20%). Mixed lithologies with bigger clasts predominantly dark VRFs (Isom?).

430 - 440	Granules/sand: Approx. 10 to 20% minus #40 fraction before screening. After screening, sample contains coarse to very coarse sand and granules (90%) and some clay masses (10%).
440 - 450	Sand: Less than 10% minus #40 fraction before screening. After screening, sample contains medium to very coarse sand (90%) and granules (10%). Mixed lithologies.
450 - 460	Sand/granules/pebbles: Approx. 10% minus #40 fraction before screening. After screening, sample contains medium to very coarse sand (70%), granules (20%), and clay masses (5%). Mixed lithologies.
460 - 470	As above.
470 - 480	Sand/granules: Approx. 10% minus #40 fraction before screening. After screening, sample contains medium to very coarse sand (90%) and granules (10%). Mixed lithologies.
480 - 490	Sand/granules: Approx. 10 to 20% minus #40 fraction before screening. After screening, sample contains medium to very coarse sand and granules (90%), and pebbles (10%). Mixed lithologies.
490 – 500	Sand/granules: Approx. 10% minus #40 fraction before screening. After screening, sample contains medium to very coarse sand and granules (90%), and pebbles (10%). Mixed lithologies.

APPENDIX G

Temperature Profile for UNOCAL drill hole Christiansen #1 (CHR-1)



Temperature profile for UNOCAL drill hole Christiansen #1 (CHR-1). Temperature profile for drill hole MN-6 shown for reference.