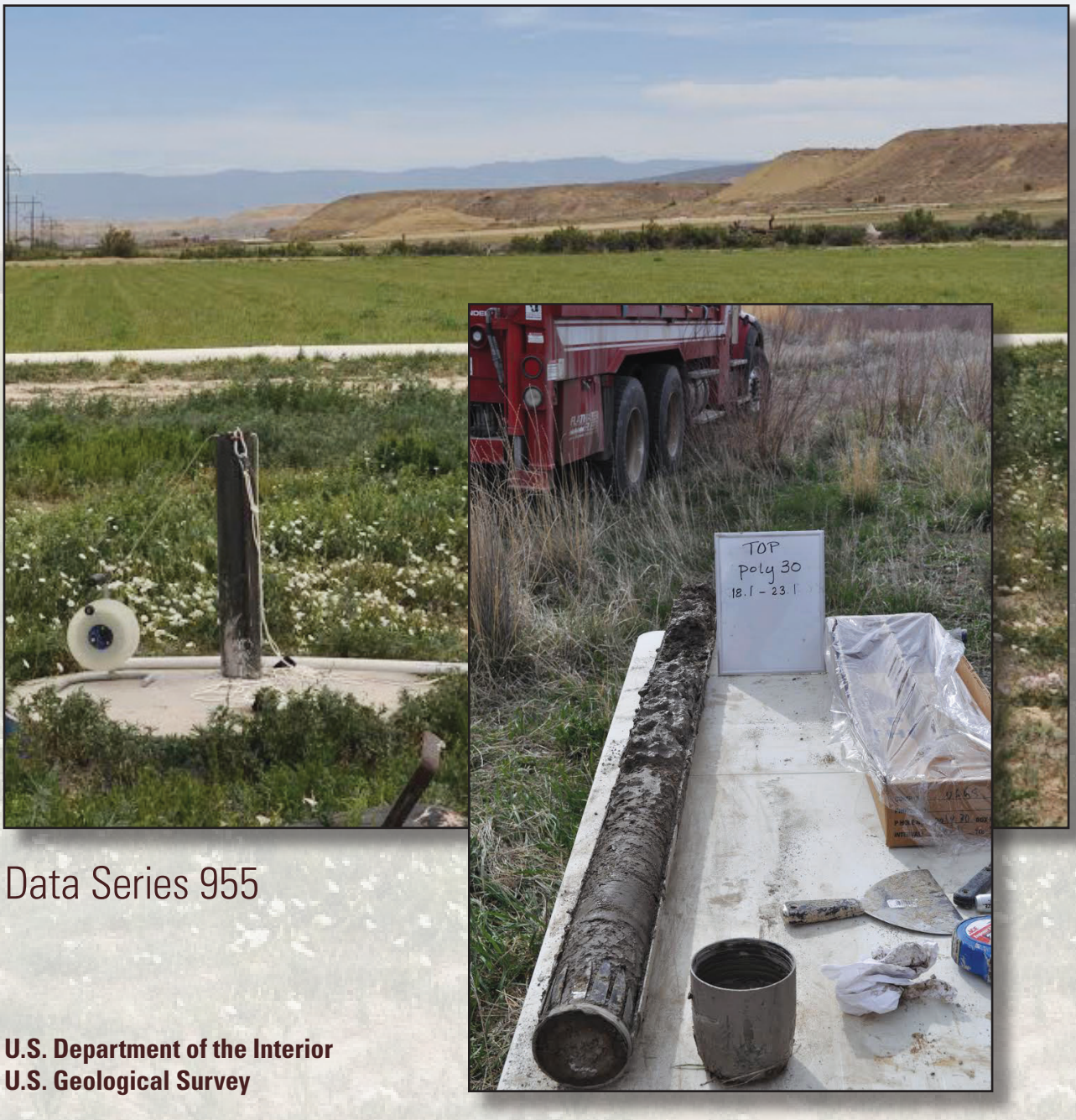
USGS
science for a changing world

Prepared in cooperation with Colorado Water Conservation Board
and the Bureau of Reclamation

Installation of a Groundwater Monitoring-Well Network on the East Side of the Uncompahgre River in the Lower Gunnison River Basin, Colorado, 2014



Data Series 955

U.S. Department of the Interior
U.S. Geological Survey

Cover: *Left*, Core from monitoring well, lower Gunnison River Basin, Montrose County, Colorado, April 2014. Photo by Judith Thomas, U.S. Geological Survey. *Right*, Monitoring well adjacent to agricultural field, lower Gunnison River Basin, Montrose County, Colorado, August 2013. Photo by Judith Thomas, U.S. Geological Survey.

Installation of a Groundwater Monitoring-Well Network on the East Side of the Uncompahgre River in the Lower Gunnison River Basin, Colorado, 2014

By Judith C. Thomas

Prepared in cooperation with Colorado Water Conservation Board
and the Bureau of Reclamation

Data Series 955

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit http://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit http://www.usgs.gov/pubprod/.

Suggested citation:
Thomas, J.C., 2015, Installation of a groundwater monitoring-well network on the east side of the Uncompahgre River in the Lower Gunnison River Basin, Colorado, 2014: U.S. Geological Survey Data Series 955, 44 p., http://dx.doi.org/10.3133/ds955.

ISSN 2327-638X (online)

Contents

Figures

Table

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.0393701	inch (in.)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)

International System of Units to Inch/Pound

Multiply	By	To obtain
	Volume	
liter (L)	0.2642	gallon (gal)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8×°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F–32)/1.8$$

Vertical coordinate information was referenced to North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information was referenced to North American Datum of 1983 (NAD 83).

Specific conductance was given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Installation of a Groundwater Monitoring-Well Network on the East Side of the Uncompahgre River in the Lower Gunnison River Basin, Colorado, 2014

By Judith C. Thomas

Abstract

The east side of the Uncompahgre River Basin has been a known contributor of dissolved selenium to recipient streams. Discharge of groundwater containing dissolved selenium contributes to surface-water selenium concentrations and loads; however, the groundwater system on the east side of the Uncompahgre River Basin is not well characterized. The U.S. Geological Survey, in cooperation with the Colorado Water Conservation Board and the Bureau of Reclamation, has established a groundwater-monitoring network on the east side of the Uncompahgre River Basin. Thirty wells total were installed for this project: 10 in 2012 (DS 923, http://dx.doi.org/10.3133/ds923), and 20 monitoring wells were installed during April and June 2014 which are presented in this report. This report presents location data, lithologic logs, well-construction diagrams, and well-development information. Understanding the groundwater system can provide managers with an additional metric for evaluating the effectiveness of salinity and selenium control projects.

Introduction

The east side of the Uncompahgre River Basin has been a known contributor of dissolved selenium to recipient streams. The U.S. Fish and Wildlife Service (USFWS) and the U.S. Geological Survey (USGS), as part of National Irrigation Water Quality Program (NIQWP), found that dissolved selenium concentrations were elevated for both groundwater and river systems in irrigated parts of the Uncompahgre River Basin in the lower Gunnison River Basin (Butler and others, 1996). As a result, selenium sourced from irrigated areas was thought to be detrimentally affecting native Colorado River Basin fish species. The Colorado Department of Public Health and Environment (CDPHE) has since adopted standards for selenium in the lower Gunnison River Basin. Many rivers and streams of the east side of the Uncompahgre River Basin are selenium impaired for cold water fisheries on the Colorado's 303(d) list , and concentrations have exceeded the 85th percentile chronic aquatic-life standard for dissolved selenium (4.6 micrograms per liter) as established by the State of Colorado (Thomas and others, 2008; Butler and Leib, 2002). Despite the implementation of control projects in the region that were designed to limit the mobilization of selenium, there are indications that selenium loads may be increasing (Moore, 2011).

Perennial streamflow on the east side of the Uncompahgre River Basin is supported by seasonal tributary inflow, irrigation-return flows, and shallow groundwater discharge from areas underlain by selenium-bearing shale. Previous work in the basin (Bureau of Reclamation, 1982) supports a conceptual model of water-table (unconfined) groundwater conditions present beneath irrigated areas and in proximity to streams. Discharge of groundwater containing dissolved selenium contributes to surface-water selenium concentrations and loads; however, the groundwater system on the east side of the Uncompahgre River Basin is not well characterized. Additional information such as depth to water, extent and thickness of saturation, hydraulic conductivity, and groundwater selenium concentrations are needed to understand the characteristics of the groundwater system. Understanding the groundwater system can provide managers with an additional metric for evaluating the effectiveness of salinity and selenium control projects. Coupled with current surface-water monitoring, groundwater monitoring can provide a more complete understanding of the factors involved in achieving successful control projects. The USGS, in cooperation with Colorado Water Conservation Board and the Bureau of Reclamation, has established a groundwater-monitoring network on the east side of the Uncompahgre River Basin. This report describes the second phase of the implementation of a monitoring-well network (20 of the 30 wells were installed in April and June 2014) to characterize the groundwater quality on the east side of the Uncompahgre River Basin. The first phase of the project involved the installation of 10 of the 30 wells (polys 8, 11, 12, 13, 15, 16, 20, 24, 26, and 28) that were installed earlier in October/November 2012 and are not included in this report (Thomas and Arnold, 2015).

The purpose of this project was to design and install a groundwater-monitoring network to characterize groundwater quality and groundwater levels on the east side of the

Uncompahgre River Basin in Colorado (fig. 1). The purpose of this report is to document network design, well drilling and installation, and well development of 20 of the 30 wells that make up this network.

Network Design

In order to better understand the shallow groundwater system, a 30-well uniform randomized groundwater-monitoring network was developed to provide a statistically robust groundwater monitoring network design. The study area is on the east side of the Uncompahgre River Basin (fig. 1), where irrigation is taking place within the Bureau of Reclamation's Uncompahgre Irrigation Project. The Uncompahgre Irrigation Project is in west-central Colorado and includes lands that surround the town of Montrose and extend 34 miles (mi) along both sides of the Uncompahgre River to Delta, Colorado (Bureau of Reclamation, 2014). The project is a series of dams, canals, laterals, and drains that draws water from the Uncompahgre and Gunnison Rivers for irrigation of land within the project area. Network design was based on methods described by Alley (1993) and has been used by the USGS National Water Quality Assessment program in national investigations. The network design was created using a computerized technique (Scott, 1990) that generates a random distribution of potential groundwater sampling sites. The study area was determined by clipping digital maps of irrigated land to an outline of the Uncompahgre Irrigation Project. The resulting study area was used as input to Scott's computerized technique for site selection. The random site-selection process divided the study area into 30 equal-area polygons and then generated three potential groundwater monitoring sites within each polygon: a primary, secondary, and tertiary location (fig. 2). When establishing sites, the primary location is considered first, followed by the secondary and tertiary sites.

Phase II Site Selection

Final well locations were established based on landowner permission and site accessibility (fig. 3). Ten of the 30 randomly-determined locations were installed in October and November of calendar year 2012 (Thomas and Arnold, 2015). The remaining 20 wells were installed during April and June 2014 and are presented in this report.

Well Drilling and Installation

Monitoring well drilling and installation occurred during April and June 2014 (table 1). Drilling services were provided by the Bureau of Reclamation Drilling Operations Group of Pleasant Grove, Utah. Borehole drilling and well installation was overseen by a USGS hydrologist, who documented daily drilling operations, logged and packaged geologic materials encountered while drilling, and prepared well construction reports. Well installation was completed in accordance with USGS Guidelines (http://ga.water.usgs.gov/gwqa/gwpd.7.4.16.html, accessed June 25, 2012) and State of Colorado drilling regulations (http://water.state.co.us/groundwater/BOE/Pages/BOERules.aspx, accessed December 31, 2013). USGS staff was responsible for coordination of drilling services and obtaining permits required by the State of Colorado for well drilling.

Eighteen of the 20 boreholes for monitoring wells were drilled with a truck-mounted CME85 drilling rig. Two of the boreholes for monitoring wells were drilled using a Gus Pech 300 CHR drilling rig (LGRB Poly 6 and LGRB Poly 23). In both cases, boreholes were advanced with 4.25-inch (in) inside diameter (ID) hollow-stem augers, and continuous cores of geologic materials were collected where possible to properly identify lithologic intervals for well installation. Lithologic logs were developed on the basis of visual inspection of cores and auger cuttings (appendix 1). Lithologic descriptions are based on the Wentworth classification system (Wentworth, 1922).

Individual well construction diagrams are presented in appendix 2. Wells were constructed using 2-in diameter, Schedule 40 polyvinyl chloride (PVC) casing (ASTM D1785-12, http://www.astm.org/Standards/D1785.htm) with a locking cap and protective surface casing. Well screens were either 5 or 10-feet (ft) long and installed near the bottom of the saturated thickness. A 0.5- to 3-ft long sump was installed below the screen in some of the monitoring wells where possible. Annular space adjacent to the screened interval was backfilled with a graded sand pack, annular space above the screened interval was plugged with bentonite, and a concrete well pad was placed at the surface. Other aspects of well construction were in accordance with USGS specifications for water-quality wells (Lapham and others, 1997) and Colorado State regulations (http://water.state.co.us/groundwater/BOE/Pages/BOERules.aspx, accessed December 31, 2013).

Well Development

Wells were developed after drilling to remove mud and any foreign material from the well and to help improve the hydraulic connection between the well and aquifer material. Well development was completed in July 2014, and was accomplished using a combination of bailing, pumping, and mechanical surging for a maximum of 8 hours or until the produced water was clear and parameters such as turbidity, specific conductance, and pH were stable. A Waterra Hydrolift 2 inertial pump system was used to develop wells. Well development information is provided for each well in appendix 3.

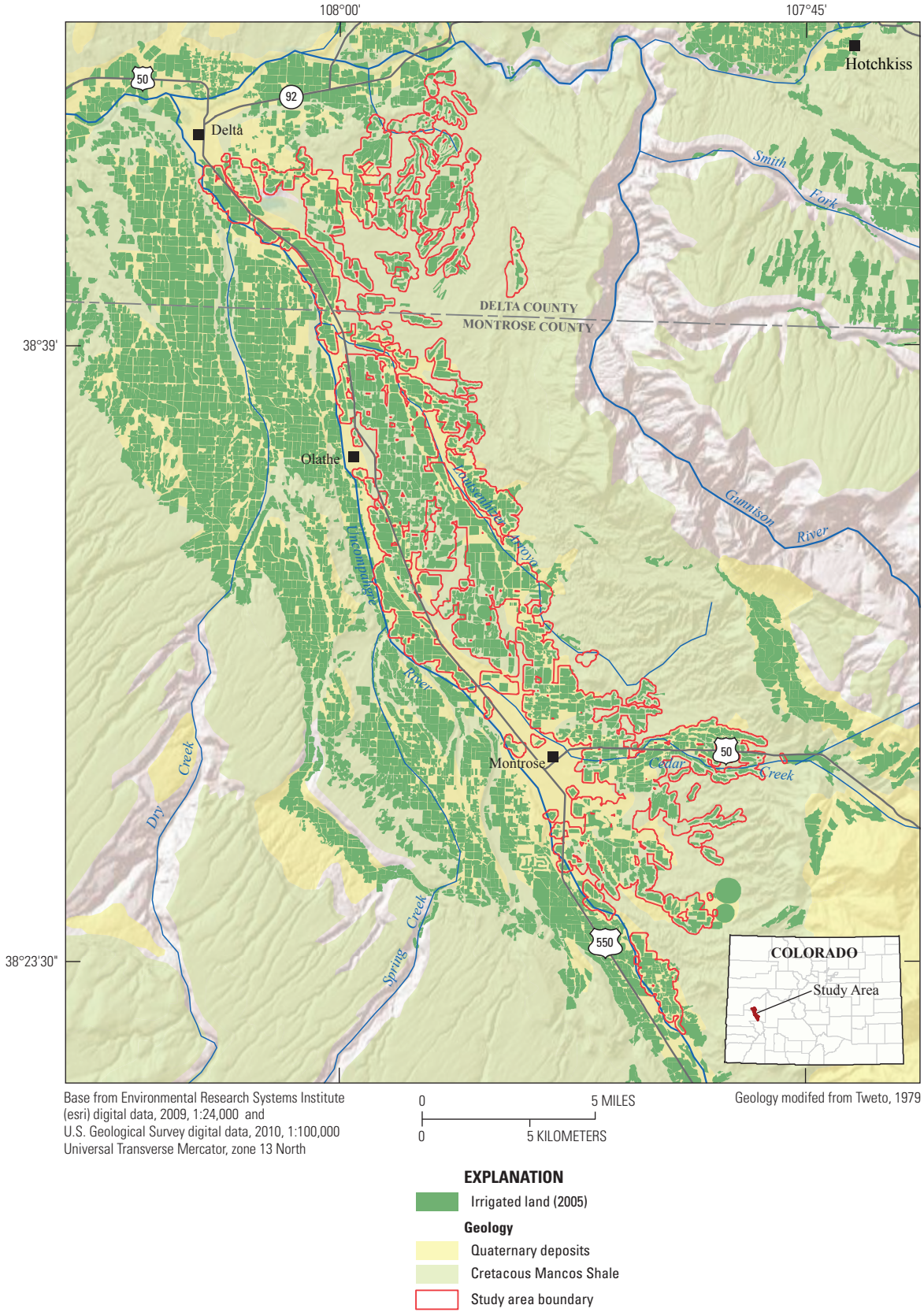


Figure 1. Location of study area on the east side of the Uncompahgre River Basin, Colorado.

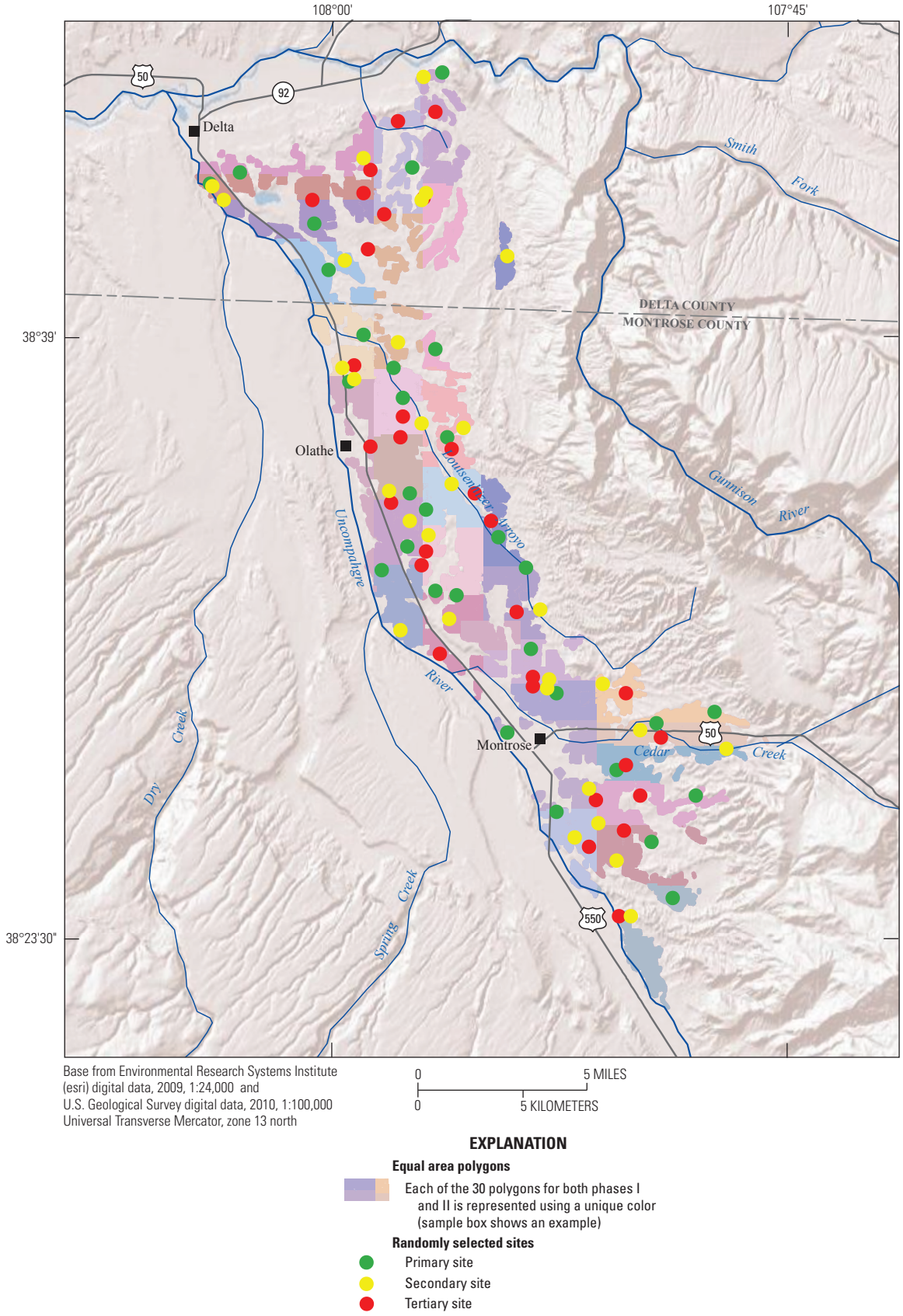


Figure 2. Location of the 30 equal-area polygons and randomly selected monitoring sites within each (primary, secondary, and tertiary), east side of the Uncompahgre River Basin, Colorado. Each polygon is represented using a unique color.

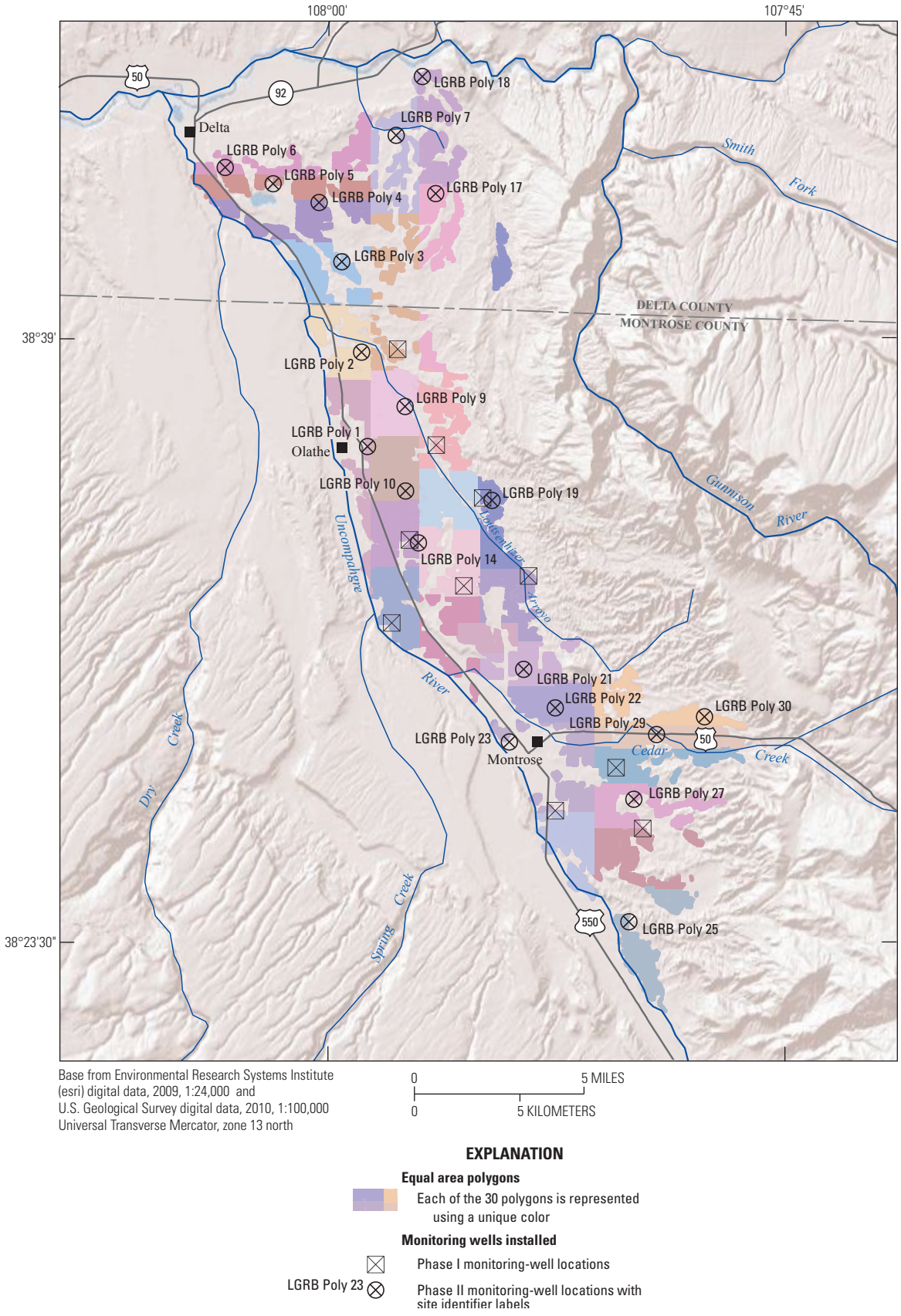


Figure 3. Location of monitoring wells installed April and June of calendar year 2014, east side of the Uncompahgre River Basin, Colorado.

Table 1. Summary of groundwater monitoring-well locations, construction, and depth to water.

[LGRB, lower Gunnison River Basin; Poly, polygon number; DDMMSS, degrees, minutes, seconds; stick-up height in feet above land surface; all depths in feet below land surface]

Well identifier	USGS site identification number	Latitude (DDMMSS)	Longitude (DDMMSS)	Date completed	Depth to water at time of drilling	Stick-up height	Depth to top of screen	Depth to bottom of screen	Depth to top of annular seal	Depth to top of sand pack	Depth to bottom of sand pack	Total well depth	Total borehole depth
LGRB Poly 1	383626107581501	383626	1075815	4/26/2014	8.5	2.4	15.7	20.7	2.0	14.0	21.0	21.0	21.5
LGRB Poly 2	383852107583301	383852	1075833	4/14/2014	7.7	3.1	6.5	11.5	2.0	5.0	13.5	13.5	13.5
LGRB Poly 3	384110107591801	384110	1075918	4/11/2014	3.8	2.6	7.2	12.2	2.0	6.0	14.7	14.7	23.5
LGRB Poly 4	384240108000701	384240	1080007	4/24/2014	11.2	2.4	17.4	22.4	2.0	15.2	22.7	22.7	22.7
LGRB Poly 5	384306108013801	384306	1080138	4/24/2014	20.4	2.9	21.7	26.7	2.0	19.0	27.0	27.0	27.0
LGRB Poly 6	384329108031301	384329	1080313	6/9/2014	29.5	2.6	34.5	44.5	2.0	30.0	46.5	46.5	46.5
LGRB Poly 7	384428107573901	384428	1075739	4/23/2014	20.5	2.2	22.2	27.2	2.0	20.5	28.2	28.2	28.2
LGRB Poly 9	383730107570501	383730	1075705	4/25/2014	9.5	2.2	26.0	31.0	2.0	24.5	31.3	31.3	31.3
LGRB Poly 10	383520107565901	383520	1075659	4/9/2014	14.2	2.7	16.0	21.0	2.0	14.5	23.5	23.5	23.5
LGRB Poly 14	383401107563001	383401	1075630	4/27/2014	22.2	2.9	26.7	36.7	6.0	25.0	42.0	42.0	42.0
LGRB Poly 17	384300107561801	384300	1075618	4/11/2014	7.1	2.9	16.3	21.3	1.9	13.8	23.3	23.3	23.3
LGRB Poly 18	384559107565201	384559	1075652	4/23/2014	14.8	2.7	12.5	17.5	1.8	10.5	18.5	18.5	18.5
LGRB Poly 19	383510107540801	383510	1075408	4/26/2014	7.5	3.1	7.5	17.5	2.0	6.0	18.5	18.5	18.5
LGRB Poly 21	383051107525501	383051	1075255	4/28/2014	8.5	3.1	12.1	17.1	2.0	10.0	18.1	18.1	18.1
LGRB Poly 22	382954107515101	382954	1075151	4/14/2014	21.3	–0.3	23.0	33.0	2.0	20.0	33.8	33.8	33.8
LGRB Poly 23	382859107531901	382859	1075319	6/9/2014	8.1	–0.2	14.5	19.5	2.0	6.0	20.9	21.1	21.6
LGRB Poly 25	382427107491401	382427	1074914	4/28/2014	9.8	2.9	8.2	13.2	2.0	6.0	16.2	16.2	16.2
LGRB Poly 27	382736107491201	382736	1074912	4/10/2014	2.0	2.9	21.3	26.3	1.3	19.6	28.3	28.3	28.3
LGRB Poly 29	382917107483101	382917	1074831	4/12/2014	7.0	2.8	7.5	12.5	2.0	5.5	15.0	15.0	18.0
LGRB Poly 30	382947107465801	382947	1074658	4/16/2014	5.0	2.8	14.1	19.1	2.0	12.2	19.5	19.5	23.1

References Cited

Alley, W.M., ed., 1993, Regional ground-water quality: New York, Van Nostrand Reinhold, 634 p.

Bureau of Reclamation, 1982, Lower Gunnison Basin Unit feasibility report—Appendix B Hydrosalinity: Colorado River Water Quality Improvement Program.

Bureau of Reclamation, 2014, Uncompahgre Project: Bureau of Reclamation, accessed August 25, 2014 at http://www.usbr.gov/projects/Project.jsp?proj_Name=Uncompahgre%20Project.

Butler, D.L., and Leib, K.J., 2002, Characterization of selenium in the lower Gunnison River Basin, Colorado, 1988–2000: U.S. Geological Survey Water-Resources Investigations Report 02–4151, 26 p. [Available at http://pubs.usgs.gov/wri/wri02-4151/.]

Butler, D.L., Wright, W.G., Stewart, K.C., Osmundson, B.C., Krueger, R.P., and Crabtree, D.W., 1996, Detailed study of selenium and other constituents in water, bottom sediment, soil, alfalfa, and biota associated with irrigation drainage in the Uncompahgre Project Area and in the Grand Valley, west-central Colorado, 1991–93: U.S. Geological Survey Water-Resources Investigations Report 96–4138, 136 p. [Available at http://pubs.er.usgs.gov/publication/wri964138.]

Munsell Color, 2013, Munsell Rock Color Book with genuine Munsell color chips: Grand Rapids, Mich., Munsell Color, 10 p.

Lapham, W.W., Franceska, D.W., and Koterba, M.T., 1997, Guidelines and standard procedures for studies of ground-water quality—Selection and installation of wells, and supporting documentation: U.S. Geological Survey Water-Resources Investigations Report 96–4233, 110 p. [Available at http://pubs.usgs.gov/wri/wri964233/.]

Moore, J.L., 2011, Characterization of salinity and selenium loading and land-use change in Montrose Arroyo, Western Colorado, from 1992 to 2010: U.S. Geological Survey Scientific Investigations Report 2011–5106, 23 p., [Available at http://pubs.usgs.gov/sir/2011/5106/.]

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water-quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90–4101, 109 p. [Available at http://pubs.er.usgs.gov/publication/wri904101.]

Thomas, J.C., and Arnold, L.R., 2015, Installation groundwater monitoring-well network on the east side of the Uncompahgre River in the Lower Gunnison River Basin, Colorado, 2012: U.S. Geological Survey Data Series 923, 29 p, http://dx.doi.org/10.3133/ds923.

Thomas, J.C., Leib, K.J., and Mayo, J.W., 2008, Analysis of dissolved selenium loading for selected sites in the lower Gunnison River Basin, Colorado, 1978–2005: U.S. Geological Survey Scientific Investigations Report 2007–5287, 25 p. [Available at http://pubs.usgs.gov/sir/2007/5287/.]

Tweto, Ogden, comp., 1979, Geologic map of Colorado: U.S. Geological Survey State Geologic Map, scale 1:500,000 (reprinted). [Available at http://ngmdb.usgs.gov/Prodesc/proddesc_68589.htm.]

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments: Journal of Geology, v. 30, p. 377–392. [Available at http://www.jstor.org/stable/30063207?seq=1#page_scan_tab_contents.]

Appendix 1. Lithologic Logs

[LGRB, lower Gunnison River Basin; Poly, polygon number]

LGRB Poly 1

Date well completed: 4/26/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–15.5	cuttings and core	Colluvium—Mudflow deposit, clay with little sand moderate yellowish brown (10YR5/4) mottled, with gray (N5), damp soft to medium soft limonite staining, dry to damp reacts to HCl
15.5–21.5	core	Weathered Mancos Shale—Dark gray (N3) abundant gypsum crystals in partings, fissile moderately well consolidated, medium stiff to stiff, clay, saturated in partings (horizontal and vertical) from about 18 to 20 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 2

Date well completed: 4/14/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; cm, centimeters; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–10.5	cuttings and core	Alluvium—Sand with gravel, very coarse, with trace cobbles (cobbles to 8 cm), moderate yellowish brown to dark yellowish brown (10YR5/4 to 10YR4/2), very loose to loose sand, subangular to rounded, poorly sorted. 8.5 to 10.5 ft saturated zone, gravel layer.
10.5–13.5	core	Alluvium—clay with little sand, moderate yellowish brown (10YR5/4), reacts to HCl, damp to moist, medium soft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 3

Date well completed: 4/11/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–12.5	cuttings and core	Alluvium—Clay with some sand, grayish orange to dark yellowish brown (10YR7/4 to 10YR 4/2), coarse sand layer, moist
12.5-23.5	core	Weathered Mancos Shale—Clay to clay with sand, grayish orange to dark yellowish brown (10YR7/4 to 10YR4/2) becoming darker with depth, dark gray (N3), stiff to hard becoming less weathered with depth, gypsum crystals, dry to moist, saturated from 18.3 to 21.8 ft, becoming more consolidated with depth, trace fossils, fossil shells, mollusks, limonite staining, gypsum crystals

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 4

Date well completed: 4/24/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–7.7	cuttings and core	Colluvium—Mudflow deposit, dark yellowish orange (10YR6/6) to dusky yellow (5Y6/4), clay with little sand, poorly sorted, medium soft to stiff, loose, dry to damp, limonite staining
7.7–22.7	core	Weathered Mancos Shale—Dark yellowish brown (10YR4/2) to dark gray (N3), abundant gypsum crystals, more competent with depth, saturated in partings from 17.7 to 21.3 ft, dry from 21.3 to 22.7 ft, fissile, limonite staining, stiff to very stiff, low plasticity, reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 5

Date well completed: 4/24/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–15.5	cuttings and core	Alluvium—Mudflow deposit, dark yellowish orange (10YR6/6) to dusky yellow (5Y6/4), clayey sand, chunks of black shale in fine grained, poorly sorted, dry to damp gypsum crystals, reacts with HCl
15.5–27.0	core	Weathered Mancos Shale—Clay, dark gray (N3), gypsum crystals in partings, moderately well consolidated, fissile limonite staining, very stiff to hard, saturated in fractures from 21.0 to 25.0 ft, abundant fossils from 21.0 to 23.0 ft, reacts with HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 6

Date well completed: 6/9/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–46.5	cuttings and core	Alluvium—Cobble gravel, grayish orange (10YR7/4), cobbles up to 150 mm, trace sand (fine), some clay, poorly sorted, dense, unconsolidated, angular to rounded, water encountered between 28.4 and 36.5 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 7

Date well completed: 4/23/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–3.2	cuttings	Alluvium—Clay with a trace of sand, dry, 10YR6/2, poorly sorted, reacts to HCl
3.2–28.2	core	Alluvium— Clay with trace sand, stiff to very stiff, poorly sorted, damp to moist, moderate yellowish brown (10YR5/4), gypsum, limonite staining, water-bearing zone from 26.7 to 28.2 ft with white to clear gypsum crystals

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 9

Date well completed: 4/25/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–25.5	cuttings and core	Alluvium—Mudflow deposit, pale yellowish brown (10YR6/2) becoming moderate yellowish brown (10YR5/4), abundant limonite staining, clay with little sand, dry to damp, medium soft, reacts to HCl
25.5–31.3	core	Weathered Mancos Shale—Dusky yellowish brown (10YR2/2) becoming dark gray (N3) with depth moderately well consolidated becoming more consolidated with depth, clay, stiff to very stiff, water in partings from 28.3 to 31.2 ft, limonite staining becoming less with depth, gypsum crystals in partings, fissile, reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 10

Date well completed: 4/9/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–2	cuttings	Alluvium—Clay with silt and fine sand, poorly sorted, yellowish brown (10YR4/2) to moderate yellow brown (10YR5/4), medium soft to stiff, damp, reacts to HCL
2–23.5	core	Weathered Mancos Shale—Clay, mottled dusky yellow (5Y6/4) to light olive gray (5Y5/2), becoming olive gray (5Y3/2) with depth, trace very fine sand, fissile, very stiff-hard, damp-moist, trace small gypsum crystals and iron staining, reacts to HCl, water-bearing fractures and partings from 18.5 to 19.3 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 14

Date well completed: 4/27/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–14.0	cuttings and core	Colluvium— Mudflow deposit, clay with trace sand, dark yellowish brown (10YR4/2), poorly sorted soft, damp, limonite staining, reacts to HCl
14.0-42.0	core	Weathered Mancos Shale—Dark gray (N3), clay, fissile, very stiff to hard dry, moist at about 33 ft., well consolidated fossils, abundant gypsum crystals, water in partings at 33 ft. , reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 17

Date well completed: 4/11/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–5.5	cuttings and core	Alluvium—Sand with some clay and gravel, grayish orange (10YR7/4) to dark yellowish orange (10YR4/2), soft to medium soft, poorly sorted, angular to subangular, loose fine to coarse grained, moist, reacts to HCl
5.5–23.3	core	Weathered Mancos Shale—Clay with sand to clay, grayish orange (10YR7/4) becoming darker with depth, dark gray (N3), stiff to hard, moist to saturated becoming more consolidated with depth, trace fossils, fossil shells, mollusks, limonite staining, gypsum crystals, saturated from 18.3 to 21.8 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 18

Date well completed: 4/23/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–7.7	cuttings and core	Alluvium—Very fine sand and little clay, dark yellowish brown (10YR4/2), damp to dry, poorly sorted
7.7–18.5	core	Alluvium—Coarse sand with trace clay, pebbles (20 mm to 80 mm), poorly sorted subangular to rounded, loose to medium dense sand, damp at 8.5 ft, becoming saturated from 11.5 to 18.5 ft, dark yellowish brown to dusky yellowish brown to moderate brown (10YR4/2 to 10YR2/2 to 5YR3/4) throughout

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 19

Date well completed: 4/26/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–18.5	cuttings and core	Colluvium—Mudflow deposit, dark yellowish brown (10YR4/2), clay with little sand, very soft, poorly sorted, moist becoming saturated at gravel layer at 8.1 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 21

Date well completed: 4/28/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–14.0	cuttings and core	Colluvium—Mudflow deposit, clay with trace sand, pale yellowish brown (10YR6/2), poorly sorted, damp to saturated from 0 to 4.1 ft, dry from 4.1 to 14.0 ft, limonite staining, reacts to HCl
14.0–18.1	core	Weathered Mancos Shale—Medium dark gray (N4) to dark gray (N3), clay, fissile, very stiff , water in partings from 14.0 to 16.5 ft, reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 22

Date well completed: 4/14/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–18.8	cuttings and core	Alluvium/fill—Clay with little fine sand dark yellowish brown to dusky yellowish brown (10YR4/2 to 10YR2/2), moist very soft, poorly sorted, reacts to HCl
18.8-23.8	core	Alluvium—Clay with little sand, moderate yellowish brown (10YR5/4), damp to moist, medium soft, reacts to HCl
23.8-29.8	core	Alluvium—Sand with little clay, coarse sand, trace gravel, dark yellowish brown to dark yellowish orange (10YR4/2 to 10YR6/6), loose to medium dense sand, poorly sorted, angular to subrounded, saturated from 28.0 to 29.8 ft
29.8-33.8	core	Weathered Mancos Shale—Clay, dark yellowish orange (10YR6/6), mottled with medium gray (N5), saturated

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013)

LGRB Poly 23

Date well completed: 6/9/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–21.6	cuttings and core	Alluvium—Cobble gravel, grayish orange (10YR7/4), cobbles up to 150 mm some sand (fine to coarse), trace clay, poorly sorted, dense, unconsolidated, angular-founded, saturated at about 12 ft

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 25

Date well completed: 4/28/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–16.2	cuttings and core	Weathered Mancos Shale—clay, dark gray (N3), clay, becoming saturated below 8.0 ft, fissile, gypsum crystals in partings

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 27

Date well completed: 4/10/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–24.6	cuttings and core	Weathered Mancos Shale—Clay, mottled yellowish brown (10YR4/2) to moderate yellow brown (10YR5/4) becoming darker with depth, trace very fine sand, fissile, reacts to HCl very stiff-hard, damp-moist, trace small gypsum crystals and iron staining, trace fossils at about 8 ft, reacts to HCl, water-bearing fractures and partings from 18.6 to 19.0 ft and from 22.5 to 24.6 ft (major water bearing zone)
24.6–28.3	core	Weathered Mancos Shale—Clay, dark gray (N3), trace very fine sand, fissile, very stiff–hard, well consolidated, damp, trace small gypsum crystals, reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 29

Date well completed: 4/12/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

Depth	Sample type	Description[1]
0–7.6	cuttings and core	Alluvium—Clay with some sand, moderate yellowish brown to dark yellowish brown (10YR5/4 to 10YR 4/2), fine grained sand, poorly sorted, damp to moist, very soft, no reaction with HCl
7.6–13.0	core	Alluvium—Sand with clay, dark yellowish brown (10YR4/2), coarse grained sand with clay, poorly sorted, saturated, very loose sand, angular-subrounded, no reaction to HCl, coarse water bearing sand layer at 7.6 ft
13.0–18.0	core	Alluvium—Clay with some sand, dark yellowish brown (10YR4/2), mottled with gray and black, well sorted, dense, moist to saturated, no reaction to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

LGRB Poly 30

Date well completed: 4/16/2014

Log prepared by J.C. Thomas

[Depth intervals in feet below land surface; mm, millimeters; ft, feet; HCl, hydrochloric acid]

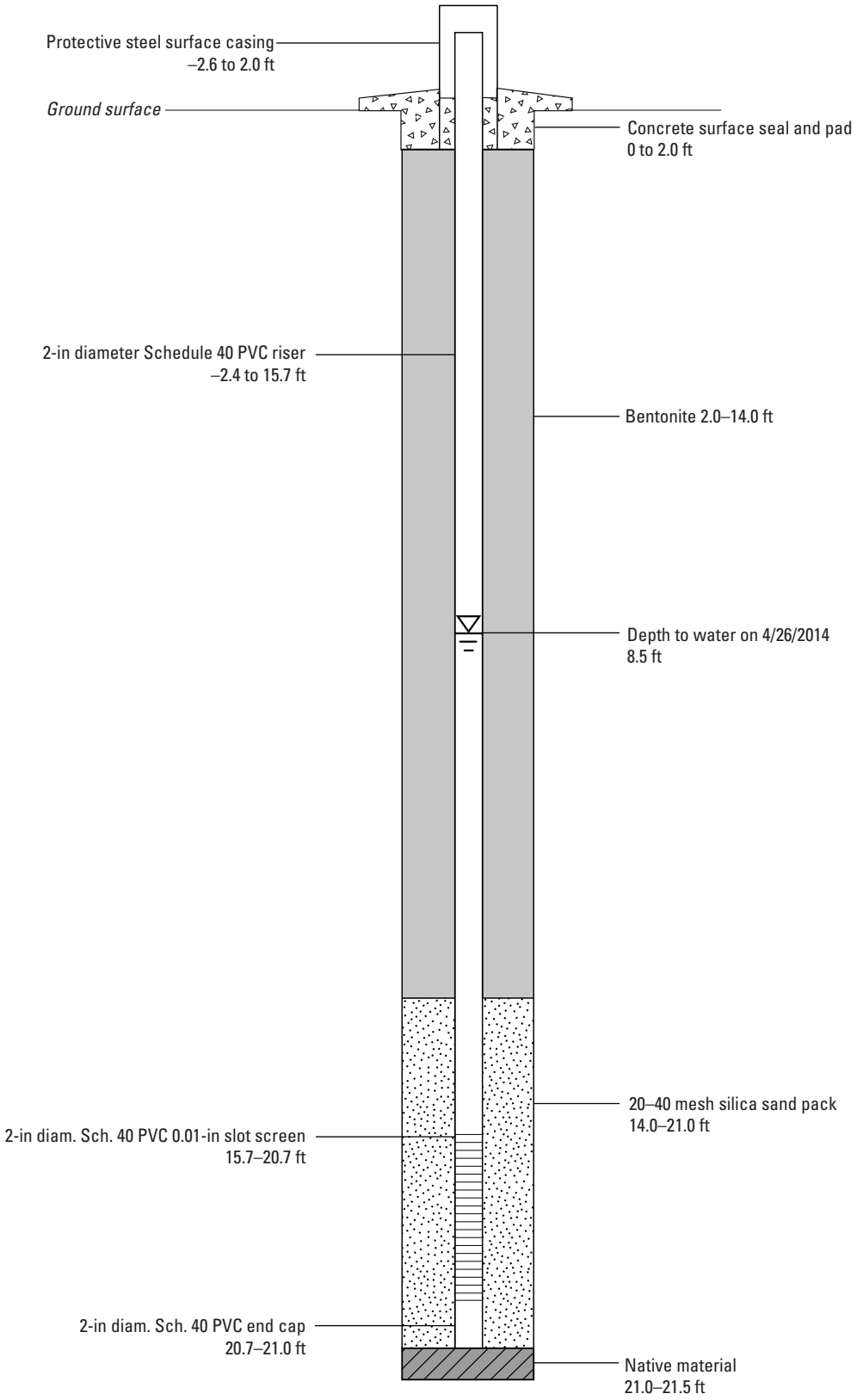
Depth	Sample type	Description[1]
0–8.4	cuttings and core	Alluvium—Clay with some sand and little gravel and cobbles (up to 70 mm in size), medium soft to stiff, poorly sorted, dry to damp, moderate yellowish brown to dark yellowish brown (10YR5/4 to 10YR4/2), limonite staining, reacts to HCl
8.4–23.1	core	Weathered Mancos Shale—Clay with little sand, dark yellowish brown to dusky yellowish brown (10YR4/2 to 10YR2/2), medium soft to stiff, damp, from 18.2 to 21.2 ft saturated zone, dry below 21.2 ft, dark yellowish brown to light olive gray to dark gray (10YR4/2 to 5Y5/2 to N3) color evolution with depth becoming more competent with depth, fissile, gypsum crystals, reacts to HCl

[1]Grain size based on the Wentworth classification system (Wentworth, 1922). Proportions defined using the following terms: "trace" (0–10 percent), "little" (10–20 percent), "some" (20–35 percent), and "and" (35–50 percent). Color codes (for example, 10YR6/2) refer to the Munsell color system (Munsell Color, 2013).

Appendix 2. Well-Construction Diagrams

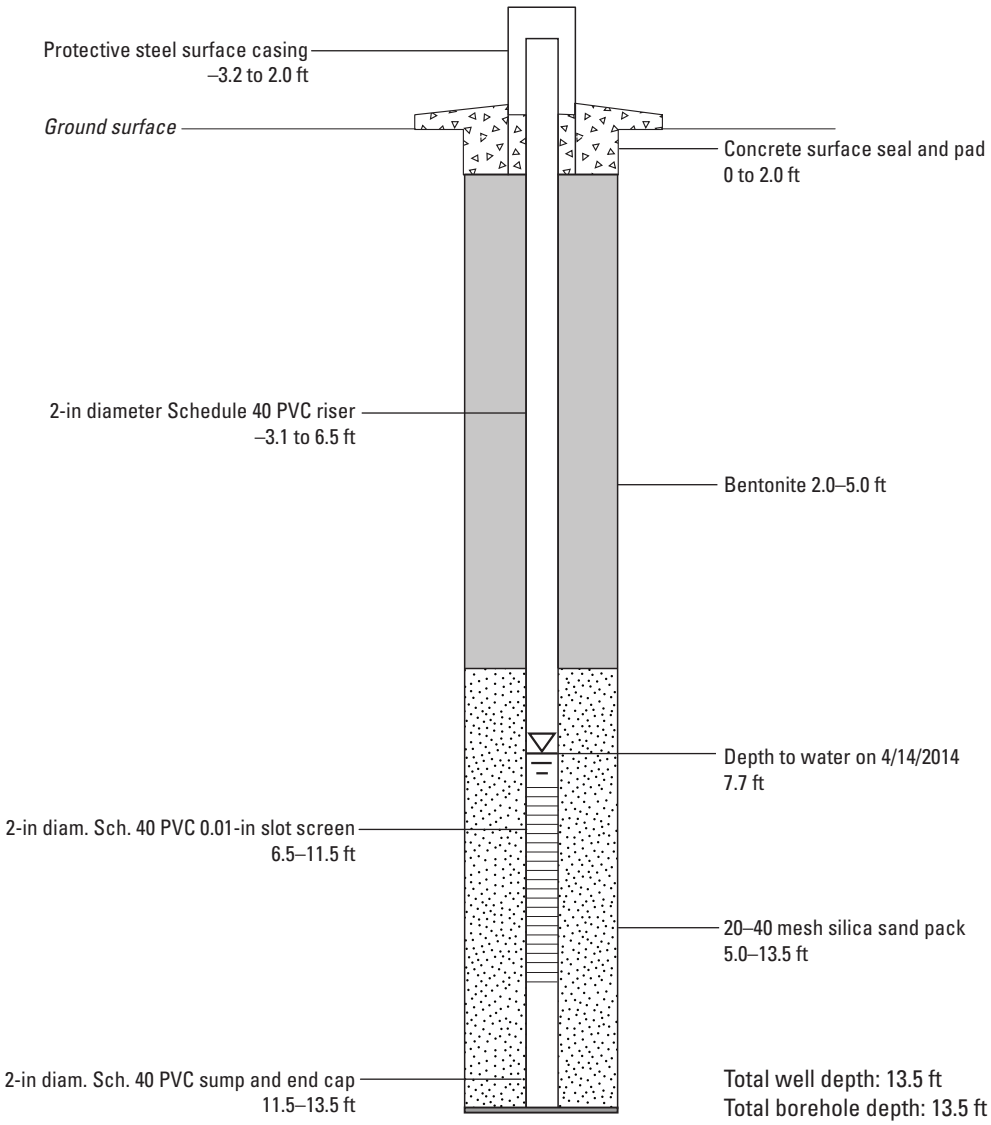
[LGRB, lower Gunnison River Basin; Poly, polygon number; PVC, polyvinyl chloride; ft, feet; in, inch; diam., diameter; Sch. 40, Schedule 40]

LGRB Poly 1

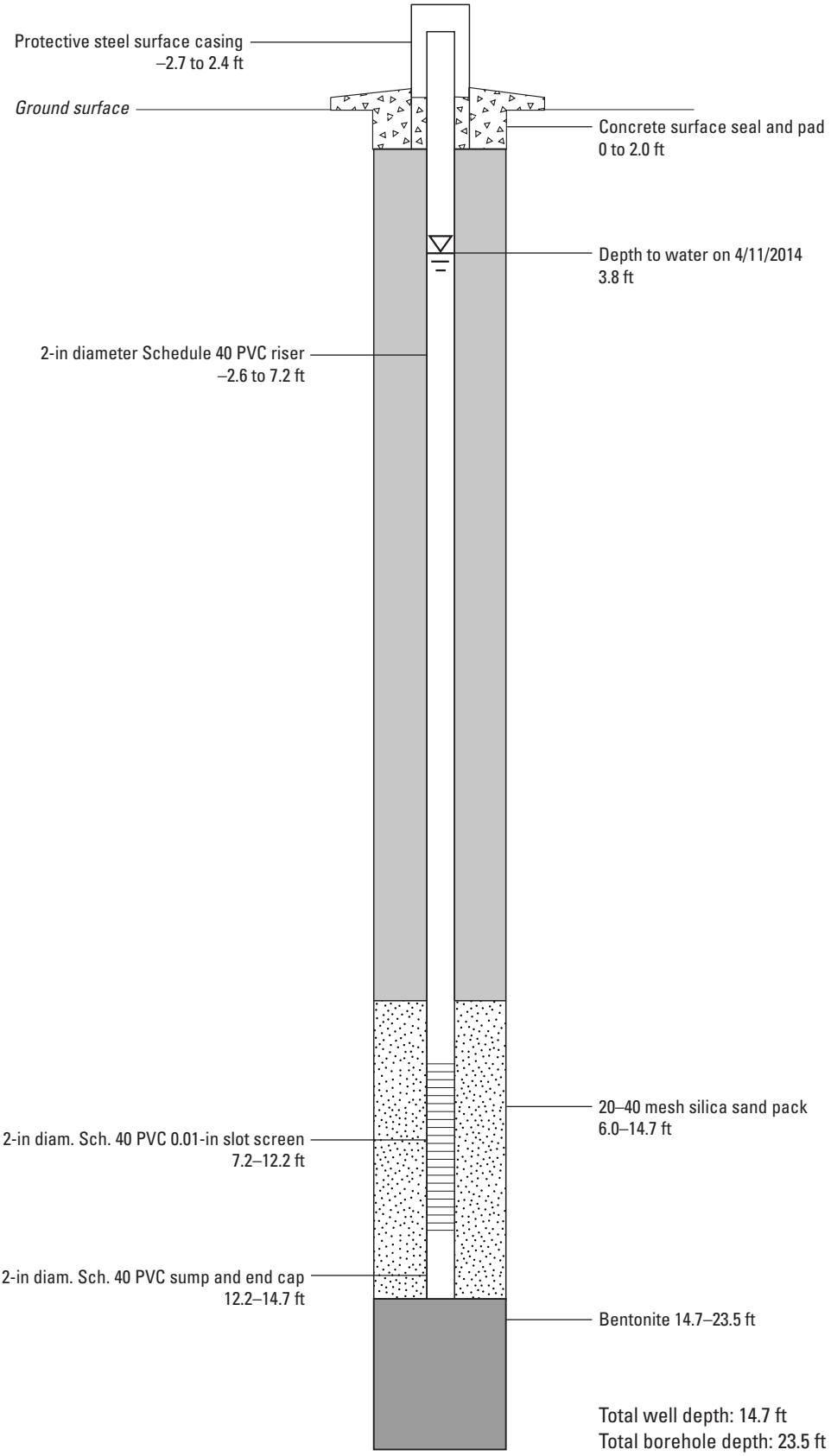


Total well depth: 21.0 ft
Total borehole depth: 21.5 ft

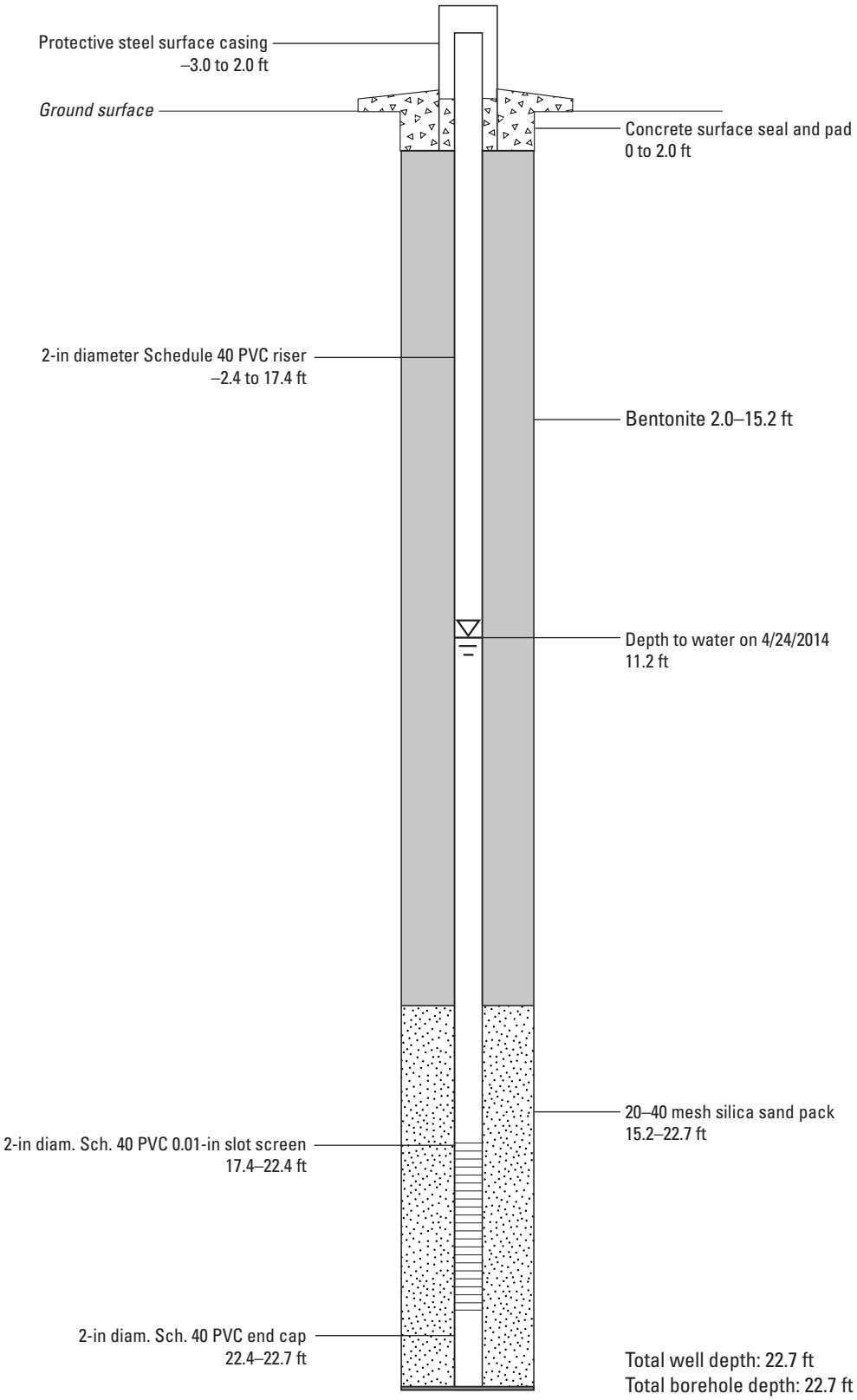
LGRB Poly 2


Protective steel surface casing
–3.2 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–3.1 to 6.5 ft
Bentonite 2.0–5.0 ft
Depth to water on 4/14/2014
7.7 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
6.5–11.5 ft
20–40 mesh silica sand pack
5.0–13.5 ft
2-in diam. Sch. 40 PVC sump and end cap
11.5–13.5 ft
Total well depth: 13.5 ft
Total borehole depth: 13.5 ft

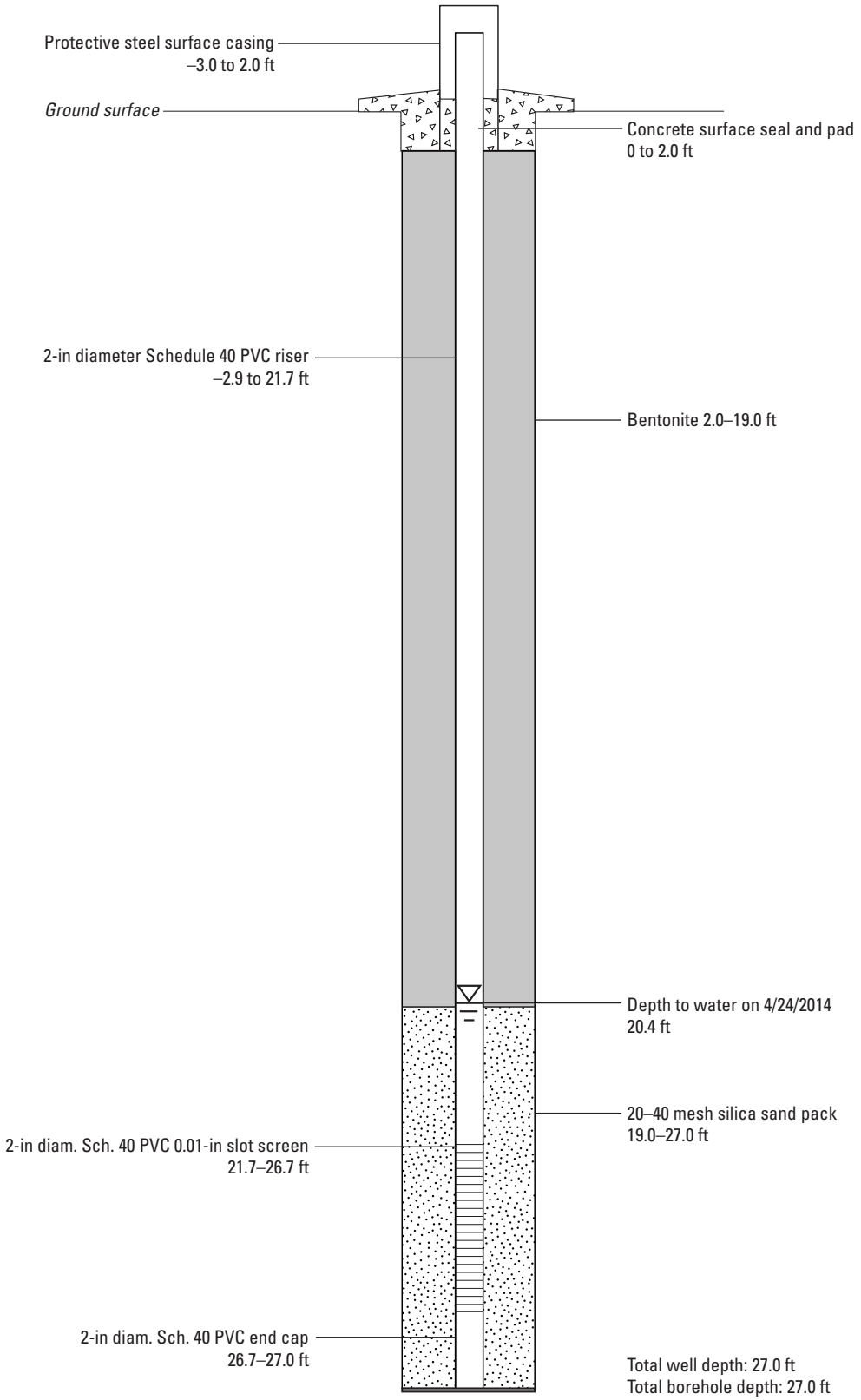
LGRB Poly 3


Protective steel surface casing
–2.7 to 2.4 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
Depth to water on 4/11/2014
3.8 ft
2-in diameter Schedule 40 PVC riser
–2.6 to 7.2 ft
20–40 mesh silica sand pack
6.0–14.7 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
7.2–12.2 ft
2-in diam. Sch. 40 PVC sump and end cap
12.2–14.7 ft
Bentonite 14.7–23.5 ft
Total well depth: 14.7 ft
Total borehole depth: 23.5 ft

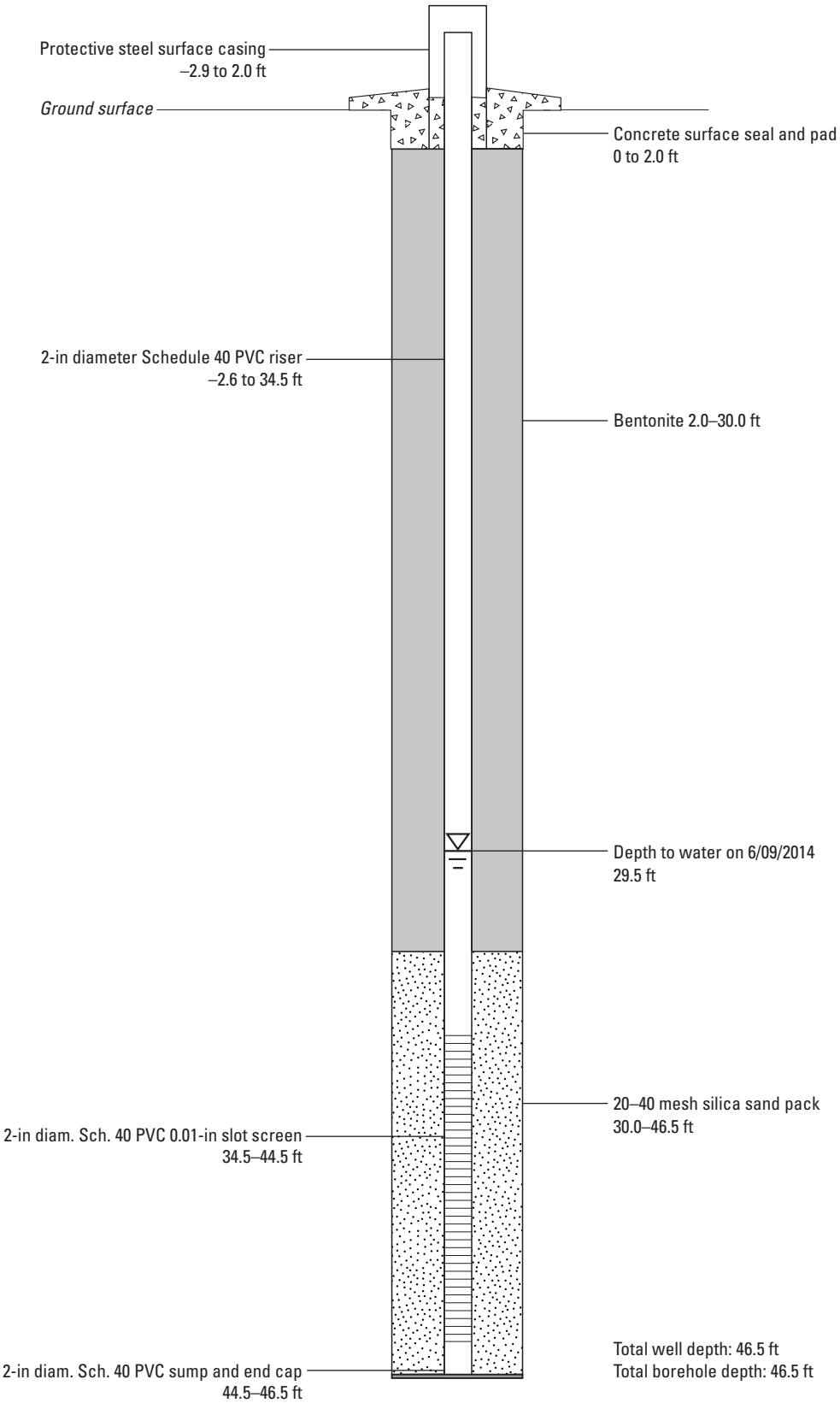
LGRB Poly 4


Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.4 to 17.4 ft
Bentonite 2.0–15.2 ft
Depth to water on 4/24/2014
11.2 ft
20–40 mesh silica sand pack
15.2–22.7 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
17.4–22.4 ft
2-in diam. Sch. 40 PVC end cap
22.4–22.7 ft
Total well depth: 22.7 ft
Total borehole depth: 22.7 ft

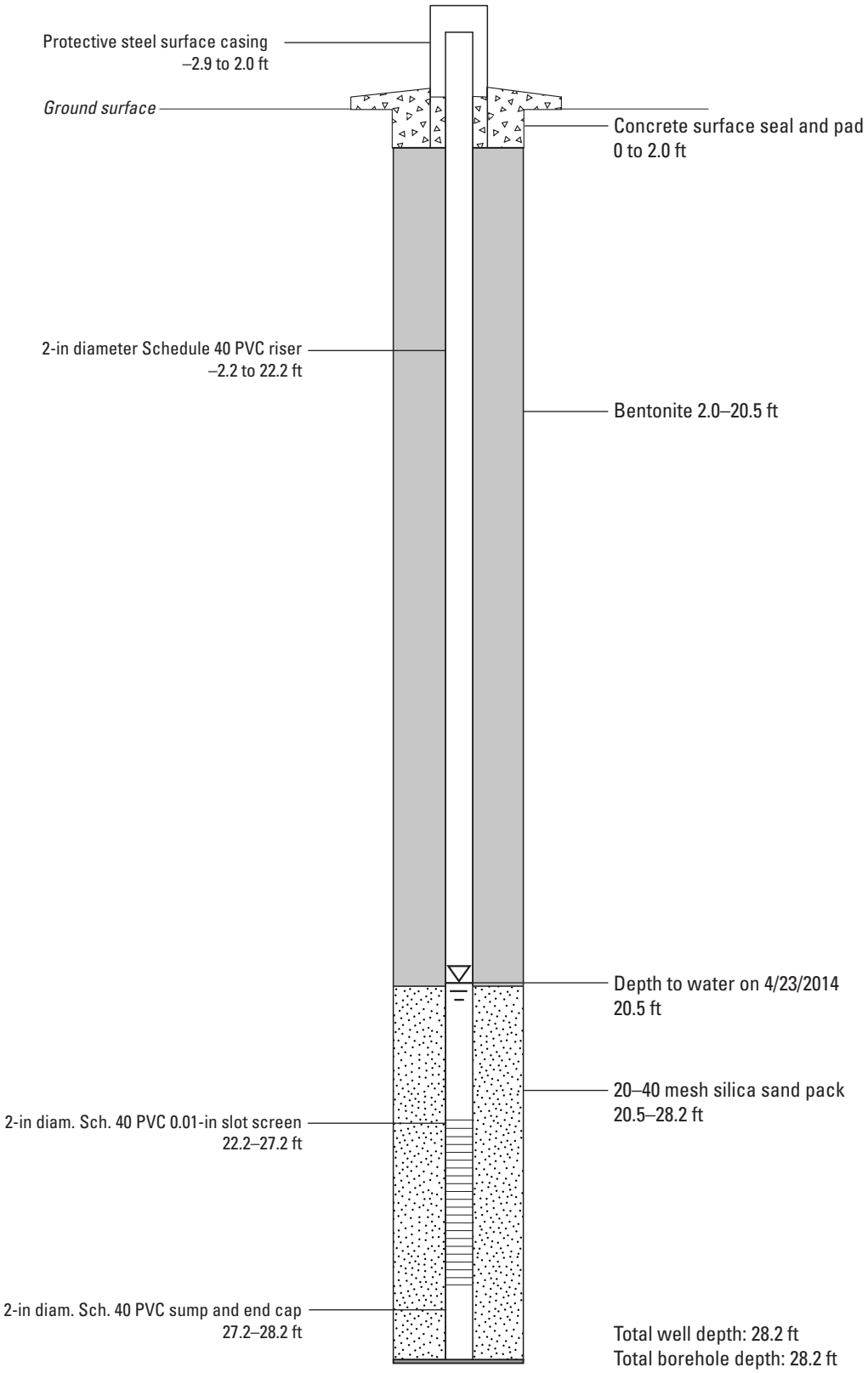
LGRB Poly 5


Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.9 to 21.7 ft
Bentonite 2.0–19.0 ft
Depth to water on 4/24/2014
20.4 ft
20–40 mesh silica sand pack
19.0–27.0 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
21.7–26.7 ft
2-in diam. Sch. 40 PVC end cap
26.7–27.0 ft
Total well depth: 27.0 ft
Total borehole depth: 27.0 ft

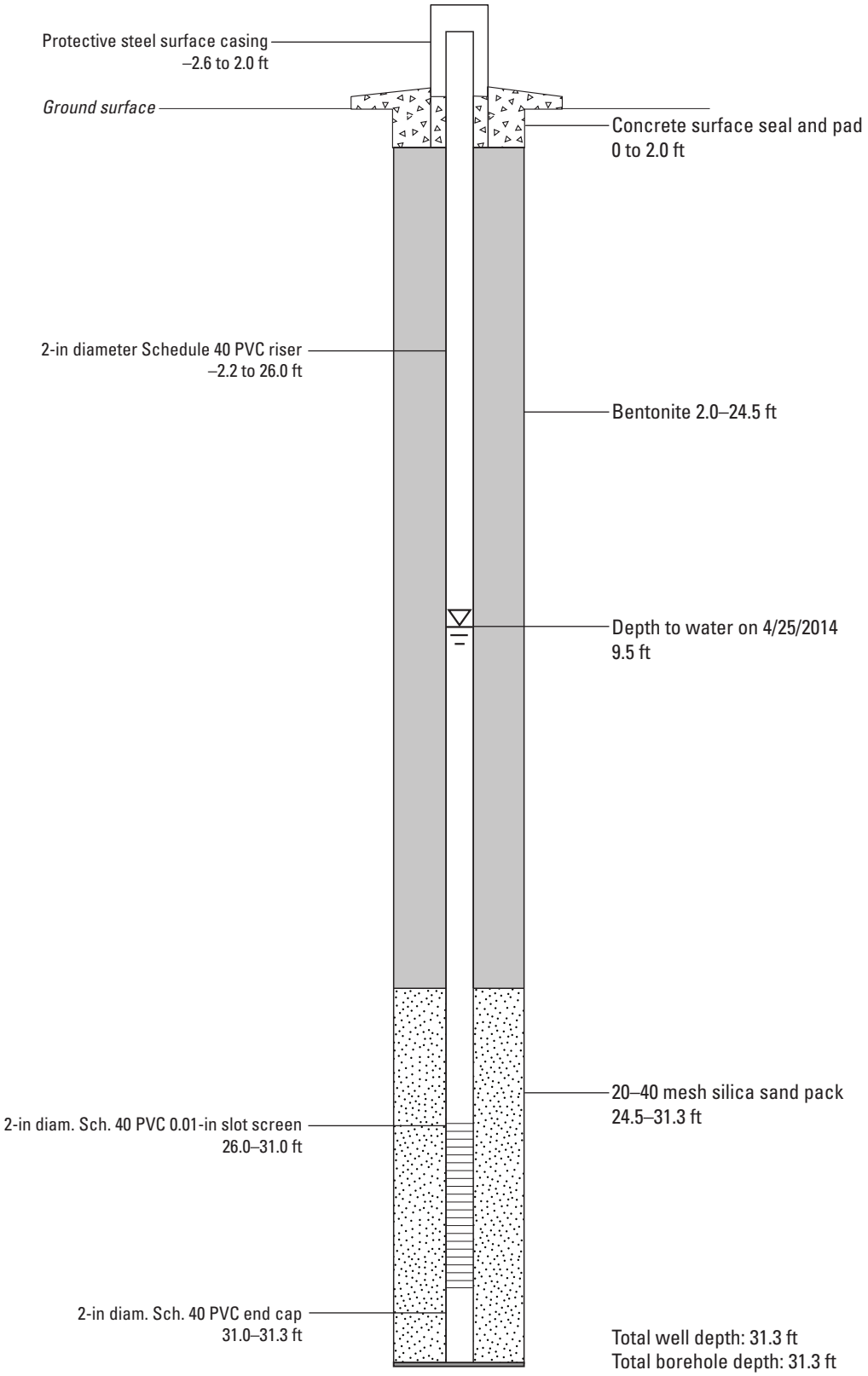
LGRB Poly 6


Protective steel surface casing
–2.9 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.6 to 34.5 ft
Bentonite 2.0–30.0 ft
Depth to water on 6/09/2014
29.5 ft
20–40 mesh silica sand pack
30.0–46.5 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
34.5–44.5 ft
Total well depth: 46.5 ft
Total borehole depth: 46.5 ft
2-in diam. Sch. 40 PVC sump and end cap
44.5–46.5 ft

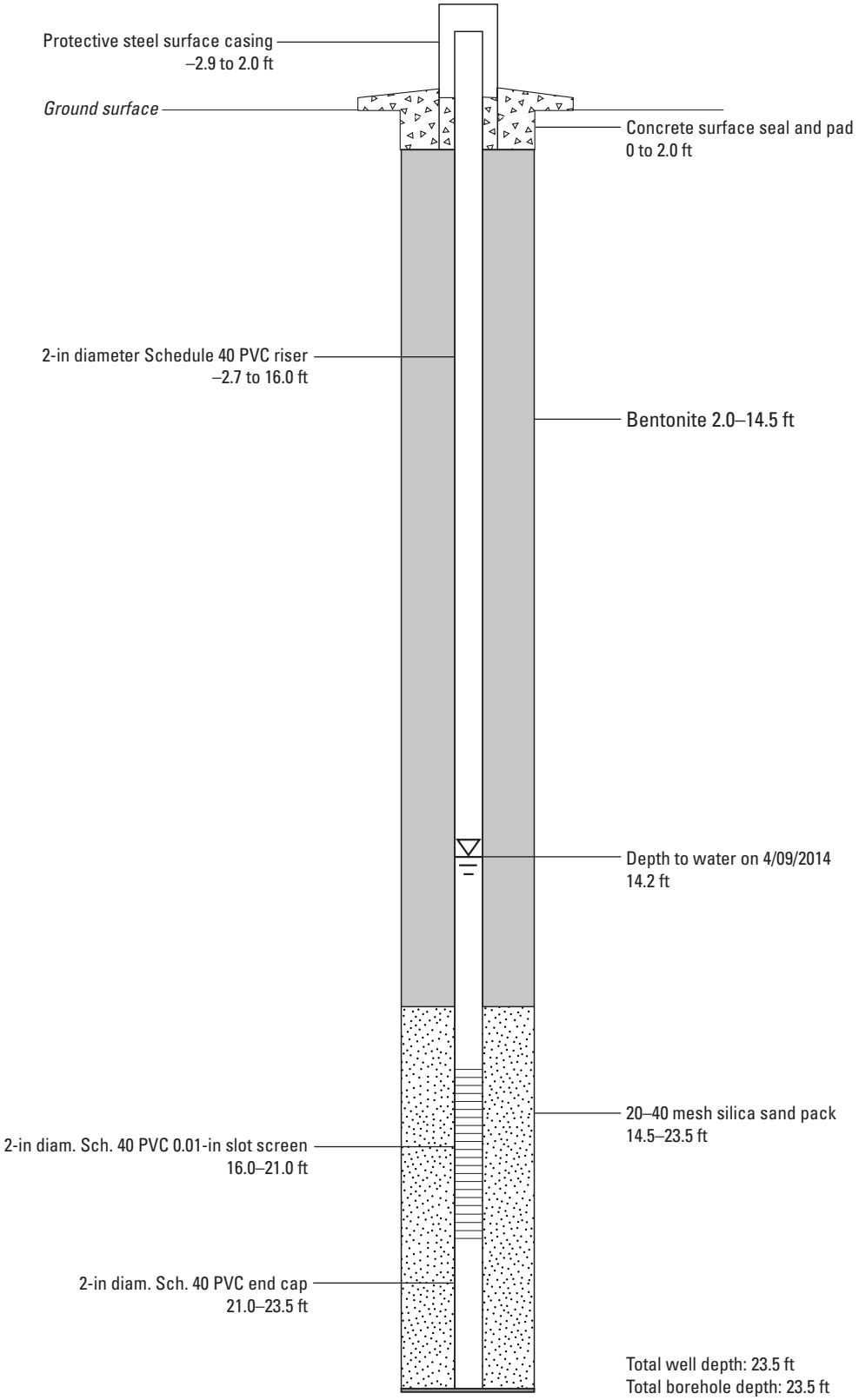
LGRB Poly 7


Protective steel surface casing
–2.9 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.2 to 22.2 ft
Bentonite 2.0–20.5 ft
Depth to water on 4/23/2014
20.5 ft
20–40 mesh silica sand pack
20.5–28.2 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
22.2–27.2 ft
2-in diam. Sch. 40 PVC sump and end cap
27.2–28.2 ft
Total well depth: 28.2 ft
Total borehole depth: 28.2 ft

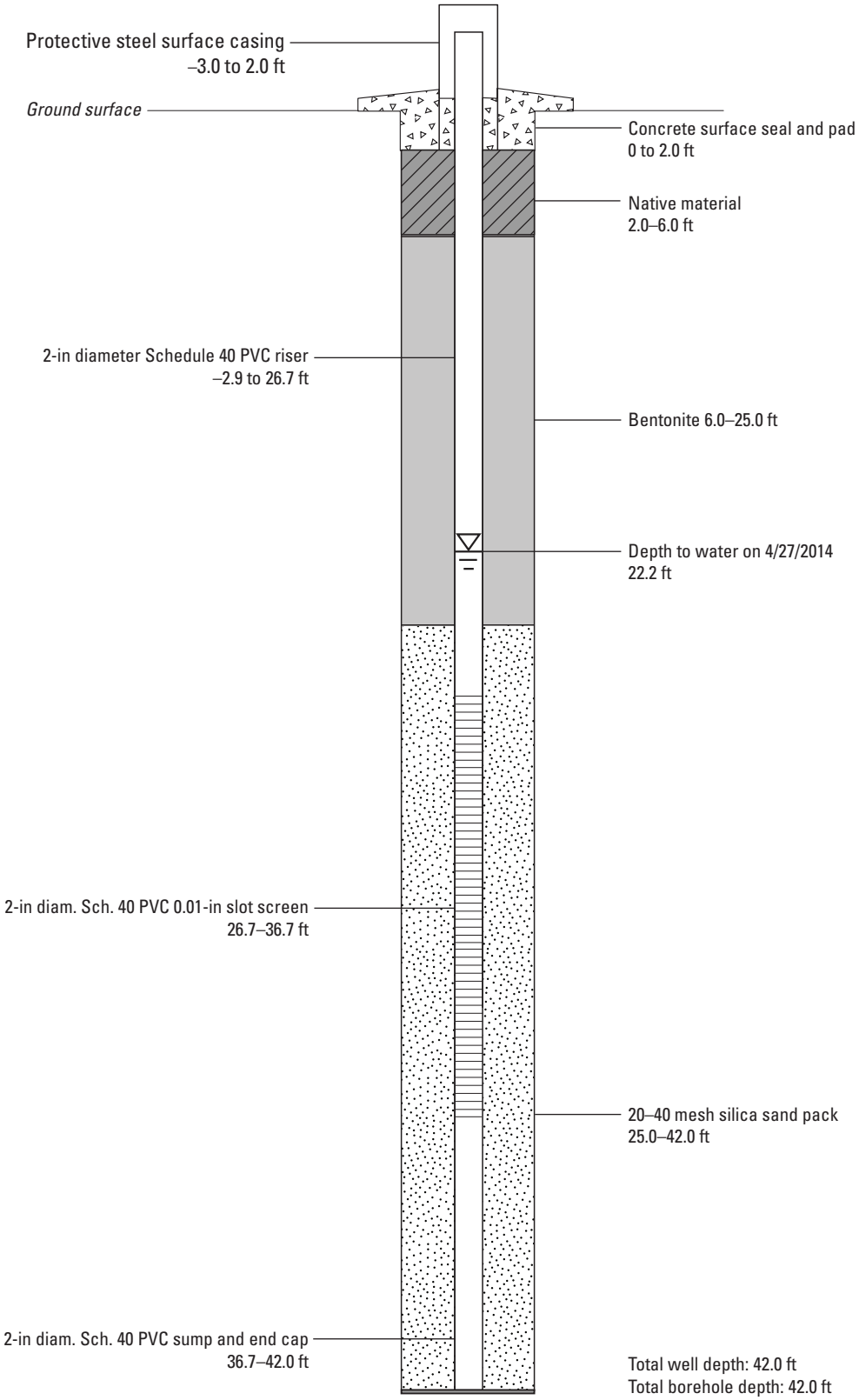
LGRB Poly 9

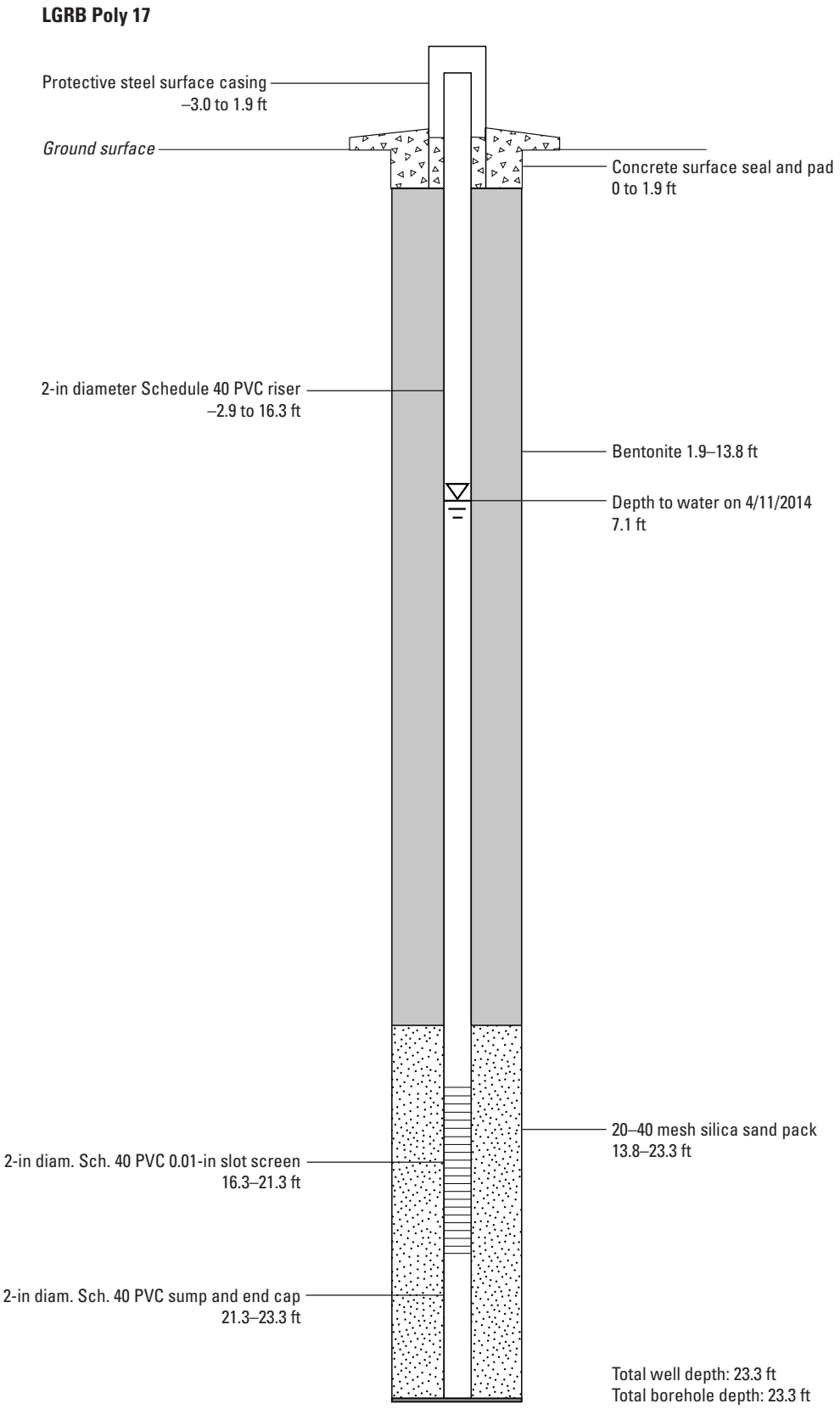

Protective steel surface casing
–2.6 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.2 to 26.0 ft
Bentonite 2.0–24.5 ft
Depth to water on 4/25/2014
9.5 ft
20–40 mesh silica sand pack
24.5–31.3 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
26.0–31.0 ft
2-in diam. Sch. 40 PVC end cap
31.0–31.3 ft
Total well depth: 31.3 ft
Total borehole depth: 31.3 ft

LGRB Poly 10

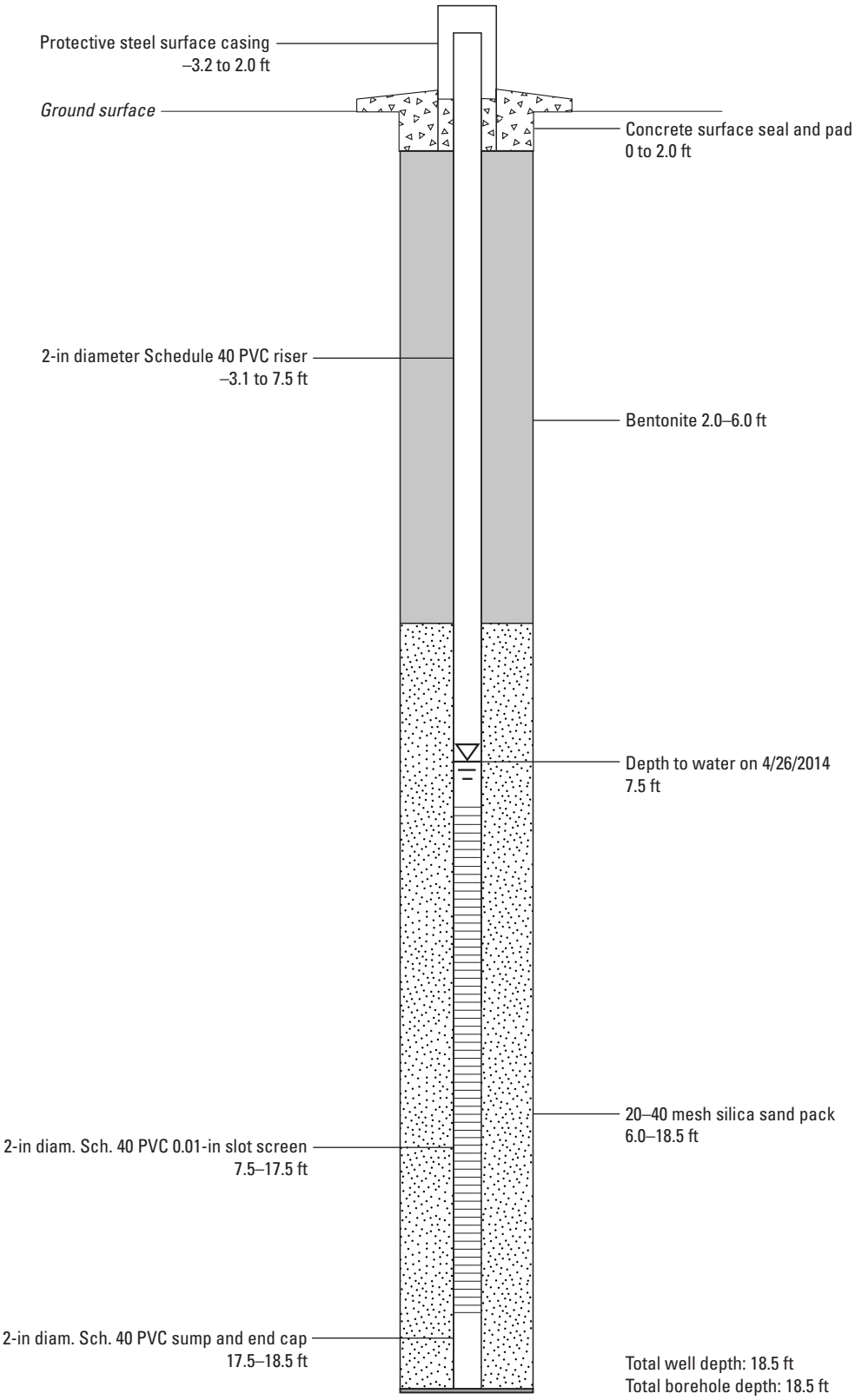

Protective steel surface casing
–2.9 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.7 to 16.0 ft
Bentonite 2.0–14.5 ft
Depth to water on 4/09/2014
14.2 ft
20–40 mesh silica sand pack
14.5–23.5 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
16.0–21.0 ft
2-in diam. Sch. 40 PVC end cap
21.0–23.5 ft
Total well depth: 23.5 ft
Total borehole depth: 23.5 ft

LGRB Poly 14

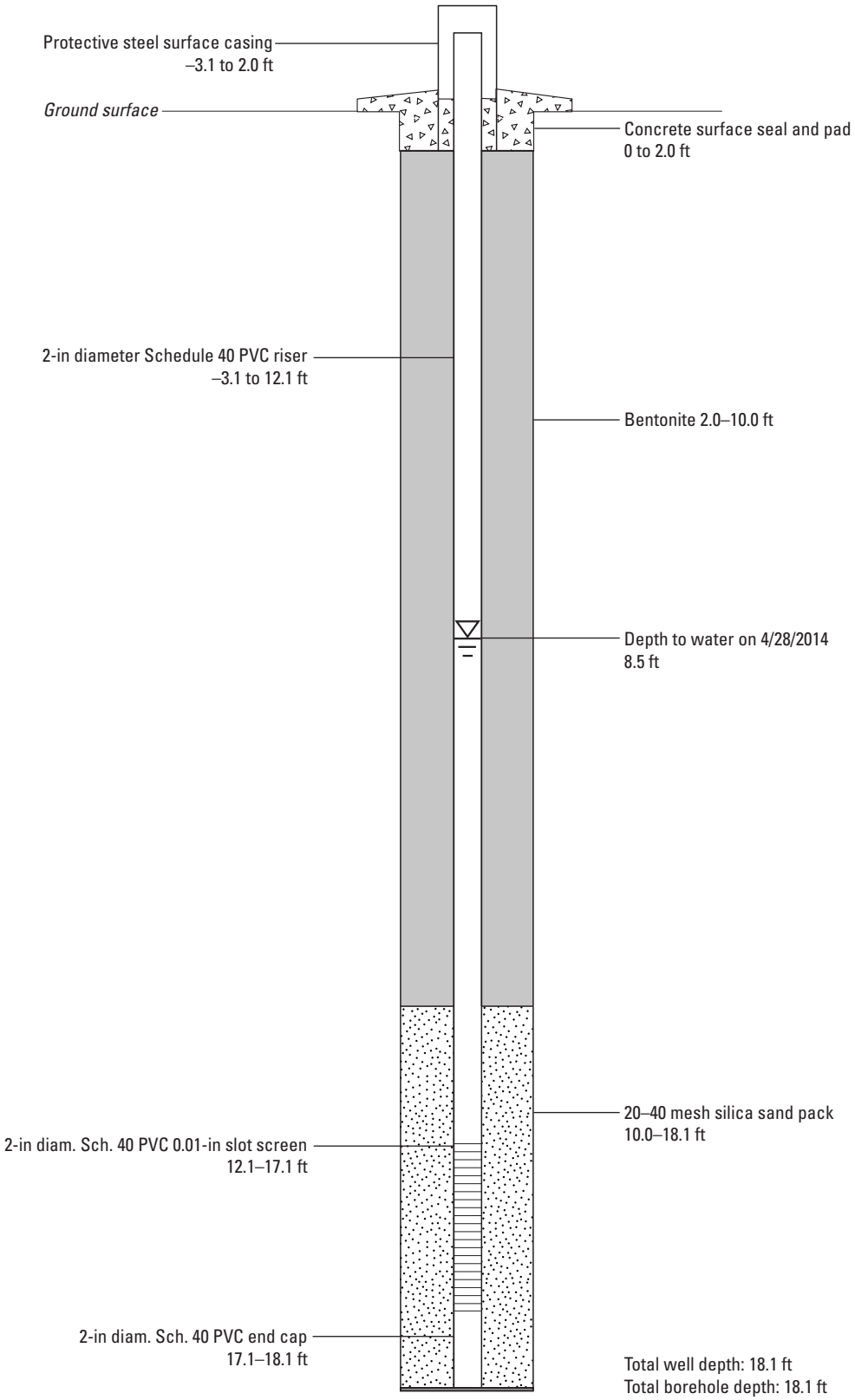

Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
Native material
2.0–6.0 ft
2-in diameter Schedule 40 PVC riser
–2.9 to 26.7 ft
Bentonite 6.0–25.0 ft
Depth to water on 4/27/2014
22.2 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
26.7–36.7 ft
20–40 mesh silica sand pack
25.0–42.0 ft
2-in diam. Sch. 40 PVC sump and end cap
36.7–42.0 ft
Total well depth: 42.0 ft
Total borehole depth: 42.0 ft


LGRB Poly 17
Protective steel surface casing
–3.0 to 1.9 ft
Ground surface
Concrete surface seal and pad
0 to 1.9 ft
2-in diameter Schedule 40 PVC riser
–2.9 to 16.3 ft
Bentonite 1.9–13.8 ft
Depth to water on 4/11/2014
7.1 ft
20–40 mesh silica sand pack
13.8–23.3 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
16.3–21.3 ft
2-in diam. Sch. 40 PVC sump and end cap
21.3–23.3 ft
Total well depth: 23.3 ft
Total borehole depth: 23.3 ft

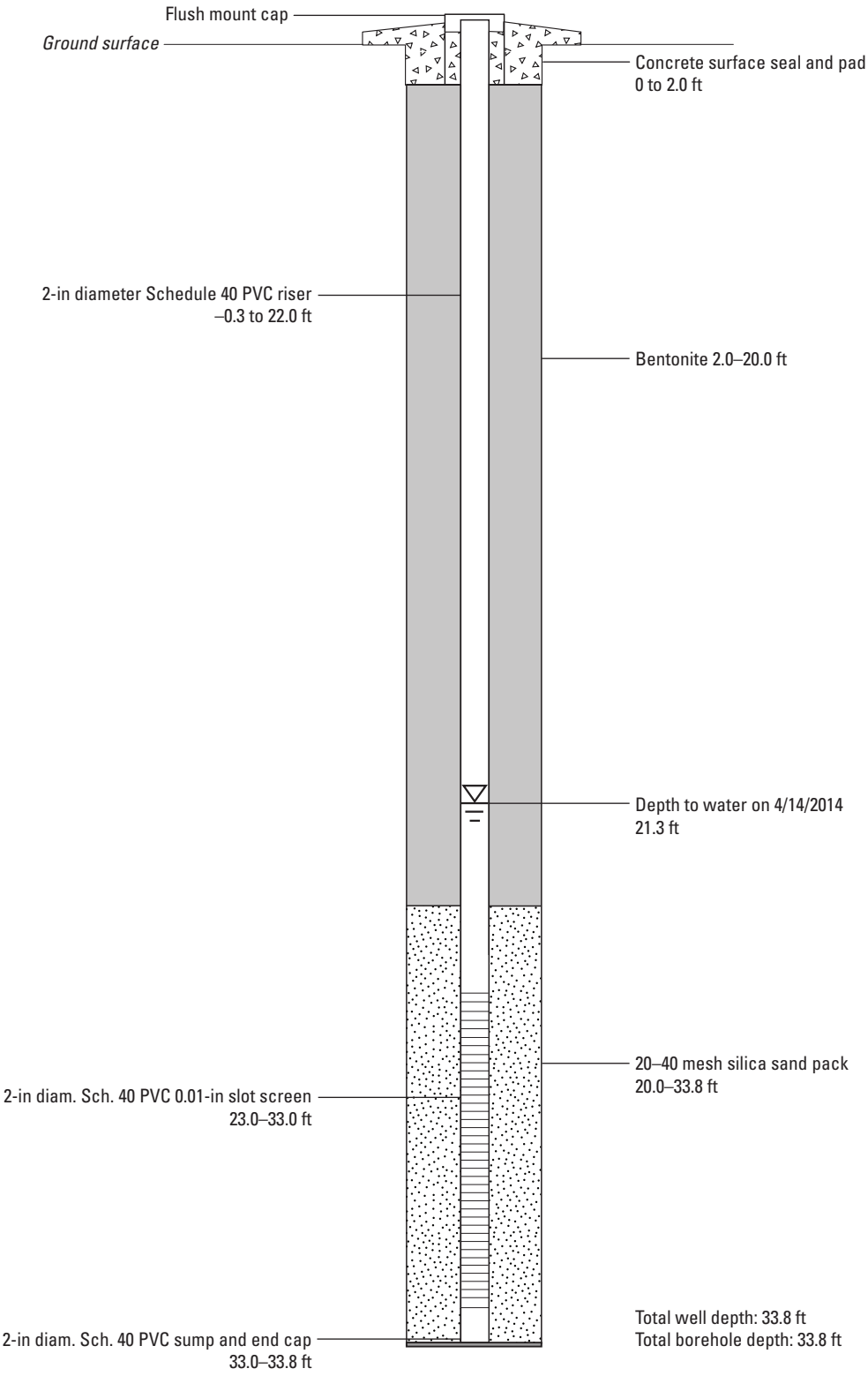
LGRB Poly 19


Protective steel surface casing
–3.2 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–3.1 to 7.5 ft
Bentonite 2.0–6.0 ft
Depth to water on 4/26/2014
7.5 ft
20–40 mesh silica sand pack
6.0–18.5 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
7.5–17.5 ft
2-in diam. Sch. 40 PVC sump and end cap
17.5–18.5 ft
Total well depth: 18.5 ft
Total borehole depth: 18.5 ft

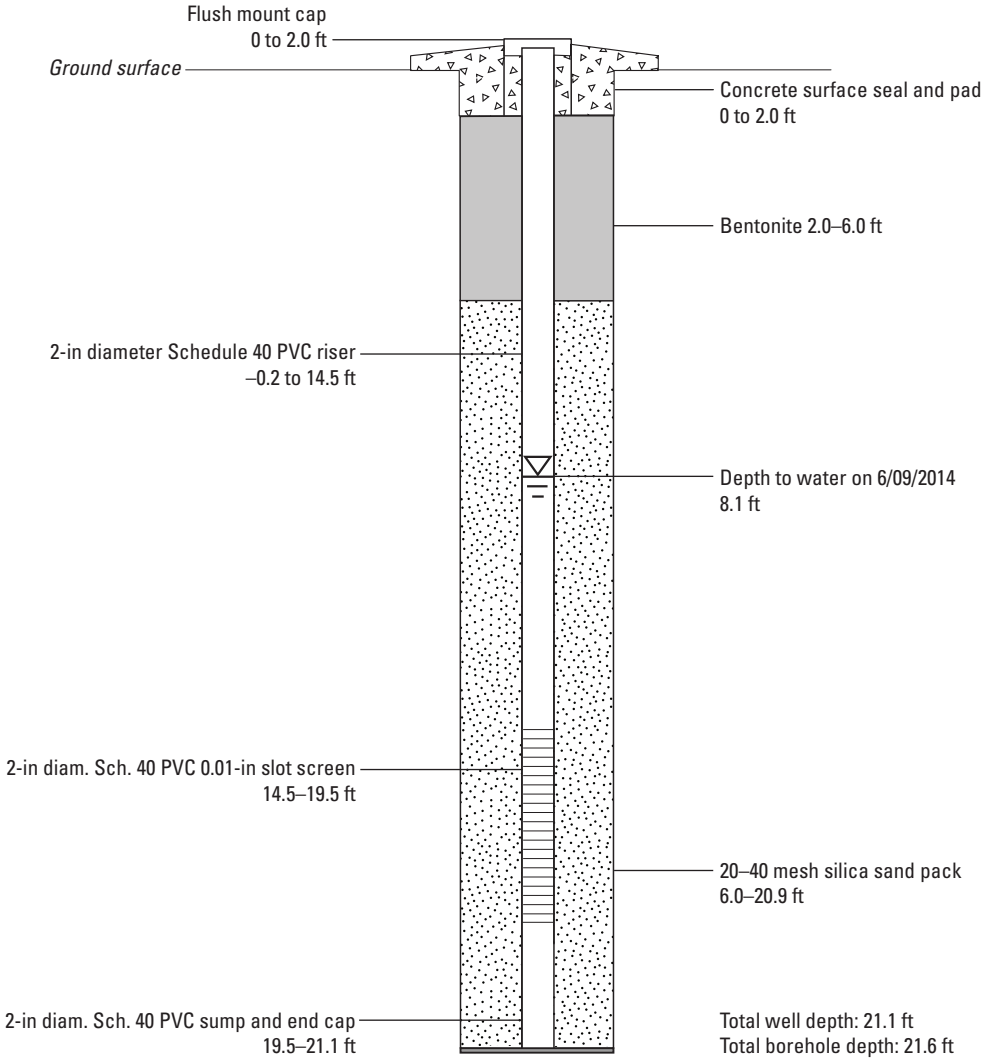
LGRB Poly 21


Protective steel surface casing
–3.1 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–3.1 to 12.1 ft
Bentonite 2.0–10.0 ft
Depth to water on 4/28/2014
8.5 ft
20–40 mesh silica sand pack
10.0–18.1 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
12.1–17.1 ft
2-in diam. Sch. 40 PVC end cap
17.1–18.1 ft
Total well depth: 18.1 ft
Total borehole depth: 18.1 ft

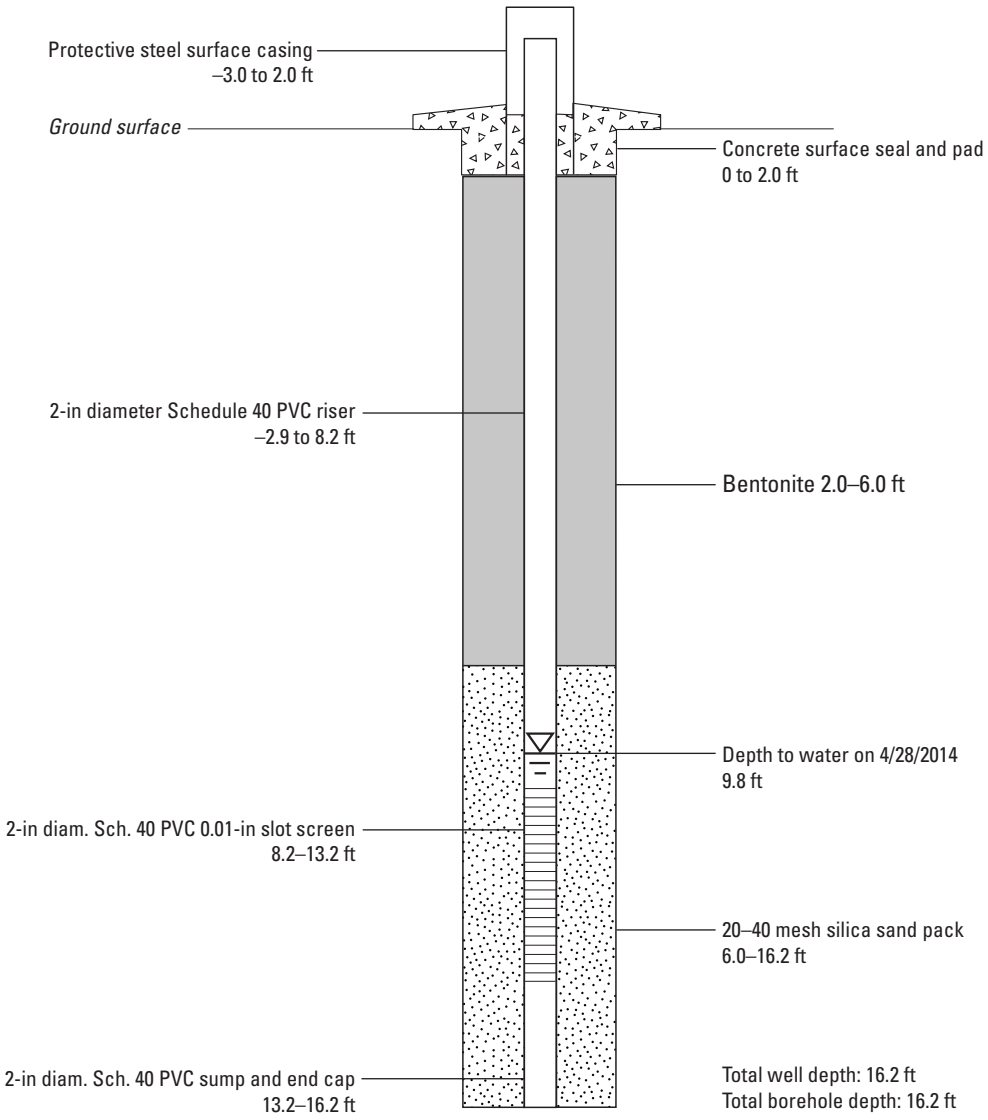
LGRB Poly 22


Flush mount cap
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–0.3 to 22.0 ft
Bentonite 2.0–20.0 ft
Depth to water on 4/14/2014
21.3 ft
20–40 mesh silica sand pack
20.0–33.8 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
23.0–33.0 ft
Total well depth: 33.8 ft
Total borehole depth: 33.8 ft
2-in diam. Sch. 40 PVC sump and end cap
33.0–33.8 ft

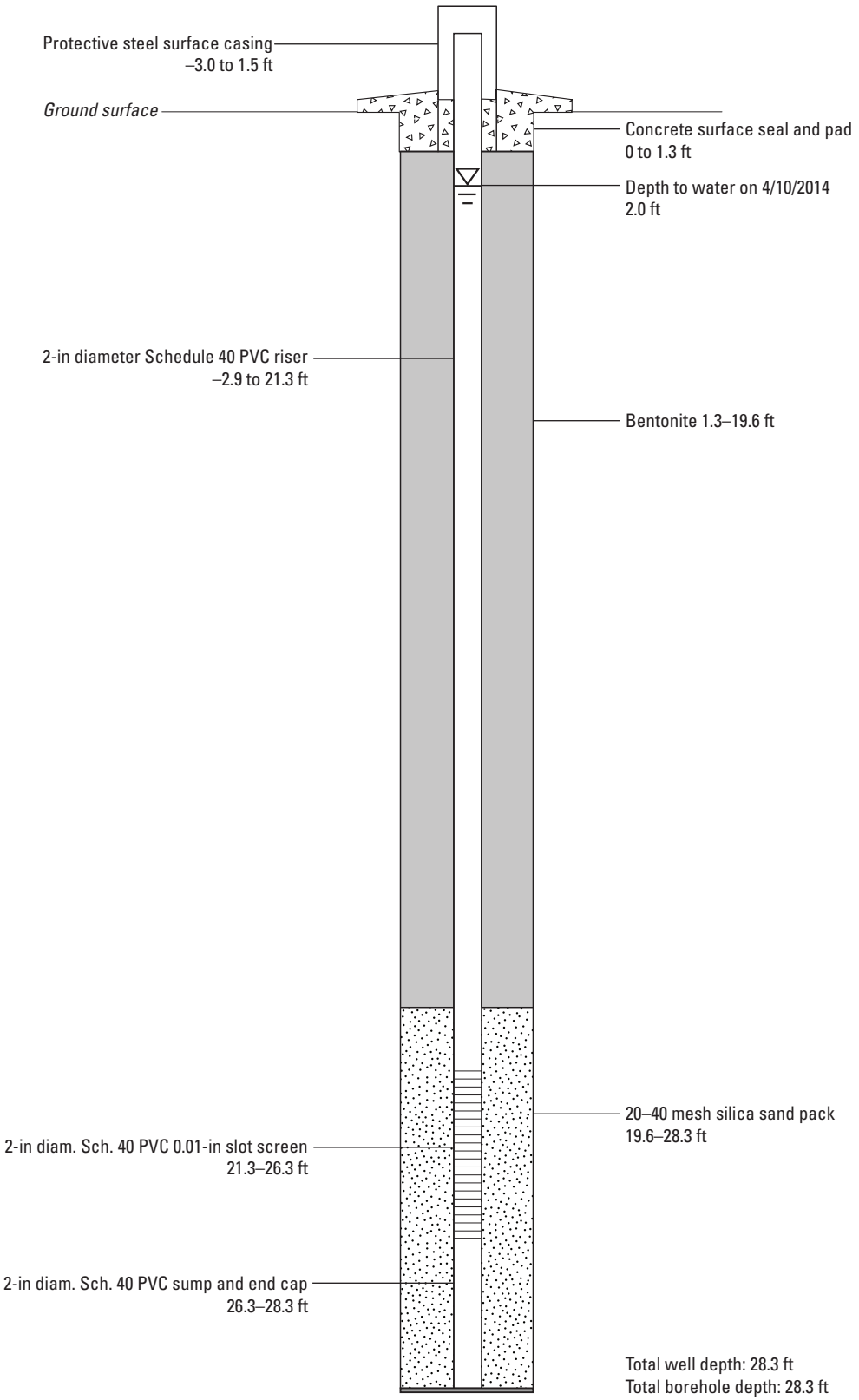
LGRB Poly 23


Flush mount cap
0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
Bentonite 2.0–6.0 ft
2-in diameter Schedule 40 PVC riser
–0.2 to 14.5 ft
Depth to water on 6/09/2014
8.1 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
14.5–19.5 ft
20–40 mesh silica sand pack
6.0–20.9 ft
2-in diam. Sch. 40 PVC sump and end cap
19.5–21.1 ft
Total well depth: 21.1 ft
Total borehole depth: 21.6 ft

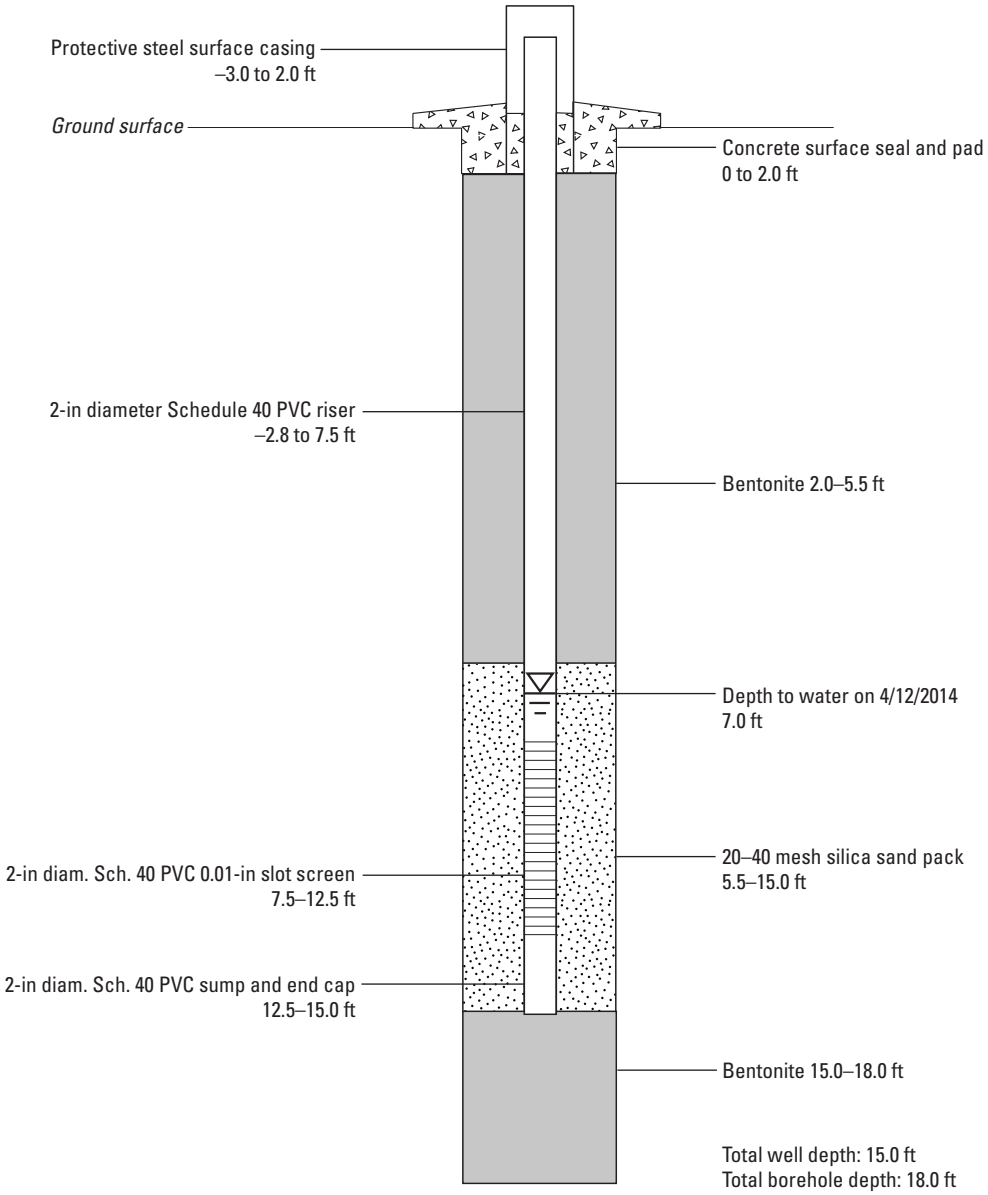
LGRB Poly 25


Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.9 to 8.2 ft
Bentonite 2.0–6.0 ft
Depth to water on 4/28/2014
9.8 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
8.2–13.2 ft
20–40 mesh silica sand pack
6.0–16.2 ft
2-in diam. Sch. 40 PVC sump and end cap
13.2–16.2 ft
Total well depth: 16.2 ft
Total borehole depth: 16.2 ft

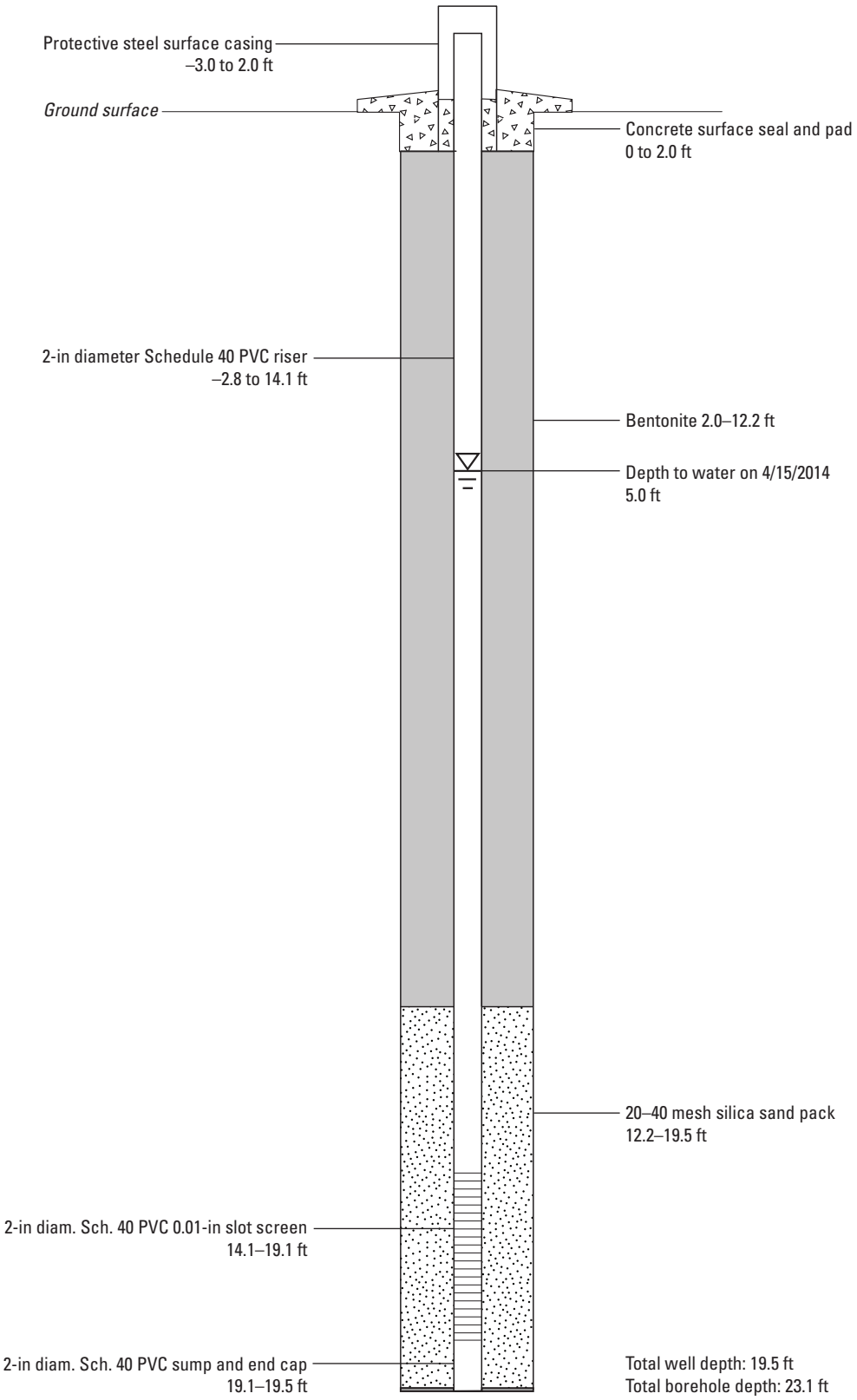
LGRB Poly 27


Protective steel surface casing
–3.0 to 1.5 ft
Ground surface
Concrete surface seal and pad
0 to 1.3 ft
Depth to water on 4/10/2014
2.0 ft
2-in diameter Schedule 40 PVC riser
–2.9 to 21.3 ft
Bentonite 1.3–19.6 ft
20–40 mesh silica sand pack
19.6–28.3 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
21.3–26.3 ft
2-in diam. Sch. 40 PVC sump and end cap
26.3–28.3 ft
Total well depth: 28.3 ft
Total borehole depth: 28.3 ft

LGRB Poly 29


Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.8 to 7.5 ft
Bentonite 2.0–5.5 ft
Depth to water on 4/12/2014
7.0 ft
20–40 mesh silica sand pack
5.5–15.0 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
7.5–12.5 ft
2-in diam. Sch. 40 PVC sump and end cap
12.5–15.0 ft
Bentonite 15.0–18.0 ft
Total well depth: 15.0 ft
Total borehole depth: 18.0 ft

LGRB Poly 30


Protective steel surface casing
–3.0 to 2.0 ft
Ground surface
Concrete surface seal and pad
0 to 2.0 ft
2-in diameter Schedule 40 PVC riser
–2.8 to 14.1 ft
Bentonite 2.0–12.2 ft
Depth to water on 4/15/2014
5.0 ft
20–40 mesh silica sand pack
12.2–19.5 ft
2-in diam. Sch. 40 PVC 0.01-in slot screen
14.1–19.1 ft
2-in diam. Sch. 40 PVC sump and end cap
19.1–19.5 ft
Total well depth: 19.5 ft
Total borehole depth: 23.1 ft

Appendix 3. Well-Development Records

[LGRB, lower Gunnison River Basin; Poly, polygon number]

LGRB Poly 1

Date developed: 6/24/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than; gal, gallon]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	11.6	13,610	>1,000	0.5–0.6	Muddy
90	11.7	13,620	>1,000	0.5–0.6	Muddy
120	12.2	13,600	>1,000	0.5–0.6	Muddy
200	--	--	--	pump off	Muddy
225	12.2	13,590	>1,000	10 gal	1st bail, muddy
250	12.1	13,590	1,000	1 gal	2nd bail, murky
275	12.3	13,600	1,000	10 gal	3rd bail, murky
300	13.5	13,590	475	10 gal	4th bail, slightly murky
325	13.3	13,590	42.3	10 gal	5th bail, clear

LGRB Poly 2

Date developed: 6/3/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	11.6	2,880	>1,000	0.5–0.6	Muddy
80	11.8	2,870	>1,000	0.5–0.6	Muddy
120	11.8	2,840	>1,000	0.5–0.6	Muddy/murky
140	11.2	2,830	>1,000	0.5–0.6	Muddy/murky
160	11.4	2,820	>1,000	0.5–0.6	Muddy/murky
190	11.8	2,820	>1,000	0.5–0.6	Muddy/murky
220	12.4	2,850	>1,000	0.5	Muddy
240	11.8	2,840	>1,000	0.5	Muddy/murky
360	12.5	2,820	>1,000	0.5	Murky
410	-- removed surge block --			0.1–0.5	
435	12.9	2,840	1000	0.1–0.4	Murky
460	--	--	--	pump off	

LGRB Poly 3

Date developed: 6/2/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	11	5,300	>1,000	0.4	Muddy
80	11.2	5,330	>1,000	0.4	Muddy/murky
100	11.6	5,310	>1,000	0.4	Muddy/murky
120	11.4	5,260	>1,000	0.4	Muddy/murky
130	11.5	5,160	569	0.25	Murky
140	11.1	5,060	>1,000	0.25	Murky
150	11.6	5,010	589	0.25	Slightly murky
160	11.7	4,970	58.7	0.25	Clear
161	--	--	--	pump off	

LGRB Poly 4

Date developed: 5/21/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	13.7	4,170	>1,000	0.5	Muddy
85	14.2	4,160	>1,001	1	Muddy/murky
110	14.6	4,140	>1,002	1	Muddy/murky
130	15	4,140	>1,003	0.2	Muddy/murky
155	14.6	4,170	>1,004	1	Murky
190	14	4,170	>1,005	1	Murky
210	13.6	4,170	>1,006	1	Murky
211	--	--	--	pump off	

LGRB Poly 5

Date developed: 5/20/2014 and 5/21/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	Very muddy
180	--	--	--	pump off	Very muddy
0	--	--	--	pump on	Muddy
80	13.1	2,830	>1,000	0.8	Muddy
100	13.1	2,830	>1,000	0.8	Muddy
120	13.1	2,840	>1,000	0.8	Muddy
140	13.5	2,840	>1,000	0.5	Very muddy
160	13.5	2,850	>1,000	0.5	Very muddy
162	--	--	--	pump off	
180	12.6	2,970	877	5 gal	1st bail, muddy/murky
200	12.5	2,890	283	5 gal	2nd bail, murky

LGRB Poly 6

Date developed: 6/23/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
50	14.5	2,550	>1,000	2	Muddy
70	14.5	2,550	1,000	2	Muddy
90	14.5	2,550	735	2	Murky
110	14.5	2,550	446	2	Murky
130	14.5	2,540	330	2	Murky
150	14.5	2,540	274	2	Murky
180	15	2,540	156	1	Slightly murky
210	15	2,540	119	1	Slightly murky
230	14.9	2,540	99.8	1	Slightly murky
240	14.9	2,540	99.9	1	Slightly murky
250	--	--	--	pump off	

LGRB Poly 7

Date developed: 5/20/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	0.3	Muddy
40	13.5	40,000	>1,000	0.3	Murky yellowish tinge
60	13.8	43,800	320	0.3	Yellowish, slightly murky
70	14.3	43,900	260	0.3	Yellowish, slightly murky
80	13.7	44,000	96.4	0.3	Clear
90	13.8	44,000	71.1	0.3	Clear
100	14.8	44,000	58.2	0.3	Clear—degassing
110	14.4	44,000	61.4	0.3	Clear—degassing
112	--	--	--	pump off	

LGRB Poly 9

Date developed: 6/23/2014 and 6/24/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; <, less than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
90	--	--	--	<0.1	Very muddy
117	--	--	--	pump off	
120	--	--	--	2 gal	1st bail, very muddy
1093	11.8	5,140	81.4	5 gal	2nd bail, slightly murky
1467	12.3	5,120	112	5 gal	3rd bail, slightly murky

LGRB Poly 10

Date developed: 6/25/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	12.6	4,170	>1,000	15 gal	1st bail, muddy
15	12.4	4,190	1,000	25 gal	2nd bail, muddy
30	12.7	4,180	1,000	10 gal	3rd bail, muddy
45	12.1	4,190	1,000	10 gal	4th bail, muddy
60	12.2	4,190	581	10 gal	5th bail, murky
75	12.2	4,190	491	5 gal	6th bail, murky
90	12	4,180	284	5 gal	7th bail, slightly murky
105	12	4,190	321	5 gal	8th bail, slightly murky
120	12.9	4,190	108	5 gal	9th bail, slightly murky
135	12.5	4,190	73.6	5 gal	10th bail, clear

LGRB Poly 14

Date developed: 6/25/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	13.7	37,400	1,000	15 gal	1st bail, murky
30	14.6	25,300	17.6	10 gal	2nd bail, murky
60	15	24,300	8.77	4 gal	3rd bail, clear yellow
90	15.1	28,100	11.3	4 gal	4th bail, clear yellow

LGRB Poly 17

Date developed: 6/19/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
50	10.7	6,300	>1,000	1	Muddy
90	10.4	6,320	>1,000	1	Murky
110	10.4	6,320	>1,000	1	Murky
140	10.6	6,320	1,000	1	Murky
180	10.8	6,320	>1,000	0.5–1.2	Murky
210	11.3	6,320	>1,000	1	Murky
240	10.6	6,320	1,000	1	Murky
360	11.3	6,320	912	0.5–1	Slightly murky
380	11	6,320	668	0.4–0.5	Slightly murky
440	11.4	6,330	436	0.4–0.5	Slightly murky
480	11.7	6,320	370	0.5	Slightly murky
485	--	--	--	pump off	

LGRB Poly 18

Date developed: 5/20/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	Muddy
1	--	--	>1,000	0.3	Muddy
70	13.1	2,920	255	0.4	Murky
80	12.9	2,930	76.5	--	Slightly murky
90	13	2,920	41.3	0.4	Mostly clear
100	13.1	2,930	20.4	0.4	Mostly clear
110	13.1	2,920	24.7	0.4	Clear
120	13.5	2,920	16.8	0.4	Clear
129	--	--	--	pump off	

LGRB Poly 19

Date developed: 7/18/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	Muddy
60	16.4	4,100	>1,000	0.3	Muddy
155	15.7	4,030	>1,000	0.5	Muddy
205	15.6	4,030	>1,000	0.3	Muddy
223	16.5	3,860	854	0.25	Muddy
250	--	--	--	pump off	
265	15.0	3,870	486	5 gal	1st bail, murky

LGRB Poly 21

Date developed: 7/8/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	13.6	3,400	1,000	0.2	Muddy
87	14	3,410	146	0.2	Clear
96	14	3,400	108	0.2	Clear
106	14.1	3,390	65.9	0.2	Clear
116	14.1	3,380	53.9	0.2	Clear
126	14	3,380	43.3	0.2	Clear
136	--	--	--	pump off	

LGRB Poly 22

Date developed: 7/8/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
50	14	8,550	1,000	1	Muddy/murky
100	14.6	8,600	907	1	Murky
115	14.5	8,610	689	1	Murky
144	14.4	8,650	450	1	Slightly murky, degassing
160	14.6	8,660	225	1	Slightly murky, degassing
180	14.5	8,640	168	1	Clear yellow
181	--	--	--	pump off	

LGRB Poly 23

Date developed: 7/2/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
80	12	1,729	>1,000	1	Muddy
120	12.6	1,734	>1,000	1	Muddy
180	12.7	1,728	>1,000	1	Muddy
240	12.4	1,723	>1,000	1	Muddy
290	12.2	1,728	1,000	1	Muddy
344	12.3	1,725	1,000	1	Muddy
352	--	--	--	pump off	

LGRB Poly 25

Date developed: 6/30/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
30	12.4	2,910	284	0.2	Slightly murky
40	12.2	2,920	149	0.2	Slightly murky
50	12.2	2,940	72.1	0.2	Clear
60	12	2,930	29.4	0.2	Clear
70	12.2	2,930	25.3	0.2	Clear
80	--	--	--	pump off	

LGRB Poly 27

Date developed: 6/30/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	12.4	9,700	1,000	1	Muddy yellowish
90	12	9,680	1,000	1	Muddy yellowish, degassing
110	12.5	9,710	971	1	Muddy yellowish, degassing
160	12.4	9,690	723	1	Murky yellowish
180	11.9	9,690	675	1	Murky yellowish
210	--	--	--	pump off	

LGRB Poly 29

Date developed: 7/16/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than; gals, gallons]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
76	14.4	3,470	>1,000	0.3	Muddy
100	13.1	3,480	>1,000	0.3	Muddy
253	13.4	3,480	>1,000	0.125	Muddy, moved surge block
293	14.2	3,480	>1,000	0.1	Muddy
330	14	3,480	>1,000	0.3	Muddy
331	--	--	--	pump off	
350	12.4	3,480	910	5 gals	1st bail, murky, clearing
370	12.4	3,480	109	5 gals	2nd bail, clearing

LGRB Poly 30

Date developed: 7/18/2014

[gal/min, gallons per minute; °C, degrees Celsius; µS/cm, microsiemens per centimeter; NTU, nephelometric turbidity units; --, no data; >, greater than; gals, gallons]

Pumping duration (minutes)	Temperature (°C)	Specific conductance (µS/cm)	Turbidity (NTU)	Pumping rate (gal/min)	Appearance
0	--	--	--	pump on	
60	12.9	4,210	>1,000	0.4	Muddy
90	--	--	--	0.3	Very muddy
135	13.4	4,400	>1,000	0.5	Very muddy
188	13.4	4,350	>1,000	0.5	Very muddy
213	--	--	--	pump off	
230	11.8	4,350	>1,000	5 gals	1st bail, muddy
250	11.8	4,340	964	5 gals	2nd bail, murky
270	12.0	4,340	690	5 gals	3rd bail, murky
290	11.9	4,340	597	5 gals	4th bail, murky

Publishing support provided by:
Denver Publishing Service Center, Denver, Colorado

For more information concerning this publication, contact:
Director, USGS Colorado Water Science Center
Box 25046, Mail Stop 415
Denver, CO 80225
(303) 236-4882

Or visit the Colorado Water Science Center Web site at:
http://co.water.usgs.gov/

This publication is available online at:
http://dx.doi.org/10.3133/ds955

ISSN 2327-638X (online)
http://dx.doi.org/10.3133/ds955