TEMPERATURE-DEPTH MONITORING IN THE NEWCASTLE GEOTHERMAL SYSTEM

by
Robert E. Blackett

REPORT OF INVESTIGATION 258
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Department of Energy, National Renewable Energy Laboratory
2007

TEMPERATURE-DEPTH MONITORING IN THE NEWCASTLE GEOTHERMAL SYSTEM

by

Robert E. Blackett

Cover Photo: *Flushing-out of a geothermal well at the Newcastle geothermal area. Milgro Nurseries greenhouse complex is in the middle ground, and the southern part of the Antelope Range is in the background. View is from Escalante Valley looking southeast.*

ISBN 1-55791-772-8

REPORT OF INVESTIGATION 258
UTAH GEOLOGICAL SURVEY
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Department of Energy, National Renewable Energy Laboratory

2007

STATE OF UTAH
Jon Huntsman, Jr., Governor

DEPARTMENT OF NATURAL RESOURCES
Michael Styler, Executive Director

UTAH GEOLOGICAL SURVEY
Richard G. Allis, Director

PUBLICATIONS
contact
Natural Resources Map/Bookstore
1594 W. North Temple
Salt Lake City, Utah 84116
telephone: 801-537-3320
toll-free: 1-888-UTAH MAP
Web site: http://mapstore.utah.gov
email: geostore@utah.gov

THE UTAH GEOLOGICAL SURVEY
contact
1594 W. North Temple, Suite 3110
Salt Lake City, Utah 84116
telephone: 801-537-3300
fax: 801-537-3400
Web site: http://geology.utah.gov

CONTENTS

FIGURES

TEMPERATURE-DEPTH MONITORING IN THE NEWCASTLE GEOTHERMAL SYSTEM

by

Robert E. Blackett

ABSTRACT

In cooperation with geothermal greenhouse operators at the Newcastle geothermal area, the Utah Geological Survey continues to monitor temperature changes within the geothermal field over time. This report presents temperature-depth data collected from six monitoring wells since a previous study was completed in 1997. Changes to the thermal regime continue to take place, possibly as a result of geothermal fluid withdrawal, effects of long-term regional drought, or lowering of ground water in Escalante Valley. Temperature profiles in three monitoring wells generally upstream from producing wells have changed little since baseline records were recorded in 2001 and 2002. Monitoring wells northeast (downstream) of the producing area show observable changes that are difficult to interpret, but are likely due to one or more of the factors listed above. One monitoring well located close to a primary production well shows significant temperature declines throughout, suggesting an influx of cooler water possibly from an upstream injection well or retreat of the geothermal plume toward the production well.

INTRODUCTION

Background, Purpose, and Scope

Commercial greenhouse development began at the Newcastle geothermal area in south-central Iron County, Utah, in the late 1970s. Agribusinesses located in the area took advantage of the recently discovered geothermal water for space heating of greenhouses. Since then, greenhouse operators have developed the geothermal system through numerous production wells and a few injection wells, and have built considerable business ventures for this rural part of the state.

Presently, two companies operate commercial greenhouses in the Newcastle area. Milgro Nurseries is the largest operator with nearly 10.2 hectares (25 ac) of greenhouses that produce ornamental flowers and cuttings. Milgro manages one large and two small greenhouse complexes at Newcastle, which combined make Milgro the nation's largest producer of chrysanthemums and chrysanthemum cuttings.

Castle Valley Greenhouses has also operated in the area for a number of years. Castle Valley's greenhouses produce hydroponic tomatoes for a statewide supermarket chain. They recently completed a 4600-m^2 (49,500-ft^2) addition of geothermal-heated greenhouse space for a total of 8360 m^2 (90,000 ft^2). Castle Valley's short-term plans include building a similar 4600-m^2 (49,500-ft^2) addition in the near future, bringing their total covered space to about 1.3 hectares (3.2 ac).

The Utah Geological Survey (UGS) has been interested in the Newcastle geothermal area since the late 1980s. As a result, the UGS maintains a database of early temperature-depth data for the field and has conducted ongoing studies in cooperation with developers, periodically collecting temperature information to monitor any changes that may be due to geothermal development, natural causes, or a combination thereof. Blackett and others (1997) reported the results of temperature-depth monitoring performed monthly over a period of three years. Since then, the UGS has periodically (usually on an annual basis) collected temperature-depth data. Additional measurements have been done as new wells have been drilled. This report presents the results of temperature-depth data measured in six accessible monitoring wells over the past several years. One of the wells was drilled in 1999 and two of the wells were drilled in 2001, subsequent to the reporting of temperature profiles in the area by Blackett and others (1997). Temperature profiles for the two wells drilled in 2001 were also reported in Blackett (2004). The other three wells are included in the 1997 study. The main purpose here is to document temperature variations in the Newcastle geothermal system over time. Some general discussion points and preliminary conclusions are noted at the end of the report.

Newcastle Geothermal Resource

General Description

Newcastle is a farming community located about 48 kilometers (30 mi) west of Cedar City along the southeastern edge of the Escalante Valley in Iron County, Utah (figure 1). The Newcastle geothermal resource, a low- to moderate-temperature hydrothermal system, was discovered accidentally

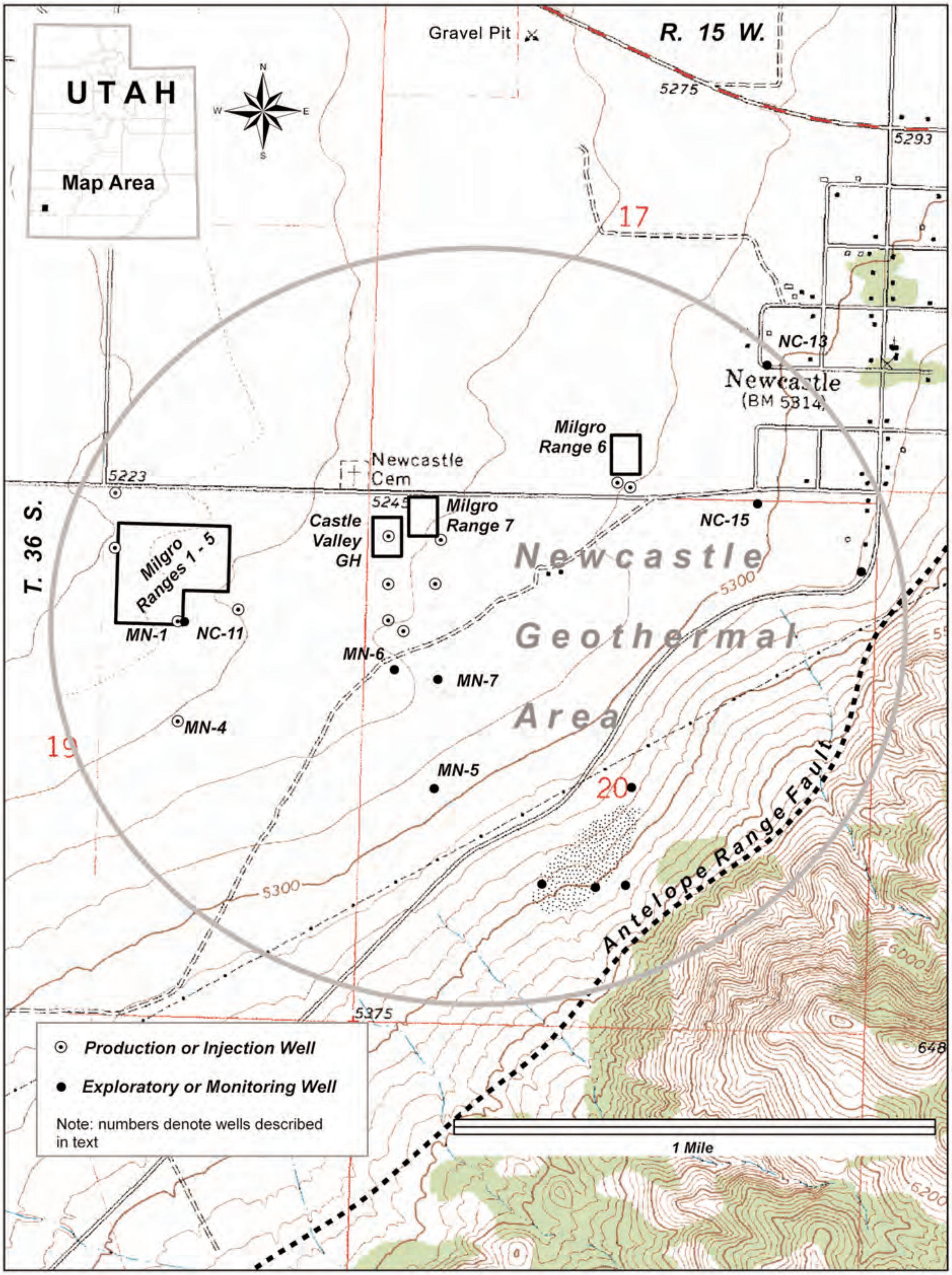

Figure 1. Location of production, injection, exploratory, and monitoring wells at the Newcastle geothermal area, Iron County, Utah. Also shown is the surface trace of the Antelope Range fault and the general outline of the main geothermal area. Stipple pattern in the south half of section 20 indicates the zone of highest measured heat flow, self-potential minima, and vegetation anomaly. Base map was taken from USGS Newcastle 7.5-minute quadrangle.

in 1975 during an aquifer test of an irrigation well. Upon pump testing of the well, Christensen Brothers—a local farming company—discovered that the well had penetrated a geothermal aquifer. Termed a "blind" geothermal resource, there are no obvious surface manifestations such as hot springs or fumaroles to suggest that a geothermal system is present at depth. The water in the well was near the boiling point and reportedly flashed to steam when pumped to the surface. Subsequent studies by the University of Utah, Department of Geology and Geophysics (Chapman and others, 1981), the UGS (Blackett and Shubat, 1992), and the University of Utah Research Institute (Ross and others, 1990, 1994) defined a buried zone of suspected geothermal upflow along the nearby Antelope Range fault postulated as the source of the hot water. Studies also defined a shallow aquifer that channels the outflow of geothermal fluids into the subsurface of Escalante Valley (figure 1).

Since 1980, several commercial greenhouse developers have used the geothermal fluid for space heating of greenhouses. The largest of these developers, Milgro Nurseries, now operates more than 10.2 hectares (25 ac) of greenhouses. Geothermal production wells, typically 152 meters (500 ft) deep, tap the geothermal fluid in this unconfined aquifer. The fluids cool by conduction and probably mix with shallow ground water at the system margins. A maximum temperature of 130°C (266°F) was measured in a 1981 geothermal exploration well, which penetrated the geothermal aquifer (Blackett and Shubat, 1992). Exploratory drilling in the summer of 2001 in the same location (MN-6) as the 1981 well, however, revealed lower temperatures (~117°C, 243°F) throughout the same interval (Blackett, 2004). Production wells at the greenhouses generally yield fluids in the range of 75°C to 95°C (167°F to 203°F).

Escalante Valley is an elliptical basin measuring roughly 70 by 45 kilometers (44 by 28 mi) on the margin of the Basin and Range-Colorado Plateau transition zone. Mountains surround the valley and are composed of mainly mid-Tertiary (26-19 m.y. old) pyroclastic rocks, and late Tertiary (10-8 m.y. old) lava flows and domes. The Antelope Range fault (an active, Quaternary-age, range-bounding structure) marks the southeastern margin of Escalante Valley (figure 1) and defines the southeastern side of the Newcastle graben (Pe and Cook, 1980). Geological and geophysical studies indicate that thermal fluids rise beneath alluvial cover at the intersection of a northwest-oriented fault and fracture zone and the northeast-oriented Antelope Range fault (Ross and others, 1990; Siders and others, 1990; Blackett and Shubat, 1992).

Previous Studies

Detailed gravity surveys, reported by Blackett and Shubat (1992), suggest that valley-fill deposits within the Newcastle graben may be 1.6 kilometes (1 mi) thick. Anderson and Christenson (1989) suggested a middle to late Pleistocene age for the most recent surface-rupturing event along the Antelope Range fault. Geologic mapping of bedrock units southeast of Newcastle revealed that the greatest bedrock offset (600 to 900 meters [1970 to 2950 ft]) occurs along northwest-striking faults (Shubat and Siders, 1988; Blackett and Shubat, 1992). Several of these older bedrock faults, in the footwall block, project beneath the valley fill near the center of the mapped thermal anomaly located a few hundred feet west of the mapped surface trace of the Antelope Range fault.

Blackett and Shubat (1992) prepared a case study of the Newcastle geothermal system based on previous work and the results of detailed geologic mapping and various geophysical surveys. Chapman (in Blackett and others, 1990) developed a heat-flow map of the Newcastle area using previously collected data from about 30 exploratory, thermal-gradient drill holes.

Ross and others (1990) completed electrical resistivity and self-potential (SP) studies that provided independent evidence for the location of the thermal fluid up-flow zone. A well-defined SP minimum was mapped nearly coincident with the zone of greatest heat flow (figure 1). Two lesser SP minima were also mapped southwest of the main SP feature. Numerical models of resistivity profiles use near-vertical low-resistivity bodies that are interpreted as up-flow zones. A shallow, low-resistivity layer within the alluvium extending to the northwest is interpreted as the geothermal outflow plume.

Blackett and others (1997) reported changes in temperature profiles for selected monitor boreholes at Newcastle for the period between 1993 and 1995. They presented the results of these temperature-depth measurements and compared them to measurements reported by others in 1976 and 1988.

As part of a U.S. Department of Energy-sponsored program to help locate 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 land belonging to Milgro Newcastle, Inc., a floral greenhouse operator at Newcastle. Temperature-depth measurements recorded in these boreholes (MN-6 and MN-7) were about 10 percent below the anticipated results (Blackett, 2004).

TEMPERATURE-DEPTH MONITORING IN 2006

As an outgrowth of earlier thermal-gradient studies at Newcastle describing temperature-depth monitoring over time (Blackett and others, 1997; Blackett, 2004), and in cooperation with geothermal operators, the UGS has continued to collect temperature-depth information from available monitoring wells at Newcastle. The following subsections describe the results of measurements taken from monitoring wells that were accessible and measured in April 2006.

Temperature measurements are made with an NP Instruments brand, high-precision thermistor probe and temperature logging equipment. Instrument characteristics and periodic calibrations result in a temperature measurement precision of 0.01ºC (0.02°F), but convection within the well can reduce measurement accuracy to ± 0.05ºC (0.09°F).

On figures 2 through 7, temperature-depth profiles for each of the available monitor wells are depicted with multiple profiles taken over a period of several years. On the right side of each profile a separate graph with the heading "change" depicts the overall change, in degrees Celsius, in the temperature profile of the well between the earliest and most recent readings. Unless otherwise noted, the earliest profile is considered the baseline from which change is measured (positive or negative) with respect to the most recent profile.

Water-Level Information

Gathering water-level information from geothermal wells at Newcastle is problematic. First, although numerous wells have been drilled at Newcastle, most are shut-in or presently in use and, therefore, unavailable for measuring ground-water levels. Secondly, because of the geothermal system, down-hole conditions often do not permit obtaining accurate data using standard water-level probes. Blackett and others (1997) described, in general terms, the hydrogeology of the Escalante Valley and the likelihood of the valley's principal aquifer connection with the Newcastle geothermal system. They also described water-level declines in the principal aquifer measured by the U.S. Geological Survey (USGS) in an irrigation well about 1.6 km (1 mi) northwest of the geothermal wells. The USGS has documented more than 12 m (39 ft) of decline in ground-water levels in the Escalante Valley since 1975. Water levels indicated for wells MN-5, 6, and 7 (on figures 2, 3, and 4, respectively) represent the levels recorded by the driller at the time of completion. Wells MN-6 and MN-7, completed for thermal-gradient studies, were sealed at completion and, therefore, water levels in the geothermal aquifer cannot be measured in these two wells. Although well NC-11 (figure 5) was previously reported to be in communication with the geothermal aquifer (see Blackett and others, 1997, p. 13), I now believe that this well is also sealed. Wells NC-13 and NC-15 (figures 6 and 7, respectively), drilled sometime in the 1980s, are similarly sealed so water levels within the geothermal aquifer also cannot be measured. Moreover, drilling records have not been found for these three wells. Well MN-5 (figure 2) is an unused production well completed so that communication was established with the geothermal aquifer (see following section). Several attempts were made to measure water levels in MN-5 using a Fisher WLT water-level indicator. However, erroneous readings led to the conclusion that steam condensation (water temperatures in this well approach 118°C [244°F]) in the casing cause the indicator buzzer to trip prematurely at random levels above what I believe to be actual standing water. The water level indicated on figure 2 is from the driller's records at the time of well completion on October 13, 1999.

Monitoring Well MN-5

In October of 1999, Milgro Nurseries completed a production-size geothermal well near the southeast corner of their property, presumably closer to the geothermal source zone. This well is referred to in this report as MN-5 (figure 1). MN-5 was completed to a depth of 290 meters (950 ft) with a drilled diameter of 61 centimeters (24 in). Drillers completed the well with a 41-centimeter (16 in) diameter casing perforated below 107 meters (350 ft). Shortly after completion, flow tests revealed low permeability in the production zone with a production temperature of 102°C (215°F). Because the well performance was not adequate for the planned use (greenhouse space heating), Milgro officials opted to leave the well open for possible future use and ongoing monitoring. Temperature profiles have been recorded in this well periodically since its completion in 1999 (figure 2). A maximum temperature of 117.5°C (243.5°F) was recorded at 200 meters (656 ft) in MN-5 during temperature-depth logging in April 2006. MN-5 is relatively far removed, and up the hydrologic gradient, from the production zone for the Newcastle geothermal system. Temperatures have remained relatively stable since its completion (appendix A).

Monitoring Well MN-6

Drill hole MN-6 was completed for temperature-depth monitoring in June 2001 to a total depth of 152 meters (500 ft). Blackett (2004) reported details regarding the purpose, drilling, and completion of this monitoring well. MN-6 was an offset to a deep (913 meters [2995 ft]) well drilled in 1981 by Unocal that recorded a maximum temperature of 130°C (266°F) at 104 meters (340 ft). MN-6 was completed with a 2.5-centimeter (1 in) diameter string of casing, sealed and cemented in the annular space. Temperature measurements have been recorded periodically in this borehole since its completion. A summary of temperature profiles is shown on figure 3. A maximum temperature of 115.0°C (239.0°F) was recorded at 102 meters (335 ft) in MN-6 (appendix B). MN-6 is situated just south of the producing area. The temperature profile for this monitoring well has varied little since its completion in 2001, although two minor temperature declines are seen near 60 meters (197 ft) and 94 meters (308 m).

Monitoring Well MN-7

Drill hole MN-7 was completed for temperature-depth monitoring in June 2001 to a total depth of 152 meters (500 ft). Blackett (2004) reported details regarding the purpose, drilling, and completion of this monitoring well. The borehole was completed with a 2.5-centimeter (1 in) diameter string of casing, sealed and cemented in the annular space. Temperature measurements have been recorded periodically in this borehole since its completion. A maximum temperature of 117.3°C (243.1°F) at 102 meters (335 ft) was recorded in MN-7 in August of 2002. A summary of temperature profiles is shown on figure 4 and the data are presented in appendix C. Temperatures have noticeably declined within the interval 54 - 102 meters (177 - 335 ft) during the period since the baseline data were obtained in 2002.

Monitoring Well NC-11

Monitoring well NC-11, located only 19 meters (62 ft) east of Milgro's main production well (MN-1), was drilled prior to 1977 and has been used since to monitor temperatures in the system. Blackett and others (1997) reported wide fluctuations in temperatures in borehole NC-11 that probably relate directly to withdrawal from the nearby MN-1 production well. Since earlier monitoring was reported, temperatures in this borehole have dropped significantly (figure 5, appendix D), suggesting invasion of cooler water from either injection wells or an overall collapse of the thermal plume in this area. Since April 1994, temperatures in this well have

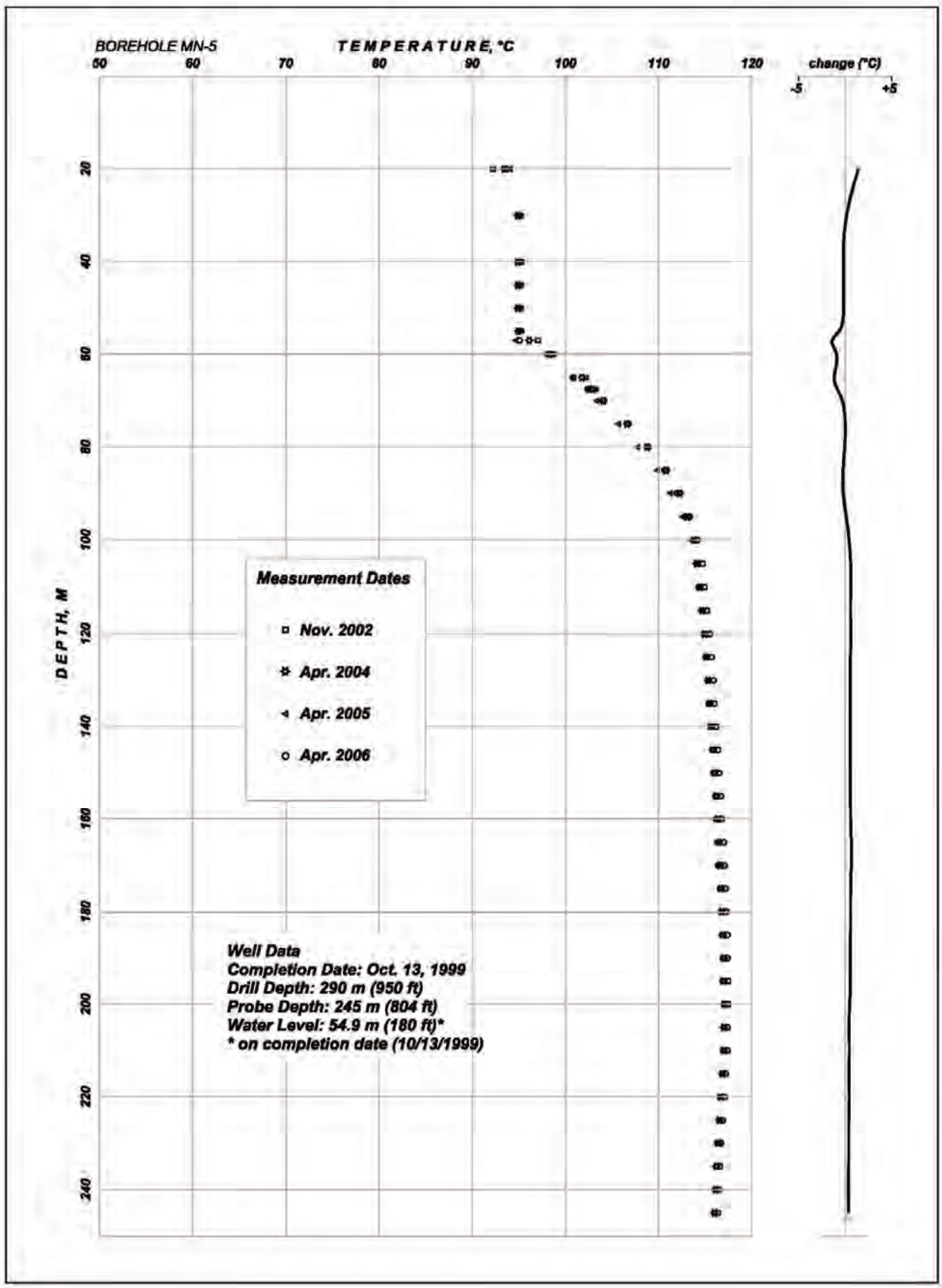

Figure 2. *Temperature profiles for Newcastle monitor well MN-5.*

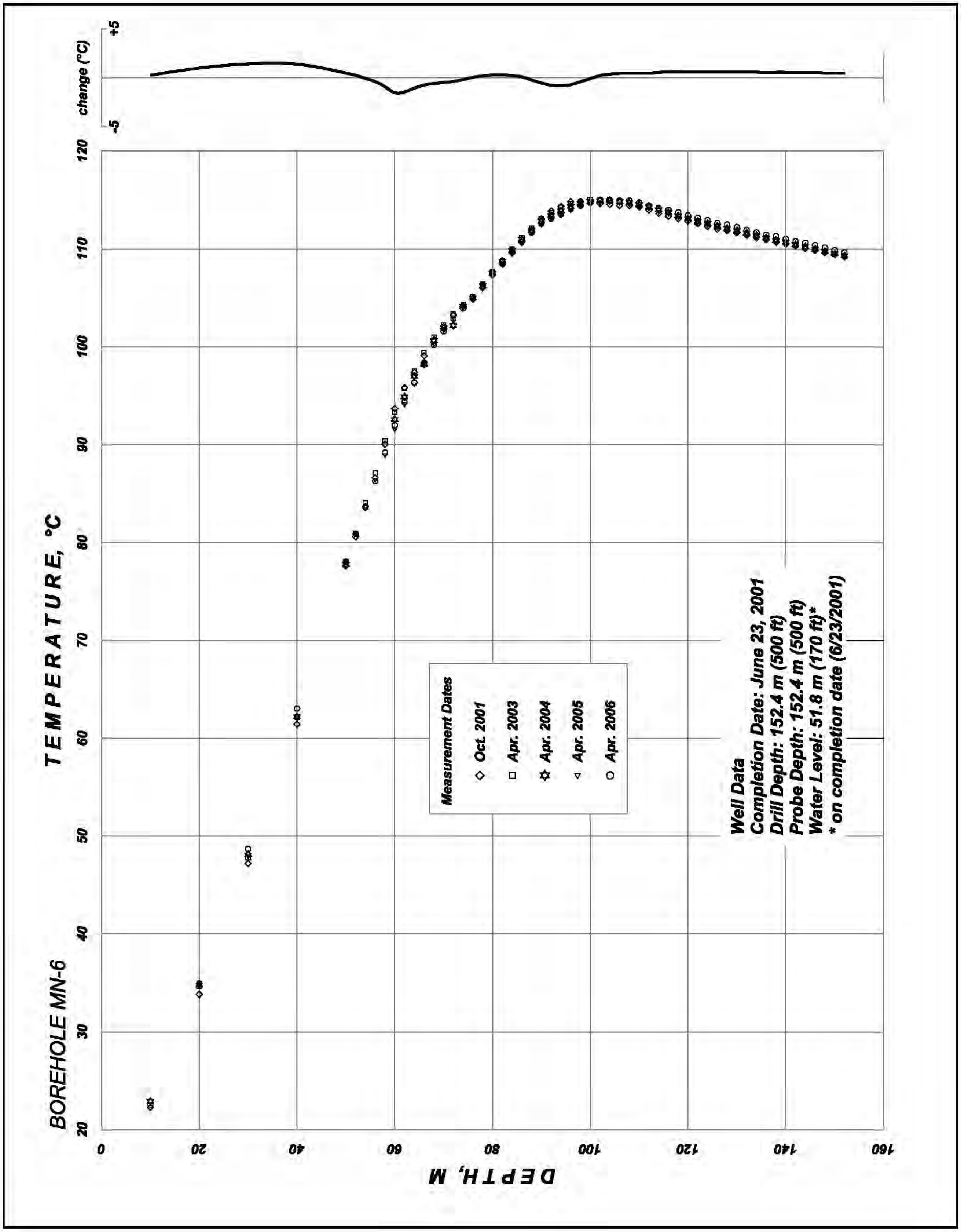

Figure 3. Temperature profiles for monitor well MN-6.

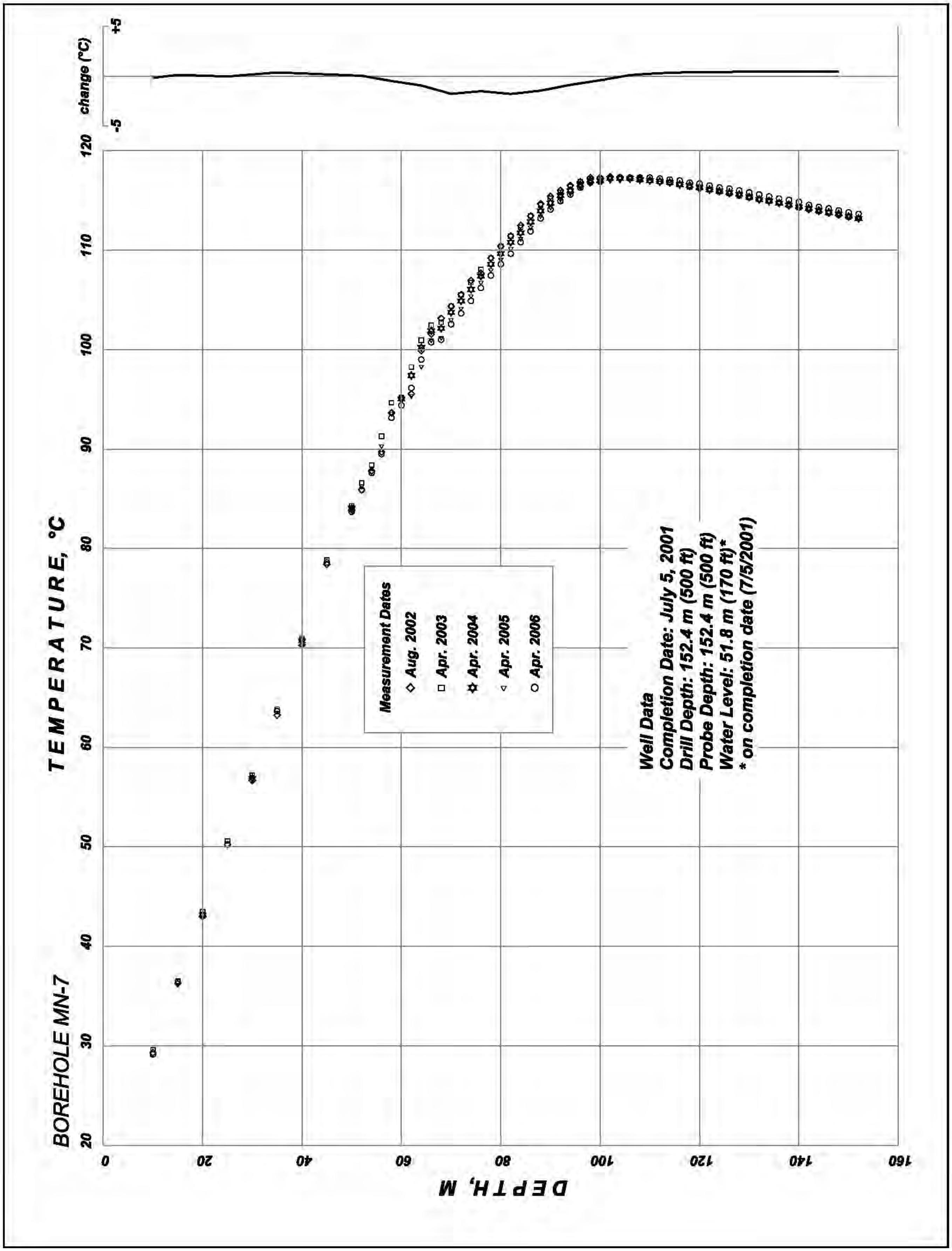

Figure 4. Temperature profiles for monitor well MN-7.

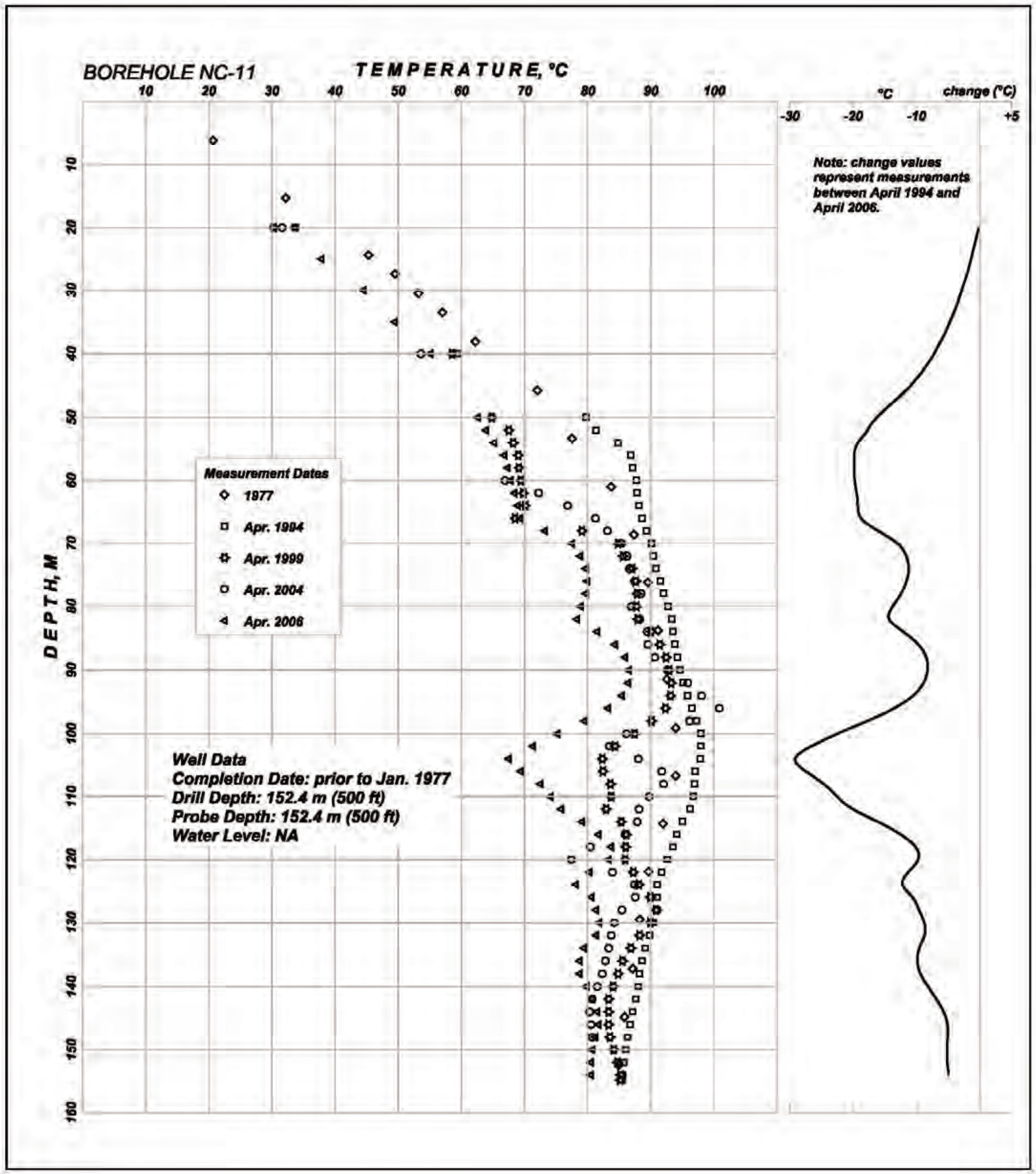

Figure 5. Temperature profiles for monitor well NC-11.

declined by as much as 30°C (54°F). The cooler water influx may be the result of breakthrough of injection fluid from an injection well and adjacent fluid disposal pond (MN-4 on figure 1) located about 300 meters (984 ft) south of MN-1 and NC-11.

Monitoring Well NC-13

This monitoring well, drilled to a depth of 122 meters (400 ft) prior to 1988, contains two concentric pipes installed as a simple down-hole heat exchanger. This residential well was never placed in service and the heating system was never completed as the homeowner decided to use conventional energy for heating and cooling. Fluid level inside the inner casing is constant at about 5 meters (16 ft) depth. Since the first temperature-depth data were collected in 1988, the overall temperature appears to have increased significantly, shown by the black curve, in the interval from about 45 meters to 94 meters (148 - 308 ft). Between 1993 and 2006, however, temperatures in this well dropped in the interval from 62 to 78 meters (203 - 256 ft) and increased in the interval 78 to 102 meters (256 - 335 ft), shown by the gray curve (figure 6, appendix E). Possibly, temperature data collected in 1988 were not in equilibrium, thereby giving a false baseline temperature profile. Other than this explanation, the reasons for the observed temperature changes are not known. This well is relatively far removed from the producing area, and it is downstream with respect to the hydrologic gradient of the system.

Monitoring Well NC-15

Monitoring well NC-15 was drilled prior to 1993 and completed with a simple U-shaped casing as a down-hole heat exchanger in anticipation of heating a residence. The well is open to a depth of 100 meters (329 ft). Reportedly, the casing was filled with ethylene glycol to be used as a working fluid, but the heating system was never completed (Blackett and others, 1997). The temperature-depth profile has two distinct step-like features near 62 meters (203 ft) and 86 meters (282 ft) that may be due to the type of well completion, lithologic variations in the valley fill, or changes of water levels in the geothermal aquifer (figure 7, appendix F). The borehole does not completely penetrate the thermal aquifer. From a temperature profile made in 1988, Blackett and others (1997) initially reported an overall increase in temperature of as much as 5°C (9°F) over a six-year period. The measurements reported in this study, however, indicate that temperatures have declined by as much as 7°C (13°F) in the interval 62 to 68 meters (203 - 223 ft) during the period from 1993 to 2006.

Discussion and Preliminary Conclusions

Changes to the thermal regime at Newcastle continue to take place possibly as a result of geothermal fluid withdrawal, effects of long-term regional drought, and/or lowering of ground water in Escalante Valley through pumping for irrigation. Temperature profiles in monitoring wells MN-5, MN-6, and MN-7, generally upstream from the producing wells, have changed little since baseline records were recorded in 2001 and 2002, although minor thermal variations were recorded. Monitoring wells NC-13 and NC-15, located northeast of the producing area, show observable changes that are difficult to interpret, but are likely due to one or more of the factors listed above. Monitoring well NC-11, located 19 meters (61 ft) east of one of Milgro's primary production wells (MN-1 on figure 1), shows significant temperature declines throughout the depth of the well, indicating an overall influx of cooler water. The cooler water influx may be the result of breakthrough of injection fluid from an injection well located 300 meters (984 ft) south of MN-1 (MN-4 on figure 1). The cooler water influx could also be the result of a retreat of the margin of the geothermal plume toward the production zone.

ACKNOWLEDGEMENTS

The National Renewable Energy Laboratory, through the U.S. Department of Energy's GeoPowering The West initiative, contributed cost-share funding for this study as one activity under DOE grant number DE-FG48-02R806711. We also thank Kyle Christensen of Milgro Newcastle, Inc. for reviewing the study and helping facilitate temperature logging.

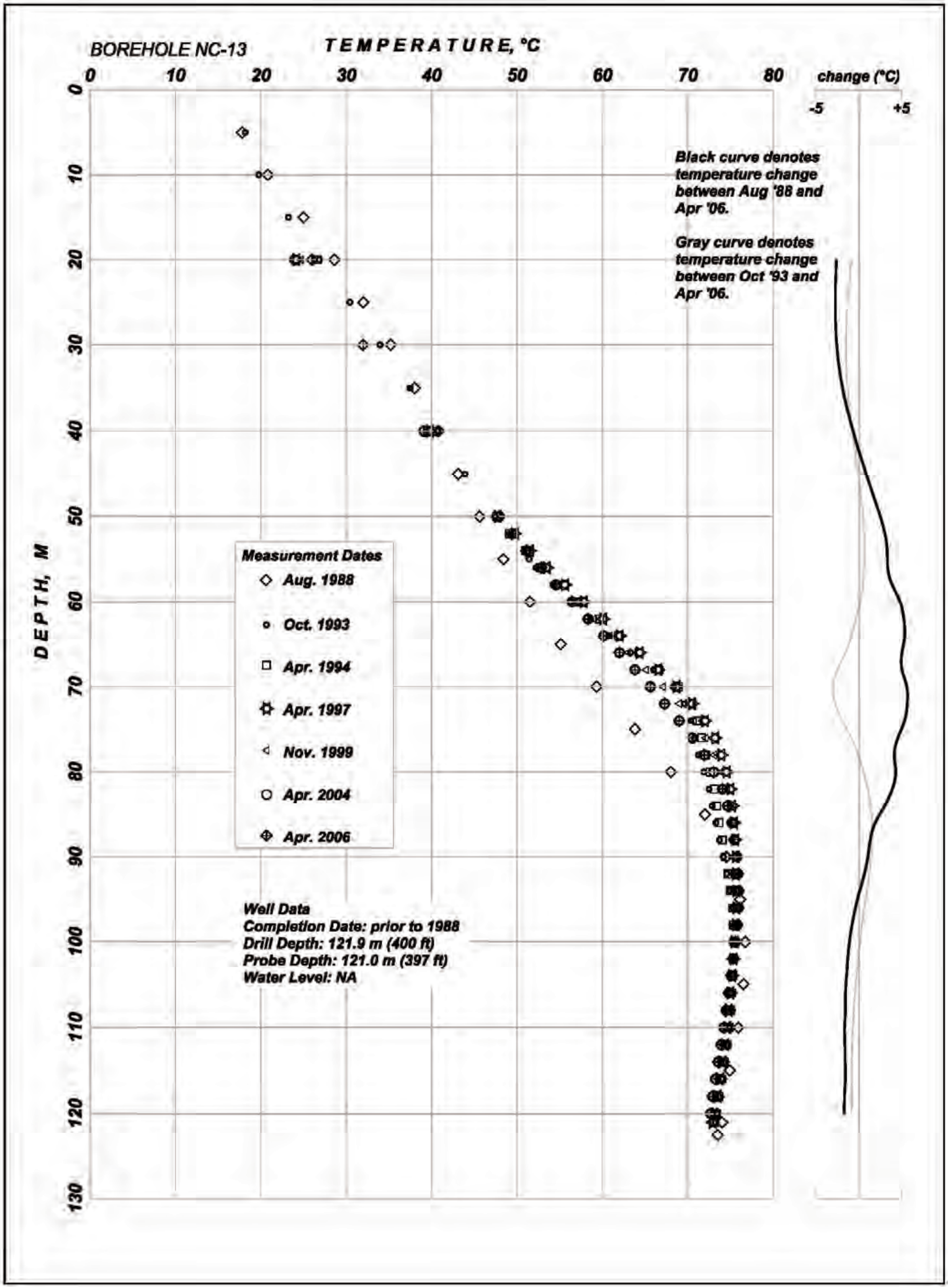

Figure 6. *Temperature profiles for monitor well NC-13.*

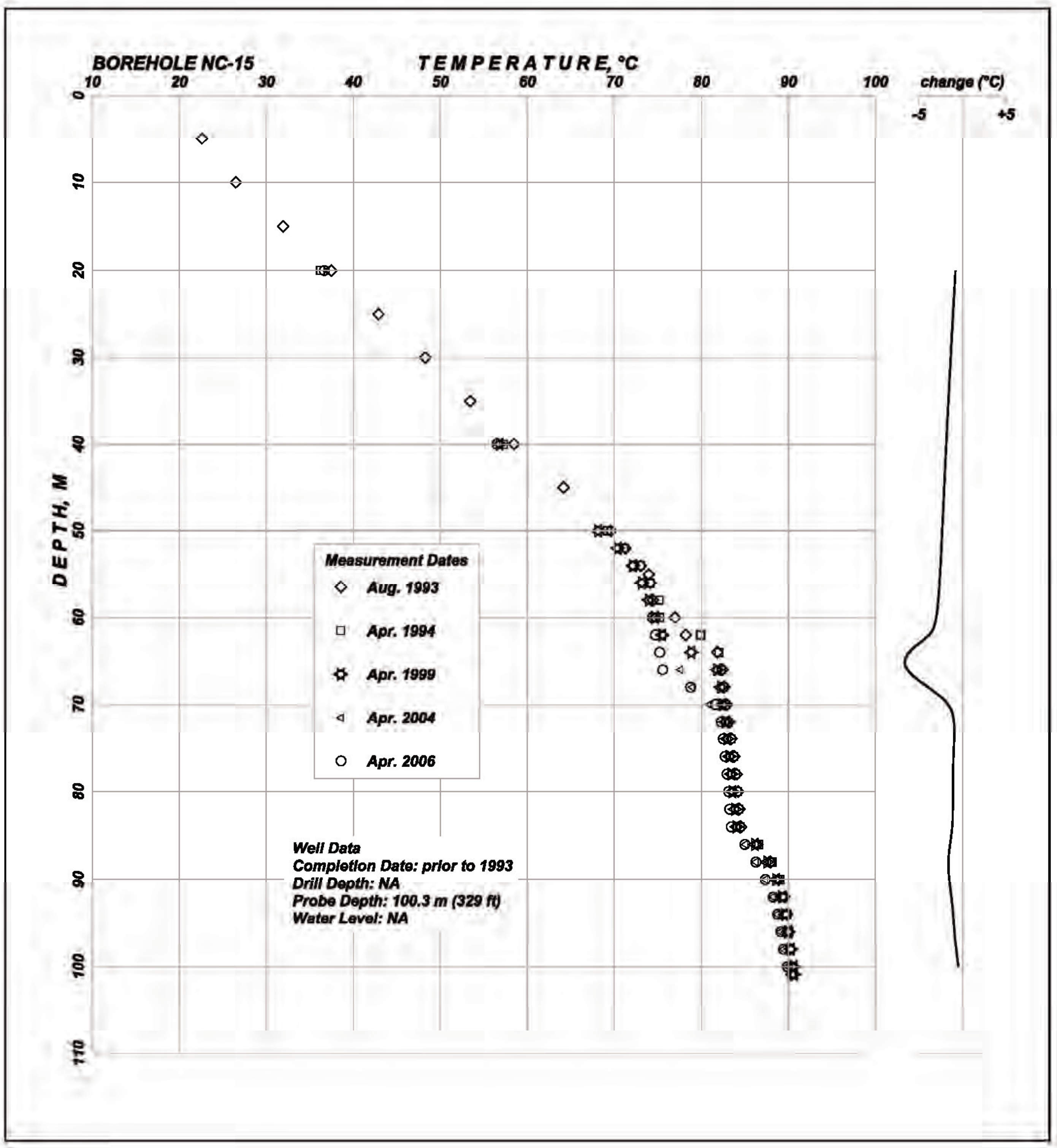

Figure 7. *Temperature profiles for monitor well NC-15.*

REFERENCES

Anderson, R.E., and Christenson, G.E., 1989, Quaternary faults, folds, and selected volcanic features, Cedar City 1° x 2° quadrangle, Utah: Utah Geological and Mineral Survey Miscellaneous Publication 89-6, scale 1:250,000.

Blackett, R.E., 2004, Newcastle, Utah small-scale geothermal power development project—exploratory drilling: Utah Geological Survey Report of Investigation 252, 8 p., 7 appendices.

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, 30 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.

Blackett, R.E., Shubat, M.A., Chapman, D.S., Forster, C.B., Schlinger, C.M., and Bishop, C.E., 1990, The Newcastle geothermal system, Iron County, Utah—geology, hydrology, and conceptual model: Utah Geological Survey Open-File Report No. 189, 179 p.

Chapman, D.S., Clement, M.D., and Mase, C.W., 1981, Thermal regime of the Escalante Desert, Utah, with an analysis of the Newcastle geothermal system: Journal of Geophysical Research, v. 86, no. B12, p. 11,735-11,746.

Pe, Win, and Cook, K.L., 1980, Gravity survey of the Escalante Desert and vicinity, in Iron and Washington Counties, Utah: Salt Lake City, University of Utah, Department of Geology and Geophysics Report no. DOE/ID/12079-14, 156 p.

Ross, H.P., Blackett, R.E., Forster, C.B., and Snelgrove, Stephen, 1994, A model for sustainable development—the Newcastle, Utah geothermal resource, *in* Blackett, R.E., and Moore, J.N., editors, Cenozoic geology and geothermal systems of southwestern Utah: Utah Geological Association Publication 23, p. 69-79.

Ross, H.P., Blackett, R.E., Shubat, M.A., and Mackelprang, C.E., 1990, Delineation of fluid up-flow and outflow plume with electrical resistivity and self-potential data, Newcastle geothermal area, Utah: Geothermal Resources Council Transactions, v. 14, p. 1531-1536.

Shubat, M.A., and Siders, M.A., 1988, Geologic map of the Silver Peak quadrangle, Iron County, Utah: Utah Geological and Mineral Survey Map 108, 13 p., scale 1:24,000.

Siders, M.A., Rowley, P.D., Shubat, M.A., Christenson, G.E., and Galyardt, G.L., 1990, Geologic map of the Newcastle quadrangle, Iron County, Utah: U.S. Geological Survey GQ-1690, scale 1:24,000.

APPENDICES

Appendix A. Temperature-Depth Data For Monitoring Well MN-5

MN-5	11/18/02	04/07/04	04/19/05	04/20/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
20.0	92.3	93.4	94.1	93.7	||	93.4	93.6	0.7942	0.6307	1.8	92.3	94.1
30.0	95.3	94.9	94.8	95.1	||	95.0	95.0	0.2012	0.0405	0.4	94.8	95.3
40.0	95.3	94.9	94.9	95.2	||	95.1	95.0	0.2100	0.0441	0.4	94.9	95.3
45.0	95.3	94.9	94.9	95.1	||	95.0	95.0	0.1864	0.0348	0.4	94.9	95.3
50.0	95.3	94.9	94.9	95.1	||	95.0	95.0	0.1864	0.0348	0.4	94.9	95.3
55.0	95.3	94.9	94.9	95.1	||	95.1	95.0	0.1909	0.0364	0.4	94.9	95.3
57.0	97.0	96.1	94.8	95.1	||	95.8	95.6	1.0307	1.0623	2.3	94.8	97.0
60.0	98.7	98.3	98.0	98.2	||	98.3	98.3	0.2883	0.0831	0.7	98.0	98.7
65.0	102.2	101.8	101.0	100.8	||	101.5	101.4	0.6453	0.4164	1.4	100.8	102.2
67.5	103.3	102.9	102.5	102.4	||	102.8	102.7	0.3954	0.1564	0.8	102.4	103.3
70.0	104.2	104.1	103.4	104.0	||	103.9	104.1	0.3573	0.1277	0.8	103.4	104.2
75.0	106.7	106.6	105.7	106.8	||	106.5	106.7	0.5033	0.2533	1.1	105.7	106.8
80.0	108.9	108.7	107.8	108.9	||	108.6	108.8	0.5050	0.2550	1.1	107.8	108.9
85.0	110.9	110.8	109.9	110.6	||	110.6	110.7	0.4577	0.2095	1.0	109.9	110.9
90.0	112.2	112.3	111.3	112.0	||	112.0	112.1	0.4612	0.2127	1.0	111.3	112.3
95.0	113.2	113.1	112.7	113.4	||	113.1	113.1	0.2971	0.0883	0.7	112.7	113.4
100.0	113.7	113.8	113.6	114.2	||	113.8	113.8	0.2695	0.0726	0.6	113.6	114.2
105.0	114.1	114.1	114.3	114.7	||	114.3	114.2	0.3022	0.0913	0.6	114.1	114.7
110.0	114.3	114.4	114.6	114.9	||	114.5	114.5	0.2794	0.0781	0.7	114.3	114.9
115.0	114.7	114.7	114.7	115.2	||	114.8	114.7	0.2733	0.0747	0.6	114.7	115.2
120.0	114.8	114.9	115.0	115.5	||	115.1	115.0	0.2938	0.0863	0.7	114.8	115.5
125.0	115.1	115.1	115.2	115.7	||	115.3	115.2	0.2774	0.0769	0.6	115.1	115.7
130.0	115.3	115.3	115.4	115.9	||	115.5	115.4	0.2774	0.0769	0.6	115.3	115.9
135.0	115.4	115.5	115.6	116.0	||	115.6	115.6	0.2554	0.0652	0.6	115.4	116.0
140.0	115.6	115.7	115.7	116.2	||	115.8	115.7	0.2610	0.0681	0.6	115.6	116.2
145.0	115.8	115.8	115.9	116.4	||	116.0	115.9	0.2731	0.0746	0.6	115.8	116.4
150.0	115.9	116.0	116.0	116.5	||	116.1	116.0	0.2659	0.0707	0.6	115.9	116.5
155.0	116.1	116.2	116.2	116.7	||	116.3	116.2	0.2684	0.0720	0.6	116.1	116.7
160.0	116.2	116.4	116.4	116.8	||	116.4	116.4	0.2517	0.0633	0.6	116.2	116.8
165.0	116.3	116.5	116.5	117.0	||	116.6	116.5	0.2986	0.0892	0.7	116.3	117.0
170.0	116.4	116.6	116.6	117.1	||	116.7	116.6	0.2986	0.0892	0.7	116.4	117.1
175.0	116.6	116.7	116.7	117.2	||	116.8	116.7	0.2708	0.0733	0.6	116.6	117.2
180.0	116.7	116.8	116.8	117.3	||	116.9	116.8	0.2757	0.0760	0.6	116.7	117.3
185.0	116.8	116.9	116.9	117.4	||	117.0	116.9	0.2757	0.0760	0.6	116.8	117.4
190.0	116.9	117.0	117.0	117.4	||	117.1	117.0	0.2266	0.0514	0.5	116.9	117.4
195.0	116.9	117.0	117.0	117.5	||	117.1	117.0	0.2784	0.0775	0.6	116.9	117.5
200.0	117.0	117.0	117.0	117.5	||	117.1	117.0	0.2478	0.0614	0.5	117.0	117.5
205.0	117.0	117.0	117.0	117.4	||	117.1	117.0	0.2050	0.0420	0.4	117.0	117.4
210.0	116.9	117.0	117.0	117.4	||	117.1	117.0	0.2266	0.0514	0.5	116.9	117.4
215.0	116.8	116.8	116.8	117.2	||	116.9	116.8	0.1931	0.0373	0.4	116.8	117.2
220.0	116.6	116.7	116.7	117.1	||	116.8	116.7	0.2217	0.0492	0.5	116.6	117.1
225.0	116.5	116.5	116.6	116.9	||	116.6	116.6	0.1797	0.0323	0.4	116.5	116.9
230.0	116.3	116.4	116.4	116.7	||	116.4	116.4	0.1732	0.0300	0.4	116.3	116.7
235.0	116.2	116.2	116.2	116.6	||	116.3	116.2	0.1931	0.0373	0.4	116.2	116.6
240.0	116.1	116.1	116.1	116.5	||	116.2	116.1	0.1950	0.0380	0.4	116.1	116.5
245.0	116.0	116.0	116.0	116.4	||	116.1	116.0	0.1950	0.0380	0.4	116.0	116.4

Appendix B. Temperature-Depth Data For Monitoring Well MN-6

MN-6	10/09/01	04/21/03	04/07/04	04/14/05	04/20/06	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	Mean	Median	Std Dev	Var	Min	Max	Range
10	22.3	22.9	22.9	35.1	22.5	25.1	22.9	5.5573	30.8839	22.3	35.1	12.8
20	33.9	34.6	34.8	-	35.0	34.6	34.7	0.4827	0.2330	33.9	35.0	1.1
30	47.2	47.8	48.1	48.2	48.7	48.0	48.1	0.5431	0.2949	47.2	48.7	1.5
40	61.5	62.2	62.2	62.4	63.1	62.2	62.2	0.5739	0.3294	61.5	63.1	1.6
50	77.6	77.8	77.8	78.1	78.1	77.9	77.8	0.2205	0.0486	77.6	78.1	0.5
52	80.6	80.9	-	80.9	80.9	80.8	80.9	0.1584	0.0251	80.6	80.9	0.3
54	83.7	84.1	-	83.7	83.6	83.8	83.7	0.1936	0.0375	83.6	84.1	0.4
56	86.7	87.1	-	86.4	86.3	86.6	86.6	0.3412	0.1164	86.3	87.1	0.8
58	90.0	90.4	-	89.0	89.2	89.6	89.6	0.6837	0.4674	89.0	90.4	1.4
60	93.7	93.3	92.6	91.6	92.0	92.6	92.6	0.8753	0.7661	91.6	93.7	2.1
62	95.8	95.8	94.9	94.1	94.4	95.0	94.9	0.7773	0.6042	94.1	95.8	1.7
64	97.4	97.6	97.0	96.2	96.3	96.9	97.0	0.6147	0.3778	96.2	97.6	1.4
66	99.1	99.4	98.2	98.4	98.4	98.7	98.4	0.5092	0.2593	98.2	99.4	1.2
68	100.8	101.0	100.7	100.3	100.2	100.6	100.7	0.3443	0.1186	100.2	101.0	0.8
70	102.1	102.3	102.0	101.7	101.6	101.9	102.0	0.2703	0.0731	101.6	102.3	0.7
72	103.3	103.4	102.2	103.0	102.9	102.9	103.0	0.4554	0.2074	102.2	103.4	1.2
74	104.2	104.4	104.2	104.0	104.0	104.1	104.2	0.1632	0.0266	104.0	104.4	0.4
76	104.9	105.2	105.0	104.9	105.0	105.0	105.0	0.1124	0.0126	104.9	105.2	0.3
78	106.0	106.4	106.3	106.1	106.3	106.2	106.3	0.1365	0.0186	106.0	106.4	0.3
80	107.3	107.7	107.5	107.5	107.6	107.5	107.5	0.1391	0.0194	107.3	107.7	0.4
82	108.4	108.8	108.7	108.5	108.7	108.7	108.7	0.1649	0.0272	108.4	108.8	0.4
84	109.6	110.0	109.8	109.7	109.8	109.8	109.8	0.1529	0.0234	109.6	110.0	0.4
86	110.7	111.1	111.0	110.7	110.9	110.9	110.9	0.1802	0.0325	110.7	111.1	0.4
88	112.0	112.1	111.9	111.6	111.7	111.9	111.9	0.2039	0.0416	111.6	112.1	0.5
90	113.1	113.1	112.8	112.5	112.6	112.8	112.8	0.2843	0.0808	112.5	113.1	0.6
92	113.9	113.7	113.5	113.1	113.1	113.5	113.5	0.3656	0.1337	113.1	113.9	0.8
94	114.4	114.3	113.9	113.6	113.6	113.9	113.9	0.3890	0.1513	113.6	114.4	0.8
96	114.8	114.7	114.4	114.0	114.1	114.4	114.4	0.3580	0.1281	114.0	114.8	0.8
98	114.8	114.8	114.7	114.4	114.5	114.6	114.7	0.2151	0.0463	114.4	114.8	0.5
100	114.8	115.0	114.8	114.7	114.7	114.8	114.8	0.1413	0.0200	114.7	115.0	0.4
102	114.7	115.0	114.9	114.7	114.9	114.9	114.9	0.1558	0.0243	114.7	115.0	0.4
104	114.6	115.0	114.9	114.8	114.9	114.9	114.9	0.1796	0.0323	114.6	115.0	0.5
106	114.5	114.8	114.8	114.7	114.9	114.8	114.8	0.1807	0.0327	114.5	114.9	0.5
108	114.5	114.7	114.7	114.7	114.9	114.7	114.7	0.1704	0.0290	114.5	114.9	0.5
110	114.3	114.6	114.6	114.5	114.7	114.5	114.6	0.1679	0.0282	114.3	114.7	0.5
112	114.0	114.3	114.3	114.2	114.5	114.2	114.3	0.1671	0.0279	114.0	114.5	0.5
114	113.6	114.0	114.0	114.0	114.2	114.0	114.0	0.1999	0.0400	113.6	114.2	0.5
116	113.4	113.7	113.7	113.7	114.0	113.7	113.7	0.2241	0.0502	113.4	114.0	0.6
118	113.1	113.4	113.4	113.4	113.7	113.4	113.4	0.2242	0.0503	113.1	113.7	0.6
120	112.8	113.1	113.1	113.1	113.5	113.1	113.1	0.2209	0.0488	112.8	113.5	0.6
122	112.6	112.8	112.8	112.8	113.2	112.9	112.8	0.2171	0.0471	112.6	113.2	0.6
124	112.3	112.6	112.6	112.7	112.9	112.6	112.6	0.2184	0.0477	112.3	112.9	0.6
126	112.1	112.3	112.4	112.4	112.7	112.4	112.4	0.2140	0.0458	112.1	112.7	0.6
128	111.9	112.1	112.1	112.1	112.5	112.1	112.1	0.2196	0.0482	111.9	112.5	0.6
130	111.6	111.8	111.9	111.9	112.2	111.9	111.9	0.2187	0.0478	111.6	112.2	0.6
132	111.4	111.6	111.6	111.6	112.0	111.6	111.6	0.2148	0.0461	111.4	112.0	0.6
134	111.1	111.3	111.4	111.4	111.7	111.4	111.4	0.2148	0.0461	111.1	111.7	0.6
136	111.0	111.1	111.1	111.1	111.5	111.2	111.1	0.1821	0.0332	111.0	111.5	0.5
138	110.7	110.9	110.9	111.0	111.3	110.9	110.9	0.2152	0.0463	110.7	111.3	0.6
140	110.5	110.6	110.7	110.7	111.1	110.7	110.7	0.2088	0.0436	110.5	111.1	0.6

Appendix B. Temperature-Depth Data For Monitoring Well MN-6

MN-6	10/09/01	04/21/03	04/07/04	04/14/05	04/20/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Min	Max	Range
142	110.3	110.4	110.5	110.5	110.8	||	110.5	110.5	0.1866	0.0348	110.3	110.8	0.5
144	110.1	110.2	110.2	110.2	110.6	||	110.3	110.2	0.2128	0.0453	110.1	110.6	0.6
146	109.8	110.0	110.0	110.1	110.4	||	110.1	110.0	0.2071	0.0429	109.8	110.4	0.6
148	109.7	109.8	109.8	109.8	110.2	||	109.8	109.8	0.1876	0.0352	109.7	110.2	0.5
150	109.4	109.5	109.5	109.6	109.9	||	109.6	109.5	0.1834	0.0336	109.4	109.9	0.5
152	109.2	109.3	109.3	109.4	109.7	||	109.4	109.3	0.1777	0.0316	109.2	109.7	0.5

Appendix C. Temperature-Depth Data For Monitoring Well MN-7.

MN-7	08/13/02	04/21/03	04/07/04	04/01/05	04/20/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Var	Std Dev	Range	Min	Max
10	29.3	29.6	-	-	29.1	||	29.3	29.3	0.0516	0.2272	0.4	29.1	29.6
15	36.3	36.5	-	-	36.4	||	36.4	36.4	0.0112	0.1060	0.2	36.3	36.5
20	43.1	43.5	43.2	42.9	43.1	||	43.2	43.1	0.0526	0.2294	0.6	42.9	43.5
25	50.3	50.6	-	-	50.2	||	50.4	50.3	0.0446	0.2113	0.4	50.2	50.6
30	56.7	57.2	56.9	-	56.9	||	56.9	56.9	0.0506	0.2249	0.6	56.7	57.2
35	63.3	63.8	-	-	63.6	||	63.6	63.6	0.0811	0.2848	0.6	63.3	63.8
40	70.3	70.9	70.7	70.3	70.7	||	70.6	70.7	0.0759	0.2755	0.7	70.3	70.9
45	78.4	78.9	-	-	78.6	||	78.6	78.6	0.0489	0.2212	0.4	78.4	78.9
50	83.8	84.3	84.0	84.1	83.7	||	84.0	84.0	0.0589	0.2427	0.6	83.7	84.3
52	85.9	86.6	-	86.3	85.9	||	86.2	86.1	0.1126	0.3355	0.7	85.9	86.6
54	87.8	88.4	-	88.1	87.6	||	88.0	87.9	0.1122	0.3349	0.8	87.6	88.4
56	89.7	91.3	-	90.3	89.5	||	90.2	90.0	0.6377	0.7985	1.8	89.5	91.3
58	93.7	94.7	-	93.6	93.2	||	93.8	93.6	0.3966	0.6297	1.5	93.2	94.7
60	95.2	95.2	95.0	95.0	94.4	||	95.0	95.0	0.1030	0.3210	0.8	94.4	95.2
62	95.6	98.2	97.4	95.4	96.1	||	96.5	96.1	1.5277	1.2360	2.9	95.4	98.2
64	99.9	101.0	100.2	98.3	99.0	||	99.7	99.9	1.0975	1.0476	2.7	98.3	101.0
66	101.5	102.4	101.9	100.9	100.8	||	101.5	101.5	0.4725	0.6874	1.7	100.8	102.4
68	103.1	102.8	102.1	101.2	101.0	||	102.0	102.1	0.8757	0.9358	2.1	101.0	103.1
70	104.4	104.4	103.8	103.0	102.6	||	103.6	103.8	0.6699	0.8184	1.9	102.6	104.4
72	105.6	105.5	104.9	104.2	103.6	||	104.7	104.9	0.7031	0.8385	1.9	103.6	105.6
74	107.0	106.8	106.0	105.4	104.9	||	106.0	106.0	0.7690	0.8769	2.1	104.9	107.0
76	107.7	108.1	107.4	106.7	106.2	||	107.2	107.4	0.5677	0.7534	1.9	106.2	108.1
78	109.2	109.2	108.6	108.0	107.5	||	108.5	108.6	0.5771	0.7597	1.7	107.5	109.2
80	110.4	110.4	109.7	109.1	108.6	||	109.6	109.7	0.6435	0.8022	1.8	108.6	110.4
82	111.5	111.4	110.8	110.2	109.7	||	110.7	110.8	0.6033	0.7767	1.8	109.7	111.5
84	112.5	112.3	111.8	111.1	110.8	||	111.7	111.8	0.5367	0.7326	1.7	110.8	112.5
86	113.5	113.5	112.8	112.3	111.9	||	112.8	112.8	0.4852	0.6965	1.6	111.9	113.5
88	114.7	114.6	114.0	113.5	113.2	||	114.0	114.0	0.4198	0.6479	1.5	113.2	114.7
90	115.4	115.2	114.7	114.3	114.1	||	114.7	114.7	0.3283	0.5729	1.3	114.1	115.4
92	116.0	115.8	115.5	115.1	114.9	||	115.5	115.5	0.1969	0.4438	1.1	114.9	116.0
94	116.5	116.4	116.0	115.7	115.6	||	116.0	116.0	0.1566	0.3957	0.9	115.6	116.5
96	116.9	116.9	116.6	116.3	116.3	||	116.6	116.6	0.0900	0.3000	0.6	116.3	116.9
98	117.3	117.2	117.0	116.7	116.8	||	117.0	117.0	0.0665	0.2579	0.6	116.7	117.3
100	117.3	117.2	117.0	116.8	116.9	||	117.0	117.0	0.0443	0.2105	0.5	116.8	117.3
102	117.4	117.3	117.2	117.0	117.2	||	117.2	117.2	0.0233	0.1527	0.4	117.0	117.4
104	117.3	117.3	117.2	117.0	117.3	||	117.2	117.3	0.0182	0.1350	0.3	117.0	117.3
106	117.2	117.2	117.2	117.0	117.3	||	117.2	117.2	0.0086	0.0926	0.3	117.0	117.3
108	117.2	117.1	117.1	117.0	117.3	||	117.1	117.1	0.0138	0.1176	0.3	117.0	117.3
110	117.0	117.0	117.0	116.9	117.3	||	117.0	117.0	0.0243	0.1559	0.4	116.9	117.3
112	116.9	116.9	116.9	116.8	117.2	||	116.9	116.9	0.0230	0.1517	0.4	116.8	117.2
114	116.8	116.8	116.8	116.7	117.1	||	116.8	116.8	0.0230	0.1517	0.4	116.7	117.1
116	116.6	116.6	116.6	116.6	117.0	||	116.7	116.6	0.0320	0.1789	0.4	116.6	117.0
118	116.4	116.4	116.5	116.4	116.8	||	116.5	116.4	0.0300	0.1732	0.4	116.4	116.8
120	116.2	116.3	116.3	116.3	116.7	||	116.3	116.3	0.0380	0.1949	0.5	116.2	116.7
122	116.1	116.1	116.1	116.1	116.5	||	116.2	116.1	0.0304	0.1744	0.4	116.1	116.5
124	115.9	115.9	115.9	116.0	116.3	||	116.0	115.9	0.0266	0.1630	0.4	115.9	116.3
126	115.7	115.7	115.8	115.8	116.2	||	115.8	115.8	0.0399	0.1997	0.5	115.7	116.2
128	115.5	115.5	115.6	115.6	116.0	||	115.6	115.6	0.0412	0.2030	0.5	115.5	116.0
130	115.3	115.3	115.4	115.3	115.8	||	115.4	115.3	0.0442	0.2102	0.5	115.3	115.8
132	115.1	115.1	115.1	115.1	115.6	||	115.2	115.1	0.0461	0.2147	0.5	115.1	115.6
134	114.9	114.9	114.9	114.9	115.4	||	115.0	114.9	0.0461	0.2147	0.5	114.9	115.4
136	114.7	114.7	114.7	114.7	115.2	||	114.8	114.7	0.0461	0.2147	0.5	114.7	115.2

Appendix C. Temperature-Depth Data For Monitoring Well MN-7.

MN-7	08/13/02	04/21/03	04/07/04	04/01/05	04/20/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Var	Std Dev	Range	Min	Max
138	114.5	114.6	114.6	114.6	115.0	||	114.6	114.6	0.0513	0.2264	0.6	114.5	115.0
140	114.3	114.3	114.4	114.4	114.8	||	114.4	114.4	0.0551	0.2347	0.6	114.3	114.8
142	114.1	114.1	114.2	114.2	114.6	||	114.2	114.2	0.0380	0.1949	0.5	114.1	114.6
144	113.9	113.9	114.0	114.0	114.4	||	114.0	114.0	0.0365	0.1910	0.5	113.9	114.4
146	113.7	113.7	113.8	113.8	114.2	||	113.9	113.8	0.0365	0.1910	0.5	113.7	114.2
148	113.6	113.6	113.6	113.6	114.0	||	113.7	113.6	0.0348	0.1866	0.5	113.6	114.0
150	113.4	113.4	113.4	113.5	113.8	||	113.5	113.4	0.0359	0.1894	0.4	113.4	113.8
152	113.2	113.2	113.2	113.3	113.6	||	113.3	113.2	0.0381	0.1951	0.5	113.2	113.6

Appendix D. Temperature-Depth Data For Monitoring Well NC-11

NC-11	1977	04/11/94	04/15/99	04/08/04	04/21/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
6.1	20.7	-	-	-	-	||	20.7	20.7	-	-	-	-	-
15.3	32.2	-	-	-	-	||	32.2	32.2	-	-	-	-	-
20.0	-	33.7	30.3	31.6	33.6	||	32.3	32.6	1.6626	2.7643	3.5	30.3	33.7
24.4	45.3	-	-	-		||	45.3	45.3	-	-	-	-	-
25.0	-	-	-	-	37.9	||	37.9	37.9	-	-	-	-	-
27.4	49.5	-	-	-		||	49.5	49.5	-	-	-	-	-
30.0	-	-	-	-	44.5	||	44.5	44.5	-	-	-	-	-
30.5	53.2	-	-	-		||	53.2	53.2	-	-	-	-	-
33.5	57.0	-	-	-		||	57.0	57.0	-	-	-	-	-
35.0	-	-	-	-	49.5	||	49.5	49.5	-	-	-	-	-
38.1	62.2	-	-	-		||	62.2	62.2	-	-	-	-	-
40.0	-	59.4	58.5	53.6	55.1	||	56.6	56.8	2.7673	7.6580	5.8	53.6	59.4
45.7	72.0	-	-	-		||	72.0	72.0	-	-	-	-	-
50.0	-	79.7	64.8	-	62.6	||	69.0	64.8	9.2971	86.4367	17.1	62.6	79.7
52.0	-	81.3	67.5	-	63.9	||	70.9	67.5	9.2245	85.0916	17.5	63.9	81.3
53.3	77.5	-	-	-		||	77.5	77.5	-	-	-	-	-
54.0	-	84.8	68.2	-	65.2	||	72.7	68.2	10.5287	110.8528	19.5	65.2	84.8
56.0	-	86.8	69.0	-	66.8	||	74.2	69.0	10.9672	120.2800	20.0	66.8	86.8
58.0	-	87.1	69.1	-	67.3	||	74.5	69.1	10.9169	119.1790	19.7	67.3	87.1
60.0	-	87.7	69.4	66.9	67.8	||	72.9	68.6	9.8747	97.5100	20.8	66.9	87.7
61.0	83.7	-	-	-	-	||	83.7	83.7	-	-	-	-	-
62.0	-	87.8	69.8	72.2	68.4	||	74.6	71.0	8.9898	80.8170	19.4	68.4	87.8
64.0	-	88.1	70.1	76.8	68.9	||	76.0	73.5	8.8148	77.7008	19.3	68.9	88.1
66.0	-	88.6	68.5	81.2	69.3	||	76.9	75.3	9.7216	94.5094	20.1	68.5	88.6
68.0	-	89.3	79.1	83.1	73.2	||	81.2	81.1	6.7740	45.8869	16.1	73.2	89.3
68.6	87.3	-	-	-	-	||	87.3	87.3	-	-	-	-	-
70.0	-	90.1	84.8	85.3	77.5	||	84.4	85.0	5.1901	26.9373	12.6	77.5	90.1
72.0	-	90.4	85.6	86.2	78.8	||	85.2	85.9	4.7681	22.7350	11.5	78.8	90.4
74.0	-	90.8	87.0	86.6	79.7	||	86.0	86.8	4.6065	21.2198	11.1	79.7	90.8
76.0	-	91.5	87.6	87.4	79.9	||	86.6	87.5	4.8214	23.2456	11.5	79.9	91.5
76.2	89.5	-	-	-	-	||	89.5	89.5	-	-	-	-	-
78.0	-	92.0	87.8	88.4	79.7	||	87.0	88.1	5.2117	27.1621	12.4	79.7	92.0
80.0	-	92.7	87.7	86.9	78.9	||	86.6	87.3	5.7139	32.6486	13.8	78.9	92.7
82.0	-	93.3	87.9	88.2	78.3	||	86.9	88.1	6.2721	39.3387	15.0	78.3	93.3
83.8	91.1	-	-	-	-	||	91.1	91.1	-	-	-	-	-
84.0	-	93.5	90.0	89.4	81.5	||	88.6	89.7	5.0640	25.6441	12.0	81.5	93.5
86.0	-	93.8	91.4	89.5	84.3	||	89.7	90.5	4.0408	16.3282	9.5	84.3	93.8
88.0	-	94.2	92.4	90.6	85.9	||	90.7	91.5	3.5562	12.6469	8.3	85.9	94.2
90.0	-	94.6	92.9	92.6	86.5	||	91.6	92.7	3.5599	12.6731	8.2	86.5	94.6
91.4	92.5	-	-	-	-	||	92.5	92.5	-	-	-	-	-
92.0	-	95.1	93.2	95.8	86.4	||	92.6	94.1	4.3166	18.6329	9.5	86.4	95.8
94.0	-	95.8	93.1	98.0	85.4	||	93.1	94.4	5.4882	30.1207	12.6	85.4	98.0
96.0	-	96.5	92.3	100.8	83.2	||	93.2	94.4	7.4964	56.1965	17.6	83.2	100.8
98.0	-	97.2	90.1	96.1	79.5	||	90.8	93.1	8.1178	65.8982	17.7	79.5	97.2
99.1	93.9	-	-	-	-	||	93.9	93.9	-	-	-	-	-
100.0	-	97.9	87.4	86.1	75.2	||	86.6	86.7	9.2983	86.4590	22.7	75.2	97.9
102.0	-	97.9	84.3	83.4	71.3	||	84.2	83.8	10.8990	118.7873	26.7	71.3	97.9
104.0	-	97.8	82.3	88.0	67.5	||	83.9	85.1	12.6478	159.9676	30.2	67.5	97.8
106.0	-	97.0	82.4	91.7	69.4	||	85.2	87.1	12.0936	146.2549	27.6	69.4	97.0
106.7	93.9	-	-	-	-	||	93.9	93.9	-	-	-	-	-
108.0	-	96.9	83.6	92.0	72.5	||	86.3	87.8	10.7194	114.9066	24.5	72.5	96.9
110.0	-	96.7	83.7	89.7	74.1	||	86.1	86.7	9.5842	91.8564	22.6	74.1	96.7

Appendix D. Temperature-Depth Data For Monitoring Well NC-11

NC-11	1977	04/11/94	04/15/99	04/08/04	04/21/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
112.0	-	96.2	82.9	88.1	75.8	||	85.7	85.5	8.6226	74.3494	20.5	75.8	96.2
114.0	-	95.0	85.3	87.8	79.1	||	86.8	86.6	6.5891	43.4164	15.9	79.1	95.0
114.3	91.9	-	-	-	-	||	91.9	91.9	-	-	-	-	-
116.0	-	94.1	86.1	85.9	81.7	||	87.0	86.0	5.1667	26.6953	12.4	81.7	94.1
118.0	-	93.5	86.0	80.4	83.7	||	85.9	84.9	5.5397	30.6881	13.0	80.4	93.5
120.0	-	92.6	85.9	77.4	83.3	||	84.8	84.6	6.3085	39.7972	15.2	77.4	92.6
121.9	89.6	-	-	-	-	||	89.6	89.6	-	-	-	-	-
122.0	-	91.7	87.2	83.9	80.3	||	85.8	85.5	4.8521	23.5424	11.4	80.3	91.7
124.0	-	91.0	88.1	87.4	78.1	||	86.1	87.8	5.5916	31.2662	12.9	78.1	91.0
126.0	-	91.0	89.9	87.5	80.6	||	87.2	88.7	4.6437	21.5639	10.4	80.6	91.0
128.0	-	91.0	90.8	85.4	81.3	||	87.1	88.1	4.6487	21.6109	9.7	81.3	91.0
129.5	88.2	-	-	-	-	||	88.2	88.2	-	-	-	-	-
130.0	-	90.4	89.9	84.2	81.8	||	86.6	87.1	4.2384	17.9641	8.6	81.8	90.4
132.0	-	89.8	88.2	83.7	81.3	||	85.8	86.0	3.9450	15.5633	8.5	81.3	89.8
134.0	-	89.1	86.8	83.3	79.4	||	84.6	85.0	4.2556	18.1104	9.7	79.4	89.1
136.0	-	88.6	85.5	82.8	78.7	||	83.9	84.2	4.2257	17.8566	10.0	78.7	88.6
137.2	87.1	-	-	-	-	||	87.1	87.1	-	-	-	-	-
138.0	-	88.2	84.8	82.3	78.7	||	83.5	83.6	4.0235	16.1884	9.5	78.7	88.2
140.0	-	88.0	84.0	81.5	79.8	||	83.3	82.8	3.5432	12.5542	8.2	79.8	88.0
142.0	-	87.6	83.3	80.7	80.7	||	83.1	82.0	3.2321	10.4464	6.9	80.7	87.6
144.0	-	87.1	83.3	80.3	81.5	||	83.0	82.4	2.9633	8.7814	6.8	80.3	87.1
144.8	85.8	-	-	-	-	||	85.8	85.8	-	-	-	-	-
146.0	-	86.7	83.3	80.5	81.7	||	83.0	82.5	2.6927	7.2504	6.2	80.5	86.7
148.0	-	86.3	83.5	80.7	81.2	||	82.9	82.4	2.5444	6.4739	5.6	80.7	86.3
150.0	-	86.0	84.1	-	80.7	||	83.6	84.1	2.6574	7.0620	5.2	80.7	86.0
152.0	-	85.7	84.7	-	80.5	||	83.7	84.7	2.7461	7.5409	5.2	80.5	85.7
152.4	84.9	-	-	-	-	||	84.9	84.9	-	-	-	-	-
154.0	-	85.5	85.2	-	80.5	||	83.7	85.2	2.7628	7.6330	4.9	80.5	85.5
154.8	-	85.4	85.1	-	-	||	85.3	85.3	0.2051	0.0421	0.3	85.1	85.4

Appendix E. Temperature-Depth Data For Monitoring Well NC-13

NC-13	08/01/88	10/5/93	04/11/94	04/24/97	11/04/99	04/08/04	04/21/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
5.0	17.8	18.2	-	-	-	-	-	||	18.0	18.0	0.2687	0.0722	0.4	17.8	18.2
10.0	20.8	19.8	-	-	-	-	-	||	20.3	20.3	0.7425	0.5513	1.1	19.8	20.8
15.0	25.0	23.2	-	-	-	-	-	||	24.1	24.1	1.2445	1.5488	1.8	23.2	25.0
20.0	28.6	26.8	26.6	24.2	24.7	24.0	26.0	||	25.8	26.0	1.6779	2.8153	4.6	24.0	28.6
25.0	32.0	30.4	-	-	-	-		||	31.2	31.2	1.1172	1.2482	1.6	30.4	32.0
30.0	35.2	34.0	-	-	-	-	32.0	||	33.7	34.0	1.6294	2.6551	3.2	32.0	35.2
35.0	38.0	37.5	-	-	-	-		||	37.7	37.7	0.3748	0.1404	0.5	37.5	38.0
40.0	40.8	40.7	40.5	39.8	39.4	39.1	39.9	||	40.0	39.9	0.6575	0.4324	1.7	39.1	40.8
45.0	43.1	43.9	-	-	-	-	-	||	43.5	43.5	0.5728	0.3281	0.8	43.1	43.9
50.0	45.6	47.4	47.6	47.8	47.3	47.9	48.2	||	47.4	47.6	0.8423	0.7095	2.6	45.6	48.2
52.0	46.7	-	49.1	49.7	49.1	49.4	49.8	||	49.0	49.3	1.1481	1.3182	3.1	46.7	49.8
54.0	47.8	-	51.0	51.5	50.9	51.1	51.2	||	50.6	51.0	1.3775	1.8976	3.7	47.8	51.5
55.0	48.4	51.4	-	-	-	-	-	||	49.9	49.9	2.1284	4.5300	3.0	48.4	51.4
56.0	49.6	52.2	52.7	53.5	52.9	52.8	52.9	||	52.4	52.8	1.2749	1.6255	3.9	49.6	53.5
58.0	50.9	54.2	54.7	55.6	54.9	54.6	54.7	||	54.2	54.7	1.5243	2.3236	4.7	50.9	55.6
60.0	51.5	56.3	57.1	57.8	57.1	56.4	56.5	||	56.1	56.5	2.0954	4.3905	6.3	51.5	57.8
62.0	52.9	58.6	59.6	60.1	59.0	58.3	58.2	||	58.1	58.6	2.3918	5.7205	7.2	52.9	60.1
64.0	54.4	60.7	61.8	62.0	60.9	60.1	59.9	||	60.0	60.7	2.5921	6.7188	7.6	54.4	62.0
65.0	55.1	-	-	-	-	-	-	||	55.1	55.1	-	-	NA	55.1	55.1
66.0	56.8	63.3	64.3	64.4	63.0	62.0	61.8	||	62.2	63.0	2.5844	6.6791	7.6	56.8	64.4
68.0	58.5	66.0	66.6	66.5	65.1	63.8	63.4	||	64.3	65.1	2.8343	8.0334	8.1	58.5	66.6
70.0	59.3	68.3	68.9	68.6	67.1	65.6	65.1	||	66.1	67.1	3.3519	11.2354	9.6	59.3	68.9
72.0	61.1	69.6	70.2	70.5	69.0	67.3	66.8	||	67.8	69.0	3.2629	10.6466	9.4	61.1	70.5
74.0	62.9	70.4	71.0	72.0	70.7	69.0	68.4	||	69.2	70.4	3.0394	9.2382	9.1	62.9	72.0
75.0	63.8	-	-	-	-	-	-	||	63.8	63.8	-	-	NA	63.8	63.8
76.0	65.5	70.8	71.6	73.2	72.1	70.5	70.0	||	70.5	70.8	2.4584	6.0438	7.7	65.5	73.2
78.0	67.2	71.3	72.1	73.9	73.1	71.9	71.2	||	71.5	71.9	2.1427	4.5914	6.7	67.2	73.9
80.0	68.0	71.9	72.6	74.5	73.9	73.0	72.5	||	72.3	72.6	2.1119	4.4600	6.5	68.0	74.5
82.0	69.6	72.5	73.1	75.0	74.6	74.1	73.6	||	73.2	73.6	1.8069	3.2649	5.4	69.6	75.0
84.0	71.2	72.8	73.3	75.2	75.1	74.6	74.3	||	73.8	74.3	1.4457	2.0901	4.0	71.2	75.2
85.0	72.0	-	-	-	-	-	-	||	72.0	72.0	-	-	NA	72.0	72.0
86.0	73.0	73.3	73.7	75.4	75.4	75.2	74.9	||	74.4	74.9	1.0446	1.0912	2.4	73.0	75.4
88.0	74.0	73.7	74.0	75.5	75.6	75.4	75.3	||	74.8	75.3	0.8517	0.7254	2.0	73.7	75.6
90.0	74.5	74.2	74.4	75.6	75.8	75.7	75.6	||	75.1	75.6	0.7313	0.5347	1.7	74.2	75.8
92.0	75.1	74.6	74.7	75.6	75.9	75.9	75.8	||	75.4	75.6	0.5687	0.3235	1.3	74.6	75.9

Appendix E. Temperature-Depth Data For Monitoring Well NC-13

NC-13	08/01/88	10/5/93	04/11/94	04/24/97	11/04/99	04/08/04	04/21/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
94.0	75.8	74.9	74.9	75.7	75.9	75.9	75.9	||	75.6	75.8	0.4524	0.2047	1.0	74.9	75.9
95.0	76.1	-	-	-	-	-	-	||	76.1	76.1	-	-	NA	76.1	76.1
96.0	76.3	75.2	75.2	75.7	75.9	75.9	75.9	||	75.7	75.9	0.3858	0.1489	1.1	75.2	76.3
98.0	76.6	75.4	75.4	75.6	75.8	75.8	75.8	||	75.8	75.8	0.4156	0.1727	1.3	75.4	76.6
100.0	76.7	75.4	75.4	75.5	75.6	75.6	75.6	||	75.7	75.6	0.4607	0.2123	1.3	75.4	76.7
102.0	76.6	75.4	75.3	75.3	75.4	75.3	75.3	||	75.5	75.3	0.4765	0.2270	1.3	75.3	76.6
104.0	76.5	75.3	75.3	75.2	75.1	75.1	75.1	||	75.4	75.2	0.5158	0.2660	1.4	75.1	76.5
105.0	76.5	-	-	-	-	-	-	||	76.5	76.5	-	-	NA	76.5	76.5
106.0	76.3	75.2	75.1	75.0	74.8	74.8	74.7	||	75.1	75.0	0.5431	0.2950	1.6	74.7	76.3
108.0	76.0	75.1	75.0	74.8	74.6	74.5	74.5	||	74.9	74.8	0.5302	0.2811	1.5	74.5	76.0
110.0	75.9	74.9	74.8	74.6	74.4	74.2	74.2	||	74.7	74.6	0.5923	0.3509	1.7	74.2	75.9
112.0	75.5	74.7	74.6	74.4	74.1	73.9	73.9	||	74.4	74.4	0.5676	0.3222	1.6	73.9	75.5
114.0	75.1	74.3	74.3	74.1	73.8	73.6	73.5	||	74.1	74.1	0.5457	0.2978	1.6	73.5	75.1
115.0	74.9	-	-	-	-	-	-	||	74.9	74.9	-	-	NA	74.9	74.9
116.0	74.7	74.0	74.0	73.8	73.5	73.2	73.2	||	73.8	73.8	0.5295	0.2804	1.5	73.2	74.7
118.0	74.5	73.7	73.6	73.5	73.2	72.9	72.8	||	73.5	73.5	0.5666	0.3210	1.7	72.8	74.5
120.0	74.2	73.4	73.4	73.2	72.9	72.7	72.5	||	73.2	73.2	0.5612	0.3150	1.7	72.5	74.2
121.0	74.0	73.2	73.1	72.9	72.6			||	73.2	73.1	0.5079	0.2579	1.4	72.6	74.0
122.5	73.5	-	-	-	-	-	-	||	73.5	73.5	-	-	NA	73.5	73.5

Appendix F. Temperature-Depth Data For Monitoring Well NC-15

NC-15	08/31/93	04/11/94	04/15/99	04/08/04	04/21/06	||	***General Statistics***						
Depth (m)	T (°C)	T (°C)	T (°C)	T (°C)	T (°C)	||	Mean	Median	Std Dev	Var	Range	Min	Max
5.0	22.6	-	-	-	-	||	22.6	22.6	-	-	-	-	-
10.0	26.5	-	-	-	-	||	26.5	26.5	-	-	-	-	-
15.0	32.0	-	-	-	-	||	32.0	32.0	-	-	-	-	-
20.0	37.5	36.2		37.0	36.7	||	36.8	36.8	0.5252	0.2758	1.3	36.2	37.5
25.0	42.9	-	-	-	-	||	42.9	42.9	-	-	-	-	-
30.0	48.3	-	-	-	-	||	48.3	48.3	-	-	-	-	-
35.0	53.5	-	-	-	-	||	53.5	53.5	-	-	-	-	-
40.0	58.5	57.3	56.8	56.6	56.5	||	57.1	56.8	0.7980	0.6368	2.0	56.5	58.5
45.0	64.2	-	-	-	-	||	64.2	64.2	NA	NA	NA	NA	NA
50.0	69.6	69.2	68.1	-	-	||	69.0	69.2	0.7504	0.5630	1.5	68.1	69.6
52.0	71.3	71.1	70.4	-	-	||	70.9	71.1	0.4672	0.2182	0.9	70.4	71.3
54.0	73.0	73.0	72.1	-	-	||	72.7	73.0	0.5139	0.2641	0.9	72.1	73.0
55.0	74.0	-	-	-	-	||	74.0	74.0	-	-	-	-	-
56.0	74.2	74.1	73.2	-	-	||	73.8	74.1	0.5551	0.3081	1.0	73.2	74.2
58.0	74.5	75.1	74.0	-	-	||	74.5	74.5	0.5724	0.3276	1.1	74.0	75.1
60.0	77.0	75.2	74.7	75.0	74.4	||	75.2	75.0	1.0255	1.0517	2.6	74.4	77.0
62.0	78.2	79.9	75.5	-	74.7	||	77.1	76.9	2.4014	5.7669	5.2	74.7	79.9
64.0	81.8	82.0	78.8	-	75.2	||	79.5	80.3	3.1842	10.1391	6.8	75.2	82.0
66.0	82.4	82.3	81.8	77.6	75.6	||	79.9	81.8	3.1573	9.9683	6.9	75.6	82.4
68.0	82.6	82.5	82.2	79.0	78.8	||	81.0	82.2	1.9820	3.9285	3.9	78.8	82.6
70.0	82.9	82.8	82.4	81.0	81.6	||	82.1	82.4	0.8287	0.6868	1.9	81.0	82.9
72.0	83.2	83.1	82.8	82.6	82.3	||	82.8	82.8	0.3676	0.1351	0.9	82.3	83.2
74.0	83.5	83.4	83.0	82.9	82.5	||	83.1	83.0	0.3970	0.1576	0.9	82.5	83.5
76.0	83.8	83.7	83.2	83.1	82.7	||	83.3	83.2	0.4327	0.1872	1.0	82.7	83.8
78.0	84.1	83.9	83.4	83.2	82.9	||	83.5	83.4	0.4695	0.2204	1.1	82.9	84.1
80.0	84.2	84.1	83.6	83.5	83.1	||	83.7	83.6	0.4571	0.2090	1.1	83.1	84.2
82.0	84.4	84.3	83.9	83.6	83.3	||	83.9	83.9	0.4636	0.2150	1.1	83.3	84.4
84.0	84.6	84.5	84.0	83.7	83.4	||	84.0	84.0	0.4788	0.2293	1.1	83.4	84.6
86.0	86.4	86.6	86.2	85.1	85.0	||	85.8	86.2	0.7695	0.5921	1.6	85.0	86.6
88.0	88.0	88.1	87.6	86.3	86.3	||	87.2	87.6	0.9027	0.8148	1.8	86.3	88.1
90.0	88.9	89.0	88.6	87.3	87.3	||	88.2	88.6	0.8310	0.6906	1.7	87.3	89.0
92.0	89.5	89.5	89.3	88.2	88.3	||	89.0	89.3	0.6605	0.4362	1.3	88.2	89.5
94.0	89.8	89.8	89.6	88.7	88.8	||	89.4	89.6	0.5657	0.3200	1.1	88.7	89.8
96.0	90.1	90.1	90.0	89.1	89.1	||	89.7	90.0	0.5039	0.2539	1.0	89.1	90.1
98.0	90.2	90.2	90.3	89.4	89.5	||	89.9	90.2	0.4373	0.1912	0.9	89.4	90.3
100.0	90.4	90.4	90.6	89.8	89.9	||	90.2	90.4	0.3325	0.1105	0.8	89.8	90.6
100.9	90.4	90.4	90.6	-	-	||	90.5	90.4	0.1514	0.0229	0.3	90.4	90.6