ANALYSES OF THREE CONSTANT-RATE AQUIFER TESTS, EAST FLATHEAD VALLEY, NORTHWEST MONTANA

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Front photo: The Swan Range to the east of the Flathead Valley is an important source of groundwater recharge. Photo by Todd Myse, MBMG.

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TABLE OF CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

Development in the Flathead Valley in Montana is ongoing, and demands for groundwater are increasing as this development continues. The East Flathead groundwater investigation was conducted to evaluate how the shallow and deep unconsolidated alluvial aquifers interact with each other as well as with surface waters (fig. 1). By understanding these interactions, the effects of increased groundwater pumping can be evaluated.

We conducted three aquifer tests in the East Flathead Valley (fig. 2) to evaluate the degree of inter-

Period	Epoch	Flathead Valley Stratigraphy	
Quaternary	Holocene	Shallow alluvium	Sand and gravel with minor silt and clay within modern stream valleys and in broad alluvial and eolian sheets.
		Ancestral Flathead Lake deposits	Brown and gray, laminated, calcareous fine sandy silt, clayey silt, and minor clay; upper surfaces are mostly broad and even; deposited from suspension in a lake that was initially pro-glacial; exposed as the lake sill was downcut and postglacial erosion occurred.
		transitional	
	Pleistocene	Glacial Lake deposits	
		Till	Gravel and boulders in a matrix of gray and brown dense sand mud (diamiction); some stratified sand gravel deposited by, or near, glacial ice; clasts are typically rounded and subrounded metacarbonate, quartzite, argillite, and diorite; more resistant clasts are commonly striated; forms cores of many glacial landforms such as drumlins and moraines.
		Deep alluvium	Brown, yellowish brown, and gray stratified coarse-grained sand and gravel conglomerate; rare calcium carbonate cement; clasts of quartzite, argillite, and metacarbonate.
		local or basin-wide unconformities	
Tertiary	Eocene–Miocene(?)	Tertiary sedimentary rocks and some volcanic rocks	**Sedimentary rocks:** Brown and orange medium and coarse-grained pebbly sandstone; pebble and cobble conglomerate; carbonaceous shale with carbonized wood; gray, yellow and orange mudstone; and orange clayey gravel (diamicton). Gravel clasts of argillite, quartzite, and siltstone are mostly well rounded. Sandstone and conglomerate beds have channelized, erosional bases. Diamicton unit locally infills fractures in Belt Supergroup bedrock. **Volcaniclastic rocks:** Sandstones, conglomerates, breccias, diamictons, and tuff (compacted deposit of volcanic particles) that contain small to large percentages of Belt Supergroup gravel- and sand-sized particles (Lange and Zehner, 1992).
		unconformity	
Proterozoic		Belt Supergroup	Numerous stratigraphic units composed mostly of metamorphosed siltstones, carbonates, and quartz sandstones (Johns, 1970; Winston, 1986; Harrison and others, 1986, 1992) and minor amount of igneous rocks (McGimsey, 1985). Most bedding thicknesses range from less than 1 inch in metasiltstone to a few feet to tens of feet in metacarbonates and quartzites.

Figure 1. Stratigraphy of the Flathead (Kalispell) Valley, modified from LaFave and others (2004). Geologic units important to the hydrogeology of the Flathead Valley mostly are unconsolidated to semi-consolidated sand, gravel, silt, and clay within the valleys. Bedrock consisting of the Belt Supergroup contains aquifers developed in fractures.

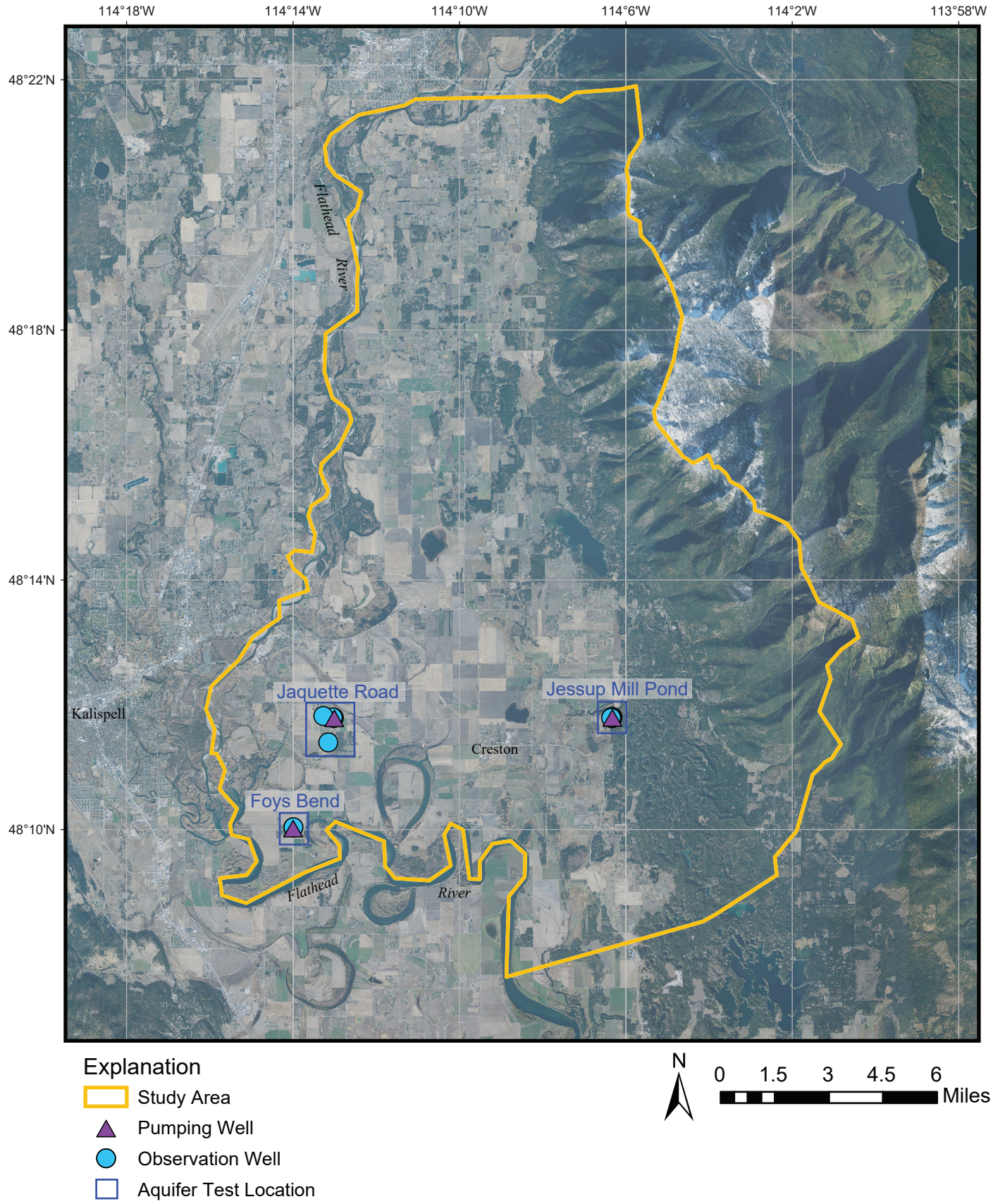

Figure 2. The aquifer tests conducted for the East Flathead groundwater investigation were located in the southern portion of the study area, where lithologic logs, water-level responses, and water-quality data suggested the till and lacustrine aquitards may not provide a continuous confining layer.

connection between the shallow and deep aquifers, and to provide information on aquifer properties. For these tests, pumping was from the deep aquifer. These results will be used to aid in developing a groundwater model of the East Flathead Valley (Berglund and Bobst, in prep.), which can be used to predict the hydrologic effects of increased groundwater pumping.

The deep aquifer is a primary source of water for the Flathead Valley. It supplies water for irrigation wells, public water supply wells, private wells, and other uses. Wells in the deep aquifer may produce over 1,000 gpm. The deep aquifer is composed of glacial outwash materials deposited by streams fed by the advancing Pinedale-age continental ice sheet. These outwash materials include fluvial sand, gravel, and cobbles. The lower portion of the deep aquifer may have been deposited by streams that occupied the valley between times of glaciation (LaFave and others, 2004; Smith, 2004a).

The deep aquifer is generally overlain by low-permeability glacial basal till and lake sediments (LaFave and others, 2004; Rose, 2018). The till is primarily composed of gravel and boulders in a matrix of fine-grained materials (diamicton). Within the till there are occasional discontinuous sand and gravel intermediate aquifers, deposited due to proglacial and subglacial fluvial activity. The lake units are typically deep-water silt and clay deposits. There are also intermediate aquifers within the lake deposits due to interfingering of sandy near-shore (deltaic) deposits with the more fine-grained deep-water deposits. While the till and lake sediments are widespread, it is unclear if they provide an effective confining layer throughout the entire area (Smith, 2004b). Understanding the continuity of the confining layers is important for predicting the effects of increased groundwater pumping from the deep aquifer.

The shallow aquifers are composed of sand and gravel associated with modern streams, deltaic deposits, and eolian loess deposits (LaFave and others, 2004; Smith, 2004a). These units are generally less productive than the deep aquifer. The shallow aquifers are directly connected to surface waters (Konizeski and others, 1968; Noble and Stanford, 1986).

The Foys Bend and Jaquette Road aquifer tests were conducted near the center of the Flathead Valley, where driller's completion reports, exploratory drilling, and RotoSonic drilling suggest that the confining layers are thick (~550 and 150 ft, respectively for each test), continuous, and have low permeability. The Jessup Mill Pond aquifer test was conducted at a site where it was unclear from water-well logs, exploratory drilling, and RotoSonic drilling if the confining layers were continuous. Also, the sediments encountered at the Jessup Mill Pond site that are interpreted to be time equivalent to the confining layer were coarser grained (and therefore, likely more permeable).

These tests were conducted in accordance with ASTM D4050-96. Aquifer-test data, including aquifer test 633 forms, are available from the Montana Bureau of Mines and Geology (MBMG) Ground Water Information Center (GWIC) online database (http://mbmggwic.mtech.edu) by using the pumping wells' GWIC ID numbers (tables 1–3). Aquifer-test drawdown data were analyzed using AQTESOLV software and a solution appropriate for the setting.

2.0 FOYS BEND AQUIFER TEST

2.1 Background

2.1.1 Purpose of Test

This test was designed to estimate the aquifer properties of the deep aquifer in the western portion of the East Flathead groundwater investigation study area (fig. 2), to evaluate leakage through the confining layer, and to identify any other boundary conditions.

2.1.2 Test Location

The aquifer test site is approximately 4 mi southeast of Kalispell to the north and east of the Flathead River, near Foys Bend. This site is in an agricultural area.

2.1.3 Test Type

A 72-h constant-rate aquifer test was performed. The constant-rate test was conducted from October 26, 2021 to October 29, 2021. Wells included the pumping well (318263) and two observation wells (318266 and 318265; fig. 3, table 1). Water-level recovery was monitored until November 1, 2021 (75 h after the end of pumping).

2.1.4 Hydrogeologic Setting

The general stratigraphy at this site is soil from 0 to 3 ft below ground surface (bgs), sand and silt from

Table 1. Well designations, locations, and completion information, Foys Bend aquifer test.

GWIC ID	Name	Latitude (deg N)	Longitude (deg W)	Measuring Point Elevation (ft-amsl)	Total Depth (ft-bgs)	Screen Interval (ft)	Distance from PW (ft)	Pre-Test DTW 10/25/2021 (ft-bMP)	Pre-Test Groundwater Elevation (ft-amsl)	Max Drawdown (ft)	Comments
318263	FB-PW	48.16721159	114.23331268	2,909.51	640	610– 630	—	7.49	2,902.02	2.60	Deep Pumping Well
318266	FB-OW-I	48.16726047	114.23317700	2,910.55	300	295– 300	33	16.66	2,893.89	0.00	Intermediate Observation Well
318265	FB-OW-S	48.16724091	114.23323494	2,910.04	50	40– 50	56	16.32	2,893.72	0.00	Shallow Observation Well

Note. All locations and elevations determined by survey. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface; ft-bMP, feet below measuring point; DTW, depth to water; Horizontal datum = NAD83; Vertical datum = NAVD88.

Table 2. Well designations, locations, and completion information, Jessup Mill Pond aquifer test.

GWIC ID	Name	Latitude (deg N)	Longitude (deg W)	Measuring Point Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft)	Distance from PW (ft)	Pre-Test DTW 12/7/2021 (ft-bMP)	Pre-Test Groundwater Elevation (ft-amsl)	Max Drawdown (ft)	Comments
318274	JMP-PW	48.196797	114.105436	2,987.99	300	278–298	—	34.94	2,953.05	7.82	Deep Pumping Well
304315	JMP-DW	48.1964928	114.105899	2,972.10	52	Open Bottom	188	26.34	2,945.76	0.09	Shallow Domestic Well
310815	JMP-OW-D	48.196444	114.1055778	2,973.07	280	Open Bottom	202	20.06	2,953.01	0.00	Ottey Deep Well
310816	JMP-OW-I	48.196439	114.105584	2,972.99	180	Open Bottom	203	22.68	2,950.31	0.00	Ottey Intermediate Well

Note. All locations and elevations determined by survey. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface; ft-bMP, feet below measuring point; DTW, depth to water; horizontal datum, NAD83; vertical datum, NAVD88.

Table 3. Well designations, locations and completion information, Jaquette Road aquifer test.

GWIC ID	Name	Latitude (deg N)	Longitude (deg W)	Measuring Point Elevation (ft-amsl)	Total Depth (ft)	Screen Interval (ft)	Distance From Pumping Well (ft)	Pre-Test DTW (ft)	Pre-Test Water Elevation (ft-amsl)	Max Drawdown (ft)	Comments
82279	JR-PW	48.1965941	-114.2168360	2,950.83	486	438–478	—	36.73	2,914.10	97.73	Pumping Well
262323	JR-OW-I	48.1965365	-114.2169773	2,948.73	217	Open Bottom	40	26.92	2,921.81	2.58	Observation Well at top of deep aquifer
262324	JR-OW-S	48.1965531	-114.2169156	2,948.46	66	56–66	24	26.66	2,921.80	0.00	Observation Well in shallow aquifer
262325	JR-OW-D	48.1965914	-114.2173620	2,952.02	480	Open Bottom	128	38.56	2,913.46	24.85	Observation Well in deep aquifer
197798[+]	JR-DW1	48.196995	-114.221201	2,941.6	298	Open Bottom	1,078	33.28	2,908.32	2.25	Observation Well in deep aquifer
143331[+]	JR-DW2	48.189944	-114.219203	2,951.5	200	Open Bottom	2,494	45.19	2,906.31	0.40	Observation Well in deep aquifer

Note. All locations and elevations determined by survey. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface; ft-bMP, feet below measuring point; DTW, depth to water; horizontal datum, NAD83; vertical datum, NAVD88.
[+]Site not surveyed, GPS located.

3 to 73 ft bgs, silt and clay with interbeds of sand and gravel from 73 to 595 ft bgs, and gravel and sand from 595 to 640 ft bgs (appendix A, figs. A1–A3).

Three wells were installed at this site (table 1; fig. 3). The deepest well (FB-PW; 318263) was screened in the deep gravel and sand zone from 610 to 630 ft bgs (appendix A). An intermediate well (FB-OW-I; 318266) was screened from 295 to 300 ft bgs in the silt and clay zone (appendix A). A shallow well (FB-OW-S; 318265) was screened from 40 to 50 ft bgs in the shallow sand and silt (appendix A).

2.1.5 Hydrologic Features

The Flathead River flows on three sides of this site. A slough connected to the Flathead River is located 0.2 mi to the east, while the Flathead River itself is about 0.75 mi to the west and south (fig. 2).

2.2 Field Procedure

A step-drawdown test was conducted to determine the sustainable pumping rate for the constant-rate test. Each of the three steps were 1 h in duration. Time-weighted mean pumping rates were 10, 27, and 58 gpm (fig. 4). Pumped water was discharged to a swale in the field approximately 200 ft east of the site. The maximum pumping rate was the highest obtainable with the equipment installed at the site. Neither of the observation wells responded to this pumping (figs. 4B, 4C). The pumping well was drawn down by a maximum of 2.7 ft. Water levels recovered in the pumping well to within 0.01 ft of pre-test levels 2 min after pumping stopped. Based on the equipment installed and that drawdown was observed, it was determined that the pumping rate of approximately 58 gpm would provide adequate drawdown during the 72-h constant-rate test.

During the constant-rate test the time-weighted mean pumping rate was 55 gpm (fig. 5A).

2.2.1 Data Collection

Pressure transducers with data loggers (transducers) were installed in the shallow and intermediate observation wells on October 20. The transducers collected readings at 15-min intervals from October 20 to October 25 (prior to the start of the step test). On October 25 the observation well transducers collected readings at 1-min intervals during the step test, from 13:45 to 17:56. At the end of the step test the observation well transducers returned to collecting readings at 15-min intervals. Given the lack of response in these wells to the step test, the 15-min interval was deemed appropriate for the constant-rate test, and data were collected until November 1.

A transducer was also installed in the pumping well on October 25, prior to the start of the step test. This transducer took readings at 1-min intervals until 2 h after the end of the constant-rate pumping period on October 29. From October 29 to November 1, the transducer was programmed to record at 15-min intervals.

Manual readings of water levels were made for all wells using an e-tape prior to placing transducers and were made periodically during the test, during recovery, and prior to transducer retrieval (figs. 4, 5). These manual measurements were taken at the frequency listed in table 4 and were used to calibrate transducer response and provide a backup in case of transducer malfunction.

Pumping rates were monitored using a bucket and stopwatch and a totalizing flow meter (figs. 4A, 5A). Due to equipment failure, the flow meter was only used during the step-drawdown test and through the first 10 h of the constant-rate test. Bucket and stopwatch readings were taken several times a day following failure of the flow meter to ensure that pumping rates were stable.

2.3 Results

Static water levels in the pumping well were 0.28 ft higher following the constant-rate portion of the aquifer test. Therefore, a correction for this antecedent trend was applied at a rate of 0.08 ft/d to remove this influence on observed drawdown.

2.3.1 Hydrographs

The drawdown in the pumping well near the end of the test was 2.6 ft. This reflects a 72-h specific capacity of 21 gpm/ft (i.e., 55 gpm divided by 2.6 ft of drawdown). Drawdown in the pumping well showed a rapid initial decline followed by relatively stable water levels. After pumping ceased, water levels reached 95% recovery in less than 1 min (fig. 5A). Neither of the observation wells responded to the tests.

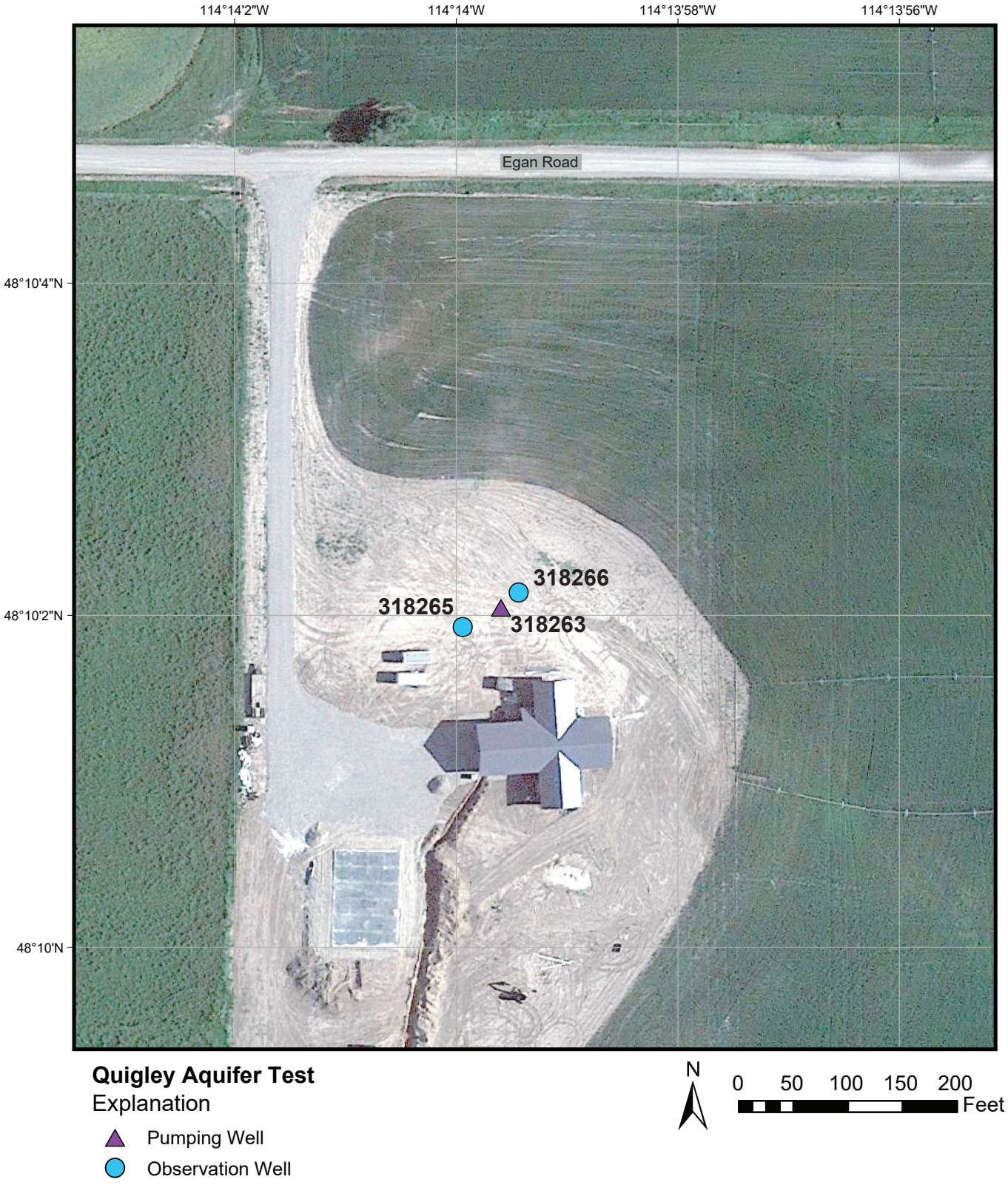

Figure 3. Site layout for the Foys Bend aquifer test site. Three wells were installed and monitored for the aquifer test. They were completed in the deep aquifer (318263), in a sandy low productivity zone within the confining layer (318266), and in the shallow aquifer (318265; table 1).

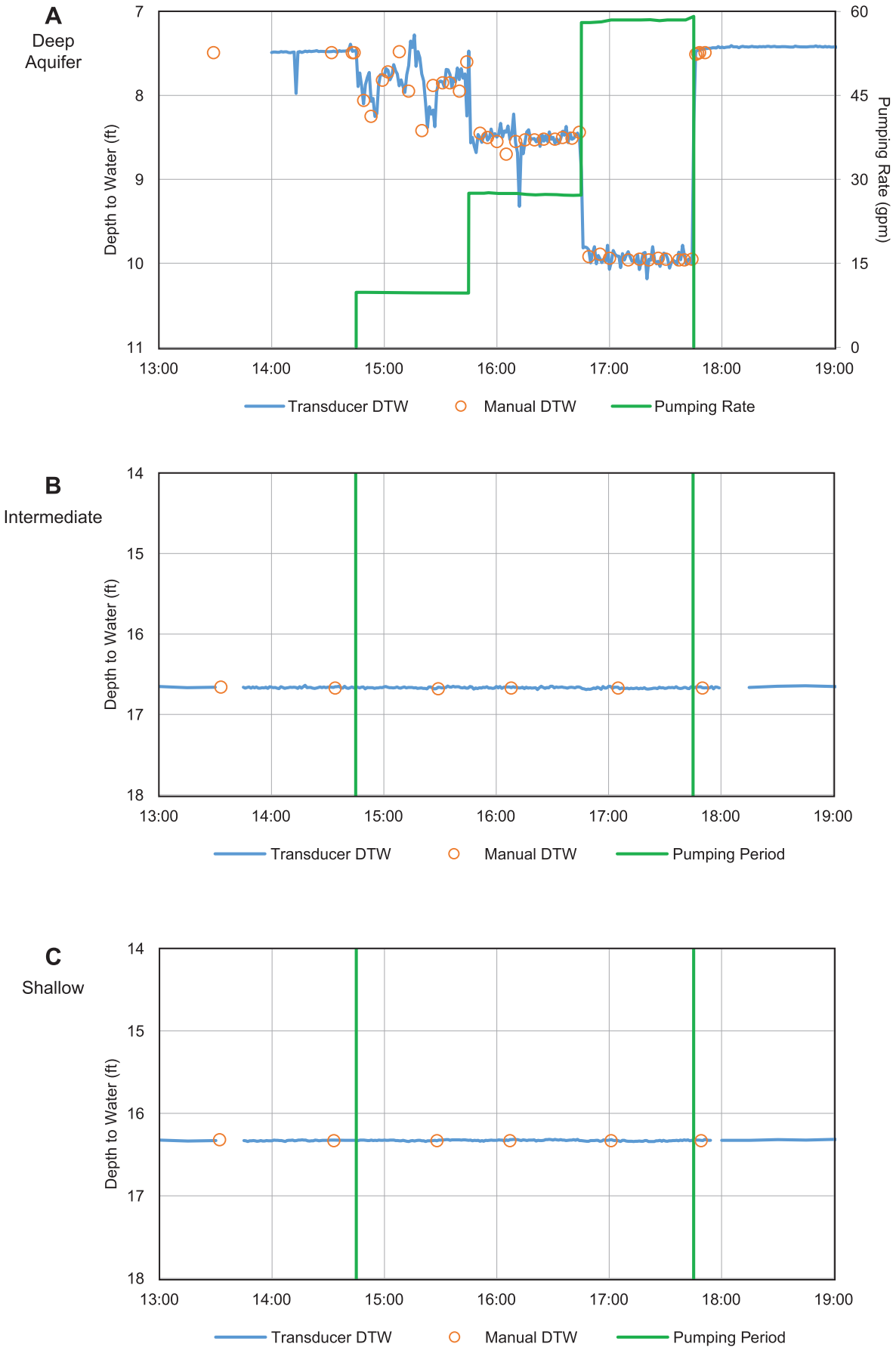

Figure 4. Hydrographs showing the response to pumping during the step test on October 25, 2021 for pumping well 318263 (A), intermediate observation well 318266 (B), and shallow observation well 318265 (C).

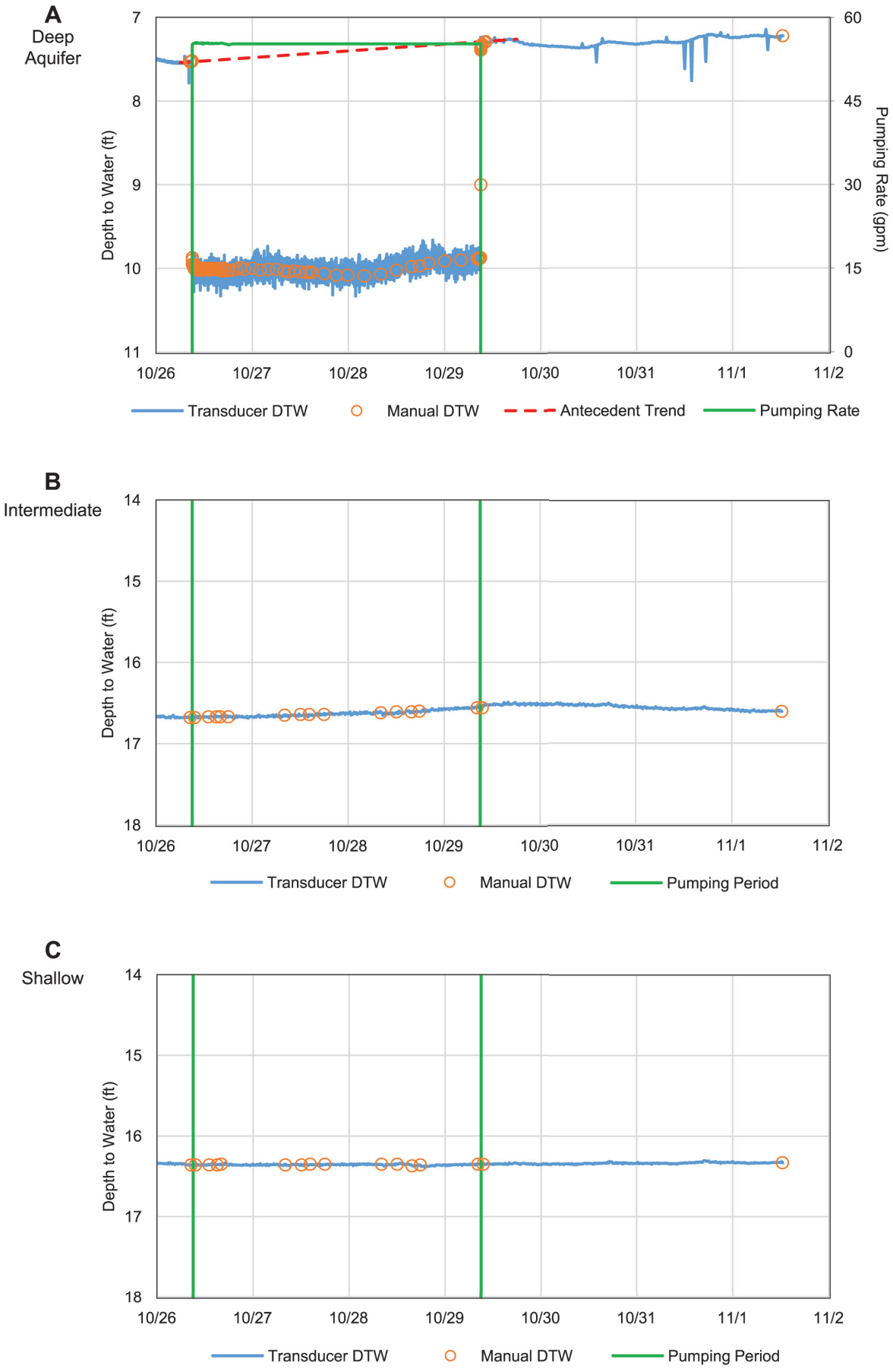

Figure 5. Hydrographs showing the response to pumping during the constant-rate test for pumping well 318263 (A), intermediate observation well 318266 (B), and shallow observation well 318265 (C).

Table 4. Manual water-level measurement frequency

Time Since Start of Test	Frequency of Manual Measurements
0–5 min	Pumping well as frequently as possible Others monitoring wells, when possible
5–60 min	5 min
1–2 h	10 min
2–4 h	15 min
4–8 h	30 min
8–16 h	1 h
>16 h	4 h

2.3.2 Aquifer Properties

Evaluation of the hydrogeologic setting and lithologic descriptions from well cuttings suggest that the pumped deep aquifer at this site is confined or leaky-confined. As such, the Theis solution (1935) for a confined aquifer was first applied, but it resulted in unrealistic aquifer properties. The leaky-confined solution of Hantush (1960) provided a good fit for the observed drawdown during the constant-rate test. This model provided an estimated transmissivity (T) value of 7,640 ft^2/d and used relatively low leakage terms (appendix B). This model estimated a very low and unreasonable storativity (S) value. However, since there was not an observation well in the deep aquifer, this S estimate is not reliable as it may be influenced by the efficiency of the pumping well. The pumping well was completed using 20 ft of screen, so if it is assumed that approximately 30 ft of aquifer thickness was contributing to the well (Weight, 2008), the calculated hydraulic conductivity (K) value is about 250 ft/d, a value appropriate for a gravel and sand zone (Freeze and Cherry, 1979; Heath, 1983).

2.4 Summary

At this test site the gravel and sand deep aquifer is productive (21 gpm/ft) and under leaky-confined conditions. The leakage through the confining layer is slight, but noticeable in the pumping well monitoring data; a confined solution does not provide reasonable aquifer properties. No other boundaries were identified. Drawdown was not detected in the shallow or intermediate observation wells.

3.0 JESSUP MILL POND AQUIFER TEST

3.1 Background

3.1.1 Purpose of Test

The purpose of this test was to estimate the aquifer properties of the sand and gravel within the deep aquifer (300 ft deep well) and whether there is a connection between the shallower aquifer above the potential confining layer.

3.1.2 Test Location

The aquifer test site is outside the town limits of Creston at a residential dwelling, just south of the Creston National Fish Hatchery. The house is located off of Kauffman Lane (figs. 2, 6).

3.1.3 Test Type

A 72-h constant-rate aquifer test was conducted. Wells included the pumping well (318274) and three observation wells (304315, 310815, and 310816; table 2). The constant-rate test was conducted from December 7, 2021 to December 10, 2021. Water-level recovery was monitored until December 13, 2021 (76 h after the end of pumping).

3.1.4 Hydrogeologic Setting

The pumping well (JMP-PW; 318274) and one observation well (JMP-OW-D; 310815) are completed in the deeper sand and gravel aquifer (table 2; fig. 6). JMP-PW is screened from 278 to 298 ft bgs and JMP-OW-D is an open bottom at 280 ft. One observation well (JMP-OW-I; 310816) is completed in an intermediate sand and gravel zone with an open bottom at 180 ft bgs and one observation well (JMP-DW; 304315) is

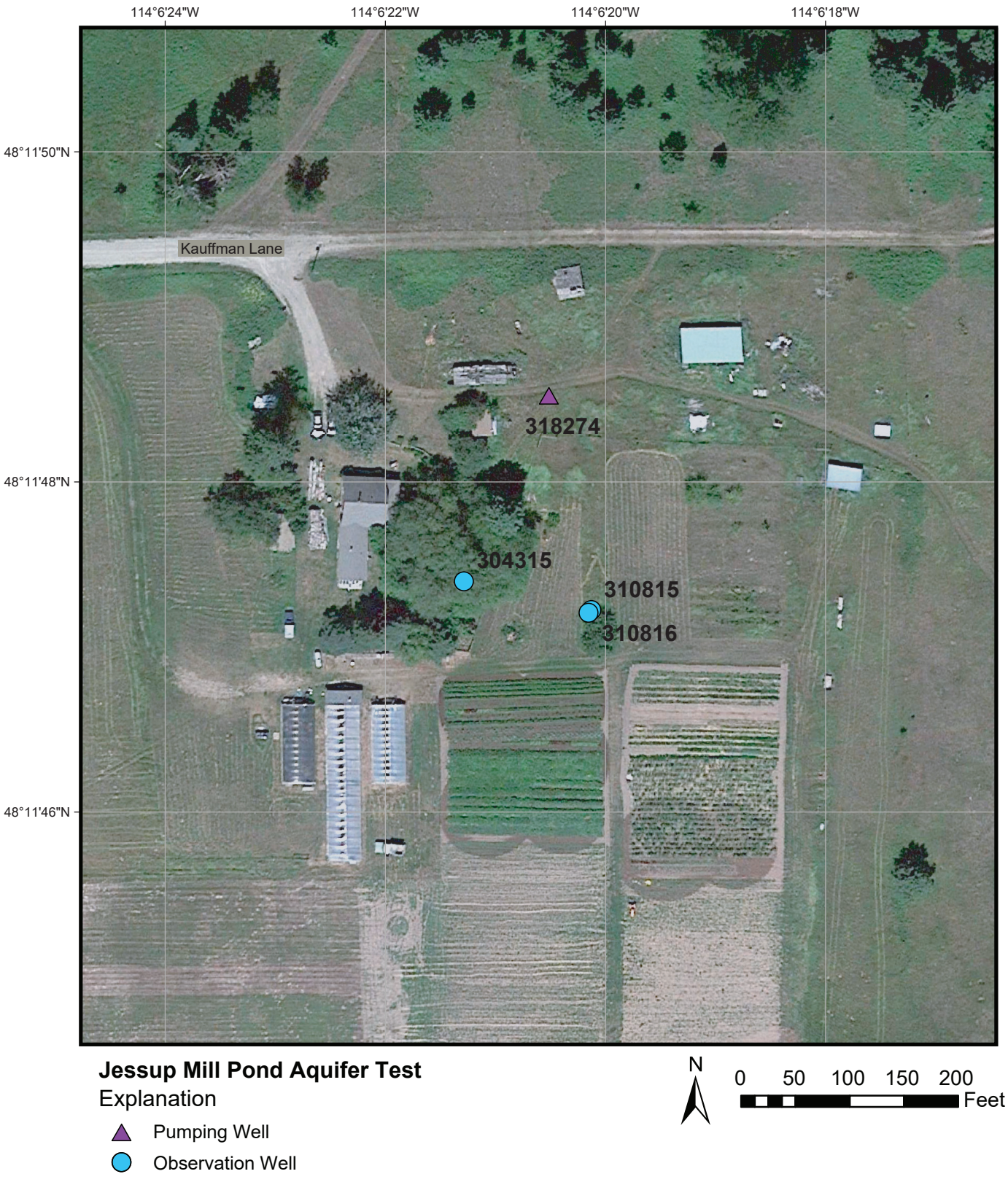

Figure 6. Site layout for the Jessup Mill Pond aquifer test. There was one pumping well and three observation wells for this test.

completed in the shallow aquifer with an open bottom at 52 ft bgs. A 210-ft RotoSonic core (319820) was also obtained at this site (appendix C).

3.1.5 Hydrologic Features

The primary hydrologic feature is Jessup Mill Pond, about 700 ft north of the pumping well. This pond feeds the Creston National Fish Hatchery.

3.2 Field Procedure

A step-drawdown test was performed on December 6, 1 d prior to the constant-rate test, to determine an appropriate pumping rate. Five steps were conducted at discharge rates of 60, 80, 100, 125, and 140 gpm. Each of the first two steps lasted about 1 h, the third step was 30 min, the fourth step was about 40 min, and the last step was for 1 h. The smaller time duration of the steps was because the water levels quickly stabilized for the previous steps. Water levels fully recovered prior to the start of the constant-rate test.

The constant-rate aquifer test began December 7 at 10:05 and continued for 72 h (December 10 at 10:19) at a time-weighted mean pumping rate of 143 gpm. Recovery was monitored for 76 h.

3.2.1 Data Collection

Each monitoring location was equipped with a transducer. Before the test, the transducers were programmed to record background water levels and temperature every hour. They were reprogrammed to record every minute during the aquifer test and for the first 15 min of recovery. After 15 min of recovery the transducers were reprogrammed in all wells for hourly readings. Recovery in the pumping well did not take long, as the water levels returned to their original water levels about 5 min after pumping ceased. Water levels in well JMP-DW, however, took about 3 d to recover.

Manual depth to water measurements were taken at a frequency shown in table 2 in case of pressure transducer failure. At the beginning of the test, the manual measurements were mostly taken at the pumping well, and then when time allowed (after 5–10 min) manual measurements were taken at the other observation wells.

A totalizing flow meter installed on the well discharge line tracked the total amount of water pumped and was used to calculate flow rate. The pumped water was discharged about 440 ft south of the pumping well and topographically downgradient.

3.3 Results

The time-weighted average pumping rate of 143 gpm was used for the test analysis. There were not any measurable water-level trends after the pumping ceased. There was no measurable drawdown in wells JMP-OW-I and JMP-OW-D. It was later discovered that both wells were sanded in due to heaving sand coming up through the open bottom, which may have affected the water-level response. There was a slight decline in water levels in well JMP-DW (0.002 ft/d), but this trend was not significant enough to correct for antecedent trends.

3.3.1 Hydrographs

Figure 7 shows the pumping and domestic well hydrographs. It includes water levels 10 d prior to the aquifer test for JMP-DW. Based on the scale of figure 7, another plot was created to provide more detail on the drawdown in well JMP-DW (fig. 8). A slight response (0.09 ft of drawdown after 72 h) was observed in the shallow domestic well completed in sands and gravels. No other boundaries were identified. Table 2 includes the maximum drawdown for each well.

3.3.2 Aquifer Properties

Evaluation of the hydrogeologic setting, lithologic descriptions from well cuttings, and drawdown data suggest that the pumped deep aquifer at this site is leaky-confined. Therefore, the Hantush–Jacob (Hantush and Jacob, 1955) solution for leaky-confined aquifers was used to analyze the drawdown data for the pumping well (appendix D).

Using 1.5 times (Weight, 2008) the screened interval for the deep sand and gravel aquifer (well 318274), the hydraulic conductivity was calculated to be 260 ft/d (T = 7,791 ft^2/d). This is reasonable for a sand and gravel aquifer (Freeze and Cherry, 1979; Heath, 1983). No storativity could be estimated since these data are from a pumping well and none of the observation wells were affected by pumping in the pumped aquifer.

3.4 Summary

At this test site the gravel and sand deep aquifer is productive (the specific capacity = 143 gpm/7.82 ft of

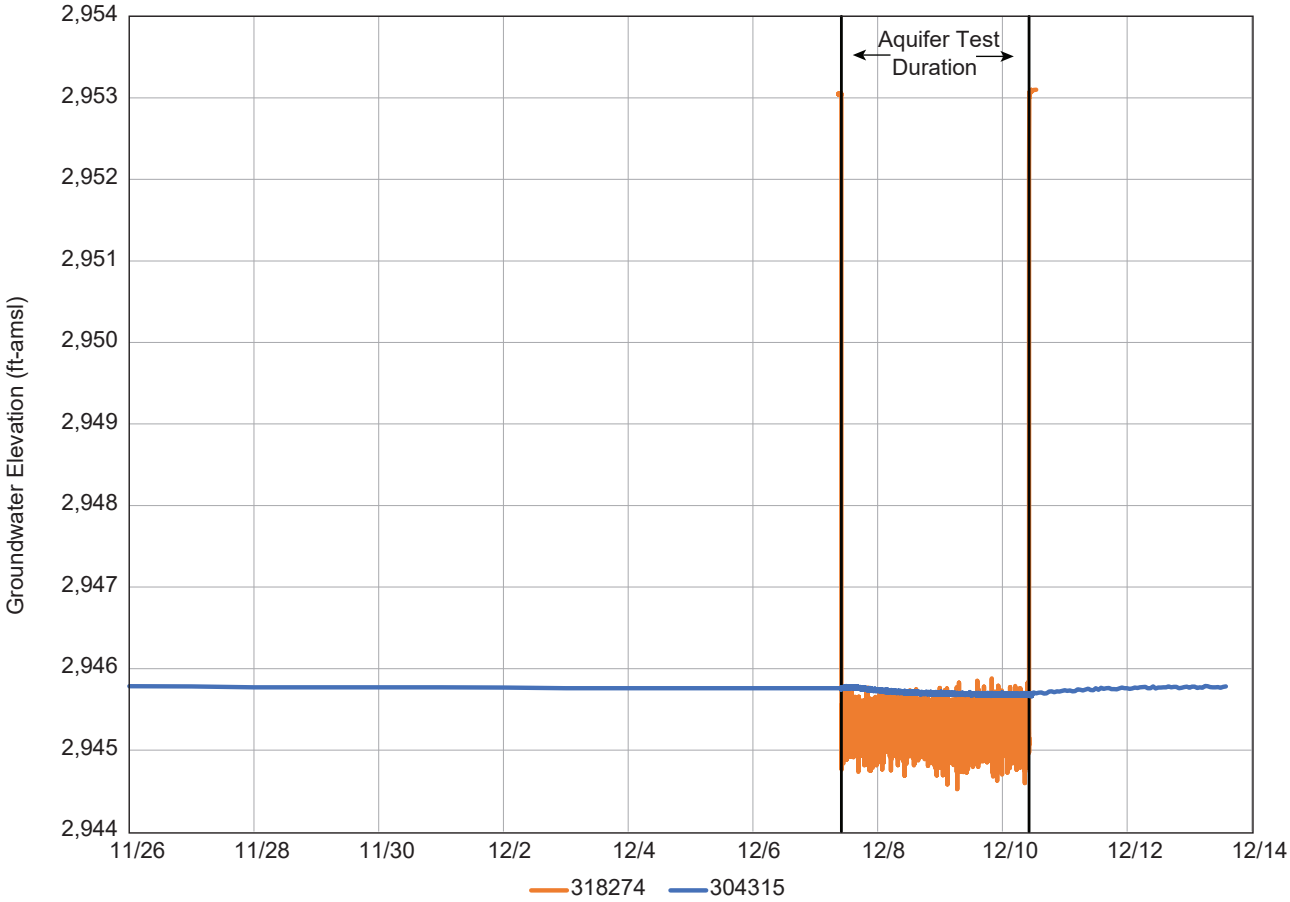

Figure 7. Hydrographs showing the water-level prior to, during, and after the constant-rate test.

drawdown = 18.2 gpm/ft) and under leaky-confined conditions; a confined solution does not provide reasonable aquifer properties. No drawdown was observed in the intermediate (180 ft deep) and deep (280 ft) wells located about 200 ft away from the pumping well. However, it was determined later that the intermediate well and deep well were compromised due to heaving sands at the bottom.

4.0 JAQUETTE ROAD AQUIFER TEST

4.1 Background

4.1.1 Purpose of Test

This test was designed to estimate the aquifer properties of the deep aquifer in the Flathead Valley and to assess boundary conditions. Specific boundary conditions of interest were recharge boundaries (Flathead River or Flathead Lake) and the amount of leakage (if any) from the overlying confining layer.

4.1.2 Test Location

The wells monitored for this test are on, or near, a farm located on Jaquette Road 4 mi east of Kalispell (figs. 2, 9). This site is in the central Flathead Valley north of Flathead Lake. The site is surrounded by farmland.

4.1.3 Test Type

The test was a constant-rate pumping test from pumping well 82279 (an existing irrigation well) completed in the deep aquifer. Water levels were monitored in five nearby wells (262323, 262324, 262325, 197798, 143331; fig. 9, table 3; appendix E). The test was started on September 28, 2011 at 13:05 and ended September 30, 2011 at 14:30, for a total pumping period of 49 h 25 min. The pumping rate was monitored throughout the test using a totalizing flow meter, and the time-weighted mean pumping rate was 538 gpm.

4.1.4 Hydrogeologic Setting

The test site is located on unconsolidated Quaternary alluvial sediments of the shallow aquifer (Smith, 2004a,b). At observation well 262323 (JR-OW-I; appendix E), which was drilled for this project, the shallow alluvium (shallow aquifer) was logged as 110 ft of sand. Beneath the sand is a 102-ft-thick layer of

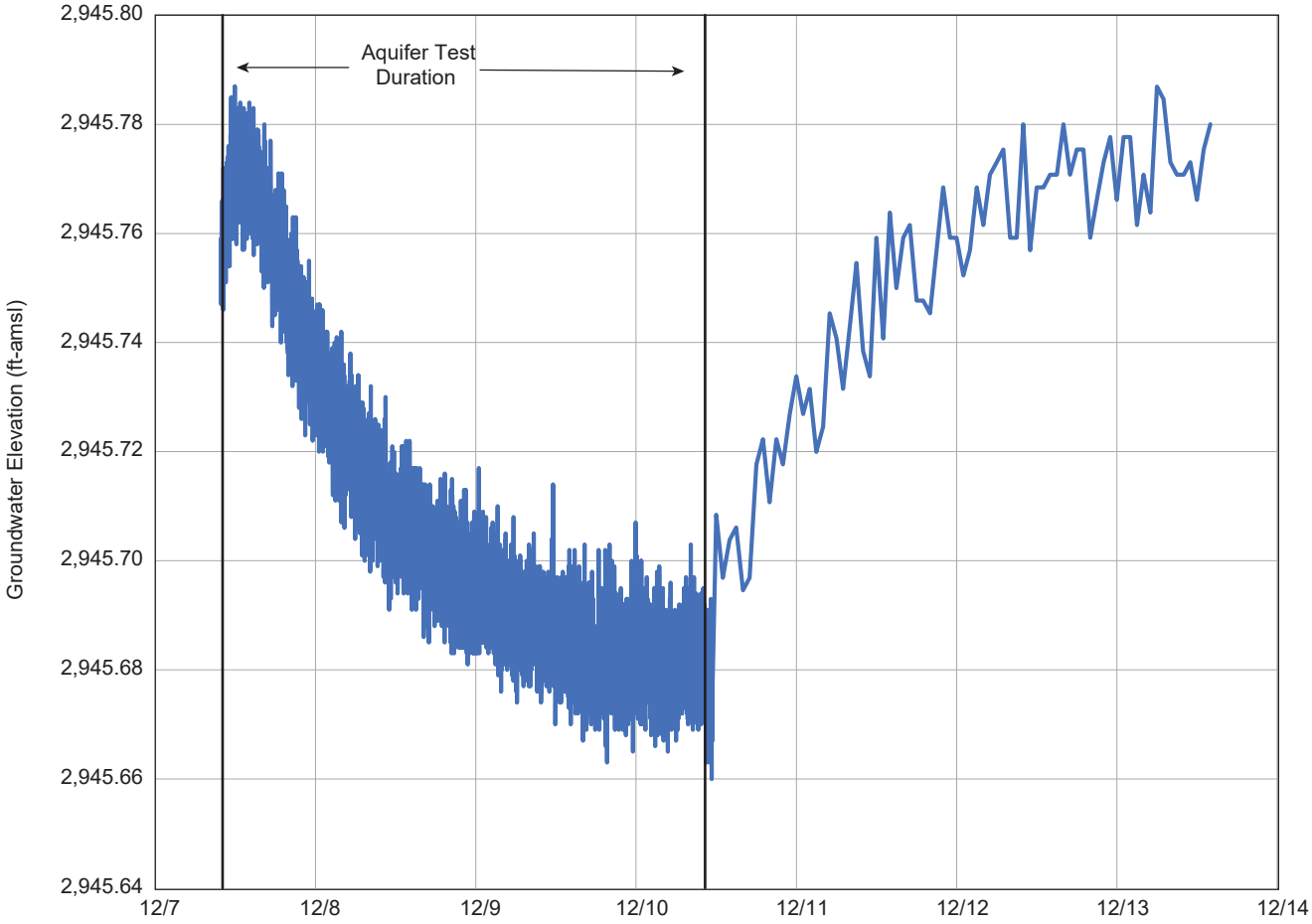

Figure 8. Response in well 304315 due to pumping during the constant-rate test.

lacustrine clay (110 ft to 212 ft). The deep unconsolidated aquifer (deep aquifer) begins at 212 ft and is an unconsolidated coarse gravel with sand. JR-OW-I is open bottom at 217 ft bgs.

The pumping well (JR-PW; 82279) and three observation wells, 262325, 197798, and 143331 (JR-OW-D, JR-DW1, and JR-DW2, respectively) are all completed in the deeper sand and gravel aquifer. JR-PW is screened from 438 to 478 ft bgs and the rest of the deeper observation wells are open bottom at 480, 298, and 200 ft bgs, respectively. The fifth observation well, 262324 (JR-OW-S), was completed in the shallow fine-grained sand aquifer and screened from 56 to 66 ft bgs.

4.1.5 Hydrogeologic Features

The primary hydrogeologic feature in the area is the Flathead River, located 2 mi west and 2 mi south of the test site (fig. 2).

4.2 Field Procedure

The pumping well is an irrigation well that supplies a center-pivot sprinkler system. The school and domestic wells (JR-DW1 and JR-DW2) were frequently pumped during the test, so observations affected by this local pumping were removed from the data prior to analysis.

The pumping rate for most of the test was 540 gpm; however, a decrease to 530 gpm occurred on September 29 at 21:00 that remained through the end of the test (fig. 10). Discharge was through a center-pivot irrigation sprinkler located over ¼ mi to the north.

4.2.1 Data Collection

Pressure transducers were used to record water levels in the wells. The transducers were installed months prior to testing to record antecedent water-level trends. The transducers recorded at 1-h intervals before and after the test and at 1-min intervals during the test. Manual water-level readings were made using

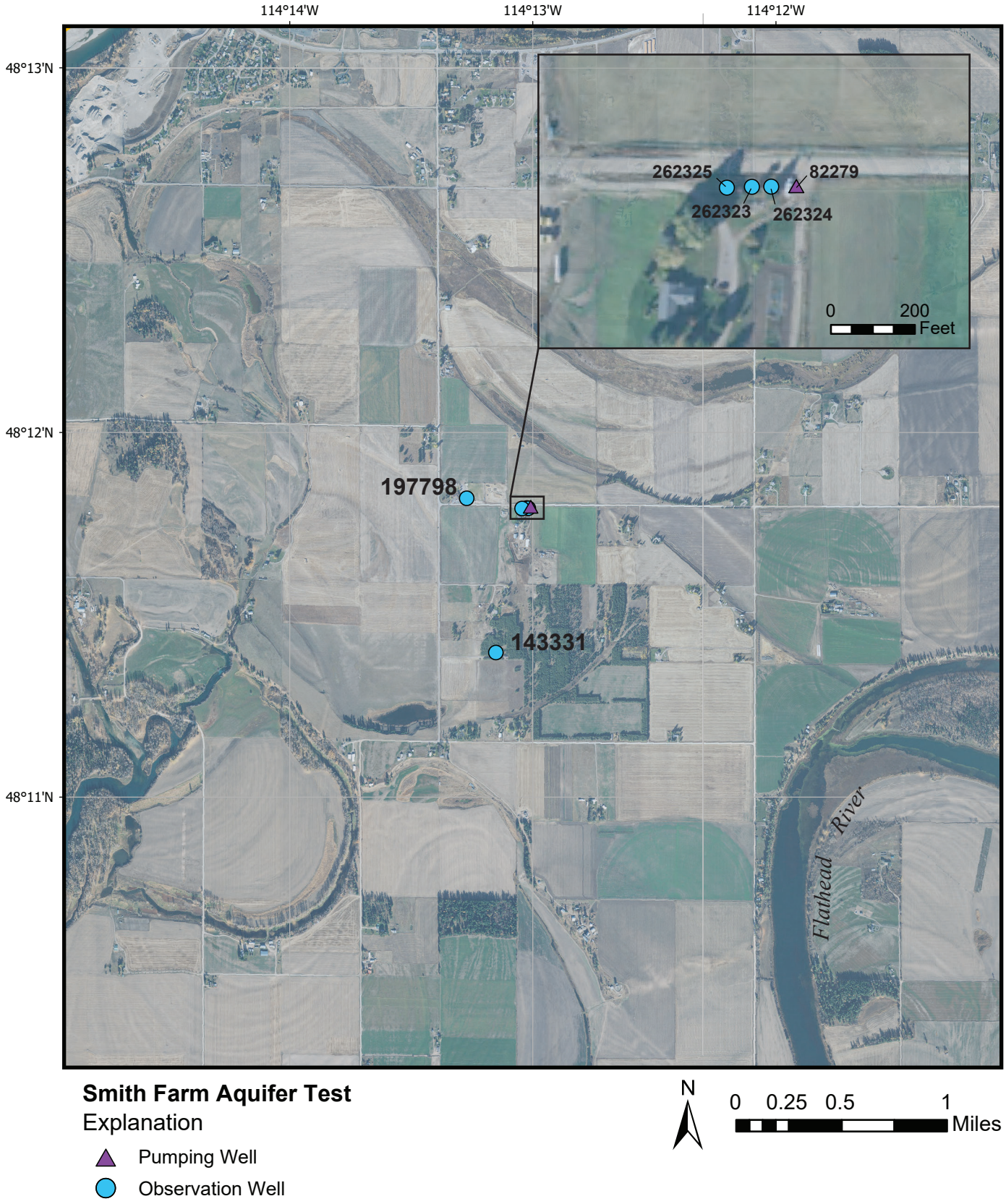

Figure 9. Site layout for the Jaquette Road aquifer test site. One pumping well and five observation wells were used for this test.

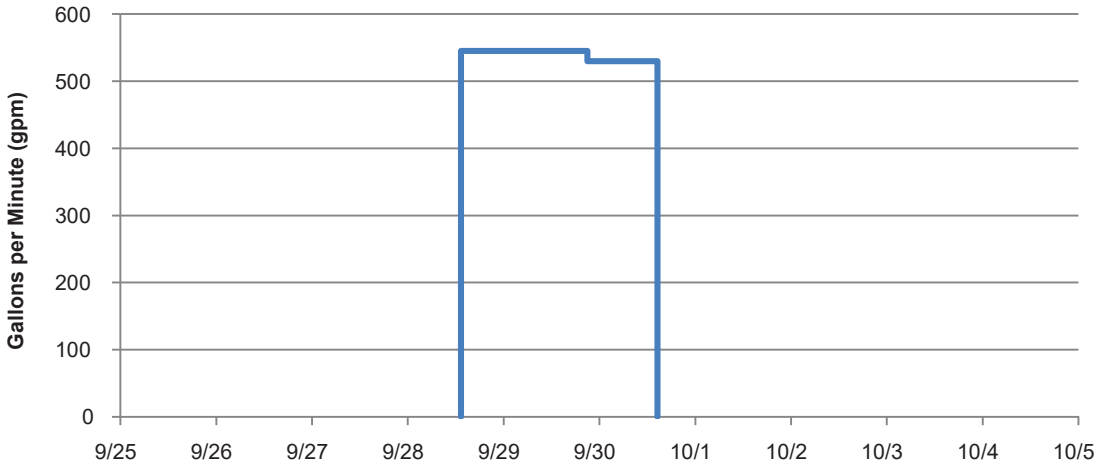

Figure 10. The aquifer test was conducted from 9/28/11 at 13:05 to 9/30/11 at 14:30, for a total pumping time of 49 h 25 min. The well was pumped at 540 gpm early in the test; however, the pumping rate decreased to 530 gpm on 9/29/11 at 21:00. The time-weighted mean pumping rate was 538 gpm.

an e-tape prior to placing transducers, during the test, and prior to transducer retrieval. These manual measurements were used to calibrate transducer response and for backup in case of transducer failure.

4.3 Results

The time-weighted-average flow rate of 538 gpm was used for the analysis.

Transducer water-level data collected before and after the aquifer test show a consistent upward trend. This groundwater-level trend was calculated for water-level hydrographs from each monitored well (approximately 0.09 ft/d). The trend was then removed using a time-weighted adjustment factor to calculate background water levels (figs. 11, 12). Drawdown was then calculated as the difference between observed and calculated background.

4.3.1 Hydrographs

Water levels in the deep aquifer responded to pumping (figs. 11, 12; table 3) while JR-OW-S (the shallow well) did not. JR-OW-D, which was completed at the same depth as the pumping well, had the greatest influence due to pumping and most rapid response. Other wells in the upper portion of the deep aquifer (JR-OW-I, JR-DW1, and JR-DW2) responded to pumping, but showed a smaller and slower response, likely due to horizontal low-permeability zones (vertical anisotropy) within the deep aquifer and distance to the pumping well.

4.3.2 Aquifer Properties

Water-level data from the pumping well and the four observation wells that indicated a response due to pumping (figs. 11, 12) were used to estimate aquifer properties. Water-level drawdown data were analyzed using the Hantush–Jacob step-drawdown method for leaky aquifers (Hantush and Jacob, 1955; Hantush, 1964; appendix F). This method allows for leakage into the aquifer and allows for analysis of the pumping well data by considering well efficiency. The vertical anisotropy observed in the deep aquifer between shallow and deep observation wells (JR-OW-I and JR-OW-D) was accounted for using a vertical anisotropy ratio of 0.025 (40:1). This method provided a good match with observations and indicates that there is noticeable leakage through the confining layer and anisotropy in the deep aquifer. No other boundaries were encountered. The aquifer parameters were estimated to be 17,000 ft^2/d for transmissivity and a storativity of 7.6×10^{-3} (appendix F). The Theis method (1935), which assumes a fully confined aquifer, did not match observations.

The pumping well is open to the aquifer for 40 ft. If 1.5 times the screened interval (Weight, 2008) is used as the thickness of aquifer providing water to the well, a hydraulic conductivity of 121 ft/d is calculated. This value is appropriate for a sandy gravel (Freeze and Cherry, 1979; Heath, 1983).

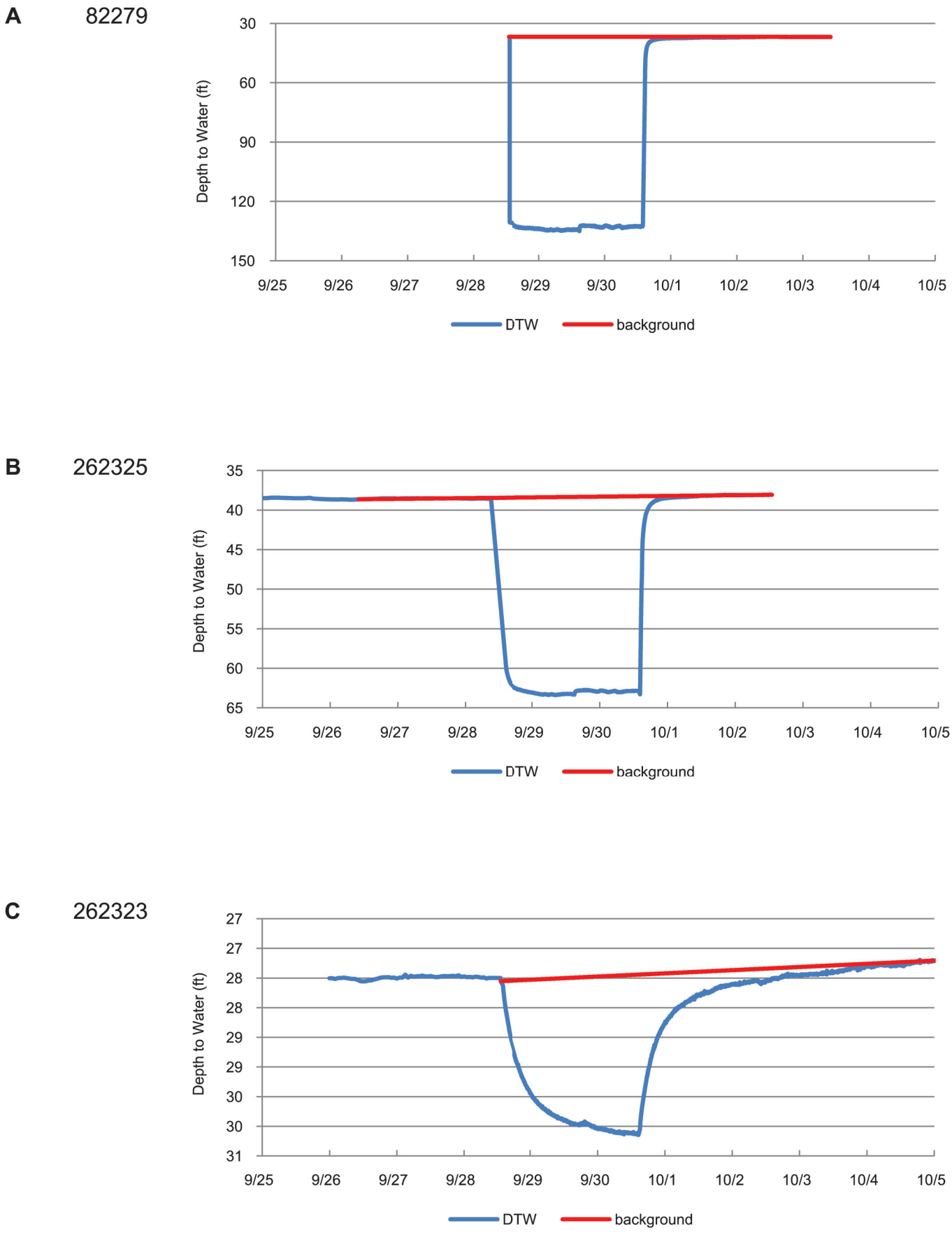

Figure 11. The pumping well 82279 (A) and the observation well completed at approximately the same elevation, 262325 (B), showed rapid drawdown and recovery. The observation well completed in the top of the deep aquifer, 862323 (C; approximately 260 ft above the pumped zone), showed a lower magnitude and slower response.

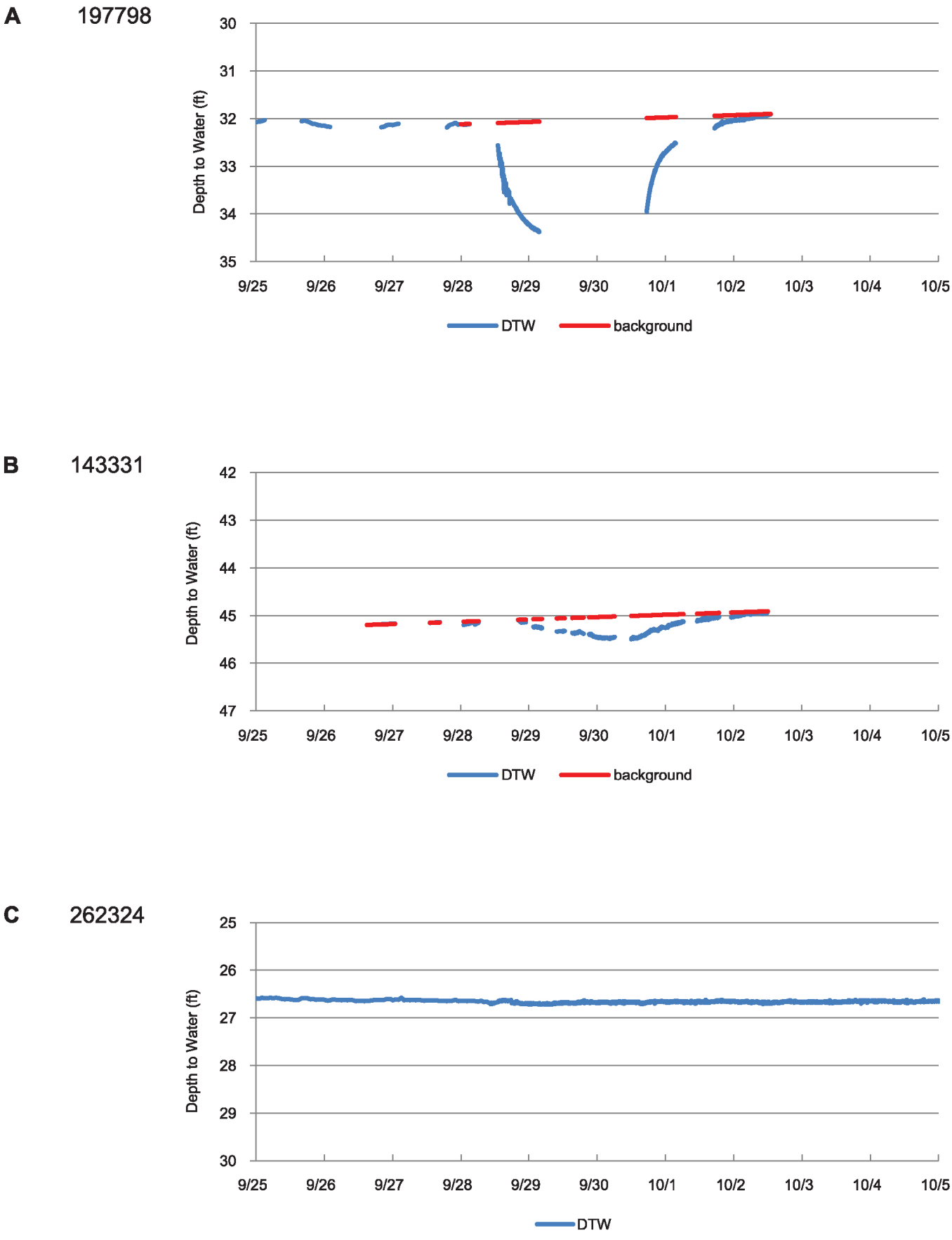

Figure 12. The school well 197798 (A) and domestic well 143331 (B) are completed near the top of the deep aquifer and show a clear response to pumping. The pumping-affected data were removed from these hydrographs, resulting in the gaps. Well 262324 (C), completed in the shallow aquifer, showed no response to the aquifer test.

4.4 Summary

The results of this aquifer test are replicated using the Hantush–Jacob step-drawdown method for leaky aquifers. This method shows that the confining unit is leaky in this area and there is vertical anisotropy in the deep aquifer. The specific capacity for the deep aquifer was 5.64 gpm/ft (538 gpm pumping rate divided by 95.38 ft of drawdown). No boundaries were encountered.

5.0 REFERENCES

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APPENDIX A
FOYS BEND WELL LOGS

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site

Site Name: QUIGLEY, EMMETT AND SUE
GWIC Id: 318263
DNRC Water Right: 30154927

Section 1: Well Owner(s)

1) QUIGLEY, EMMETT AND SUE (MAIL)
120 EGAN ROAD
KALISPELL MT 59901 [10/14/2021]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	26	NW¼ NE¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.167211594444	-114.233312677778	SURVEY	NAD83

Ground Surface Altitude	Ground Surface Method	Datum	Date
2908.01	SURVEY	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2909.51	SURVEY	NAVD88	10/1/2021

Addition: **Block**: **Lot**:

Section 3: Proposed Use of Water

DOMESTIC (1)

Section 4: Type of Work

Drilling Method: ROTARY DR
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Thursday, October 14, 2021

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	400	8
400	640	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	610	6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
610	630	6		.050	SCREEN-CONTINUOUS-STAINLESS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
608	608	K-PACKER	

Section 7: Well Test Data

Total Depth: 640
Static Water Level: 8
Water Temperature:

Air Test *

35 gpm with drill stem set at 628 feet for 3 hours.
Time of recovery 1 hours.
Recovery water level 8 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log
Geologic Source

Unassigned

From	To	Description
0	3	SOIL
3	5	SANDY SILT
5	12	COURSE SAND
12	20	FINE SAND WITH MINOR CLAY
20	20	WATER IN SAND
20	68	SILT AND CLAY
68	73	SILT AND FINE SAND
73	295	SILT AND CLAY
295	295	MORE COMPETENT CLAY
295	314	COHESIVE CLAY AND MINOR SILT
314	320	CORSE SAND AND FINE GRAVEL
320	385	CLAY WITH SOME SILT
385	385	COURSE SAND
385	420	GREY CLAY WITH SILT
420	440	CLAY WITH LITTLE SILT

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MIKE DOWNEY
Company: OKEEFE DRILLING CO
License No: WWD-90
Date Completed: 10/14/2021

MONTANA WELL LOG REPORT

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Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site

Site Name: QUIGLEY, EMMETT AND SUE
GWIC Id: 318266

Section 1: Well Owner(s)

1) QUIGLEY, EMMETT AND SUE (MAIL)
120 EGAN ROAD
KALISPELL MT 59901 [08/19/2021]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	26	NW¼ NE¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.167260472222	-114.233177002778	SURVEY	NAD83

Ground Surface Altitude	Ground Surface Method	Datum	Date
2908.48	SURVEY	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2910.55	SURVEY	NAVD88	10/19/2021

Addition: **Block**: **Lot**:

Section 3: Proposed Use of Water

OTHER (1)

Section 4: Type of Work

Drilling Method: SONIC
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Thursday, August 19, 2021

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	300	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2.5	2.5	6	0.25		WELDED	A53B STEEL
-2	295	2			SPLINE	PVC-SCHED 40

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
295	300	2		.020	FACTORY SLOTTED

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	279	BENTONITE	
279	300	10/20 SAND	

Section 7: Well Test Data

Total Depth: 300
Static Water Level:
Water Temperature:

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log
Geologic Source

Unassigned

From	To	Description
0	1	SOIL
1	8	COBBLES
8	15	SAND, GRAVEL, CLAY
15	55	GRAVEL
55	100	WATER PRODUCING GRAVELS (BEGIN CORING AT 100 FT, UPPER AQUIFER SAND/GRAVEL NOT RECORDED OR RETURNED CUTTINGS)
100	110	SILTY CLAY WITH VERY FINE SAND, LIGHT AND DARK BANDING ON MM TO CM SCALE, VERY SLIGHT VARIATION IN GRAIN SIZE WITH BEDDING
110	115	SILTY CLAY, VERY FAINT LAYERING DISTINGUISHED BY COLOR CHANGES (GREEN, PINK, BROWN, TAN), POTENTIALLY RHYTHMITES
115	120	SILTY CLAY WITHOUT DISTINCT BANDING
120	125	SILTY CLAY WITH LAYERS OF SOUPY WET FINE SAND AND COHESIVE CLAY
125	130	FAINT LAYERING OF LIGHT AND DARK BANDS, DARKER FINE SANDS, TAN CLAY IN LIGHT COLORS, CM TO INCH SCALE BANDS
130	140	CM SCALE BANDING LIGHT/DARK SILTY CLAY
140	155	SEDIMENT LOST - FELL OUT OF CORE SAMPLE
155	160	SILTY CLAY
160	170	MM SCALE LAYERING SILTY CLAY, DISTINCT COLOR CHANGES LIGHT TO DARK, DEEP RHYTHMITES?
170	180	SEDIMENT LOST - FELL OUT OF CORE SAMPLE

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: LARRY PHILLIPS
Company: OKEEFE DRILLING CO
License No: MWC-704
Date Completed: 8/19/2021

MONTANA WELL LOG REPORT

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Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site

Site Name: QUIGLEY, EMMETT AND SUE
GWIC Id: 318265

Section 1: Well Owner(s)

1) QUIGLEY, EMMETT AND SUE (MAIL)
120 EGAN ROAD
KALISPELL MT 59901 [10/18/2021]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	26	NW¼ NE¼

County
FLATHEAD

Geocode

Latitude	Longitude	Geomethod	Datum
48.167241	-114.233235	SUR-GPS	WGS84

Ground Surface Altitude	Ground Surface Method	Datum	Date
2907.98	SURVEY	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2910.04	SURVEY	NAVD88	10/19/2021

Addition **Block** **Lot**

Section 3: Proposed Use of Water

MONITORING (1)

Section 4: Type of Work

Drilling Method: ROTARY DR
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Monday, October 18, 2021

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	50	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	40	2			THREADED	PVC-SCHED 40

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
40	50	2		.020	FACTORY SLOTTED

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	38	BENTONITE	
38	50	10/20 SAND	

Section 7: Well Test Data

Total Depth: 50
Static Water Level:
Water Temperature:

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log
Geologic Source

Unassigned

From	To	Description
0	3	SOIL
3	15	SILT AND SAND
15	50	CLEAN, UNIFORM SAND

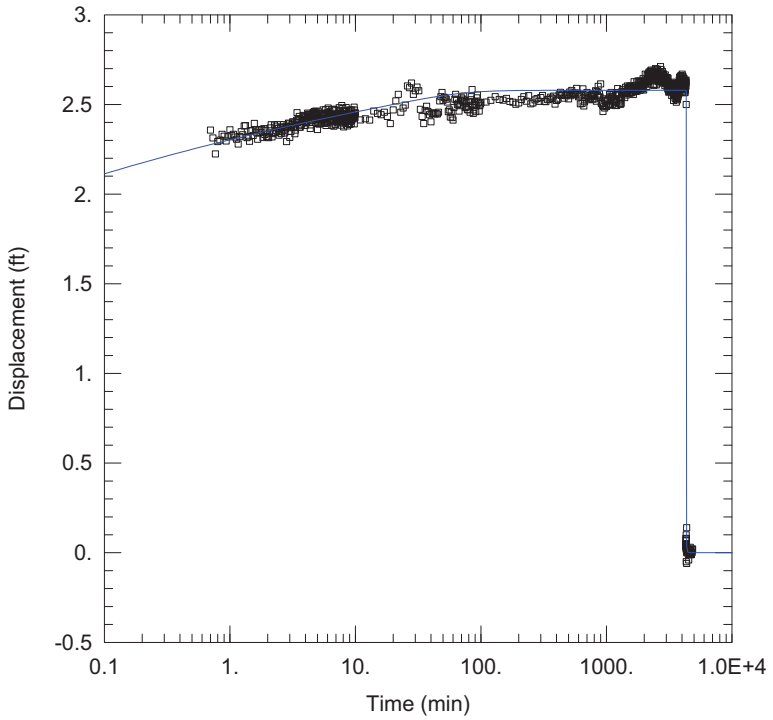
Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MIKE DOWNEY
Company: OKEEFE DRILLING CO
License No: WWD-90
Date Completed: 10/18/2021

APPENDIX B

FOYS BEND CONSTANT-RATE TEST



QUIGLEY CONSTANT RATE TEST

Data Set: M:\...\QuigleyCR_Hantush.aqt
Date: 04/07/22 Time: 08:19:48

PROJECT INFORMATION

Company: MTech
Client: Quigley
Project: BWIPEF
Location: Kalispell, MT
Test Date: 10/26/21

AQUIFER DATA

Saturated Thickness: 800. ft
Aquitard Thickness (b'): 477. ft
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 100. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Quigley Deep	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ Quigley Deep	0	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 7640. ft^2/day
r/B' = 1.0E-5
r/B" = 0.
S = 3.7E-8
ß' = 1.0E-5
ß" = 0.

APPENDIX C

JESSUP MILL POND WELL LOGS

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site

Site Name: OTTEY, MARK
GWIC Id: 318274

Section 1: Well Owner(s)

1) OTTEY, MARK (MAIL)
270 KAUFFMAN LANE
KALISPELL MT 59901 [10/27/2021]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	20W	14	NE¼ NW¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.196807	-114.105685	NAV-GPS	WGS84

Ground Surface Altitude	Ground Surface Method	Datum	Date
2984.66	LIDAR	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2987.16	SURVEY	NAVD88	10/19/2021

Addition: **Block**: **Lot**:

Section 3: Proposed Use of Water

DOMESTIC (1)

Section 4: Type of Work

Drilling Method: ROTARY DR
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Wednesday, October 27, 2021

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	300	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	278	6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
278	298	6		.050	SCREEN-CONTINUOUS-STAINLESS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
276	276	K-PACKER	

Section 7: Well Test Data

Total Depth: 300
Static Water Level: 30
Water Temperature:

Air Test *

35 gpm with drill stem set at 296 feet for 2.5 hours.
Time of recovery 1 hours.
Recovery water level 30 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	1	TOP SOIL
1	8	GRAVELS
8	15	SAND, SILT AND CLAY
15	42	GRAVELS
42	85	SILT
85	150	SAND AND GRAVELS
150	300	GRAVEL

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MIKE DOWNEY
Company: OKEEFE DRILLING CO
License No: WWD-90
Date Completed: 10/27/2021

MONTANA WELL LOG REPORT

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Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site
View scanned well log (10/27/2020 1:37:59 PM)

Site Name: OTTEY, MARK
GWIC Id: 304315

Section 1: Well Owner(s)
1) OTTEY, MARK (MAIL)
270 KAUFFMAN LN.
KALISPELL MT 59901 [08/13/2019]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	20W	14	NE¼ NW¼ NW¼

County
FLATHEAD

Geocode

Latitude	Longitude	Geomethod	Datum
48.196492805556	-114.105899466667	SUR-GPS	NAD83

Ground Surface Altitude	Ground Surface Method	Datum	Date
2969.95	SUR-GPS	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2972.1	SUR-GPS	NAVD88	8/13/2019

Addition **Block** **Lot**

Section 3: Proposed Use of Water
DOMESTIC (1)

Section 4: Type of Work
Drilling Method: DRILLED
Status: NEW WELL

Section 5: Well Completion Date
Date well completed: Monday, November 13, 1972

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	51	5.875

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	51.75	6				STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
51.75	51.75	6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 51
Static Water Level: 25.5
Water Temperature:

Pump Test *

Depth pump set for test _ feet.
18 gpm pump rate with _ feet of drawdown after 4 hours of pumping.
Time of recovery 2 hours.
Recovery water level 24 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log
Geologic Source
110ALVM - ALLUVIUM (QUATERNARY)

From	To	Description
0	6	TOPSOIL
6	26	HARD SAND AND ROCK
26	35	CLAY AND ROCK
35	37	SILT; SOME WATER
37	46	CLAY AND ROCKS
46	51.75	SAND AND GRAVEL

Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name:
Company:
License No: -
Date Completed: 11/13/1972

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site

Site Name: OTTEY , MARK
GWIC Id: 310815

Section 1: Well Owner(s)
1) OTTEY , MARK (MAIL)
270 KAUFFMAN LANE
KALISPELL MT 59901 [10/20/2020]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	20W	14	NW¼ NW¼ NE¼

County	Geocode
FLATHEAD	

Latitude	Longitude	Geomethod	Datum
48.196444486111	-114.105577805556	SUR-GPS	NAD83

Ground Surface Altitude	Ground Surface Method	Datum	Date
2971.28	SUR-GPS	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2973.07	SUR-GPS	NAVD88	12/10/2020

Addition	Block	Lot

Section 3: Proposed Use of Water
DOMESTIC (1)

Section 4: Type of Work
Drilling Method: DUAL ROTARY
Status: NEW WELL

Section 5: Well Completion Date
Date well completed: Tuesday, October 20, 2020

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	280	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	280	6.6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
0	280	6.6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	10	CASING SEAL	

Section 7: Well Test Data

Total Depth: 280
Static Water Level: 18
Water Temperature:

Air Test *

10 gpm with drill stem set at 260 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 18 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks
WELL DRILLED BY PETER CHINIKAYLO AKD

Section 9: Well Log
Geologic Source
112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	1	BLACK TOPSOIL
1	7	REDDISH BROWN SILTY MEDIUM SAND WITH SOME COBBLES AND GRAVEL
7	17	MULTICOLORED (BELT) COBBLES
17	19	MULTICOLORED (BELT) GRAVEL WITH LITTLE REDDISH BROWN SAND
19	29	REDDISH BROWN SILTY SAND WITH LITTLE FINE GRAVEL
29	34	REDDISH BROWN SILTY SAND AND FINE TO MEDIUM MULTICOLORED (BELT) GRAVEL
34	39	MULTICOLORED (BELT) COBBLES
39	43	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND FINE TO MEDIUM GRAVEL
43	44	MULTICOLORED (BELT) COBBLES
44	47	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND FINE TO MEDIUM GRAVEL
47	48	MULTICOLORED (BELT) COBBLES
48	54	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND FINE TO MEDIUM GRAVEL
54	64	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND FINE TO MEDIUM GRAVEL WITH LITTLE BLACK SILT
64	69	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND FINE TO MEDIUM GRAVEL WITH LITTLE BLACK SILT AND SOME COBBLES
69	74	REDDISH BROWN MEDIUM TO COARSE SAND WITH LITTLE FINE MULTICOLORED (BELT) GRAVEL

Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MARTIN WILSON
Company: AK DRILLING INC

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site in State Library Digital Atlas
Plot this site in Google Maps
View hydrograph for this site
View field visits for this site
View water quality for this site

Site Name: OTTEY , MARK
GWIC Id: 310816

Section 1: Well Owner(s)
1) OTTEY , MARK (MAIL)
270 KAUFFMAN LANE
KALISPELL MT 59901 [10/21/2020]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	20W	14	NW¼ NW¼ NE¼

County	Geocode
FLATHEAD	

Latitude	Longitude	Geomethod	Datum
48.196439966667	-114.105584866667	SUR-GPS	NAD83

Ground Surface Altitude	Ground Surface Method	Datum	Date
2970.87	SUR-GPS	NAVD88	10/19/2021

Measuring Point Altitude	MP Method	Datum	Date Applies
2972.99	SUR-GPS	NAVD88	12/10/2020

Addition	Block	Lot

Section 3: Proposed Use of Water
DOMESTIC (1)

Section 4: Type of Work
Drilling Method: DUAL ROTARY
Status: NEW WELL

Section 5: Well Completion Date
Date well completed: Wednesday, October 21, 2020

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	180	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	180	6.6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
0	180	6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	10	CASING SEAL	Y

Section 7: Well Test Data

Total Depth: 180
Static Water Level: 18
Water Temperature:

Air Test *

5 gpm with drill stem set at 180 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 18 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

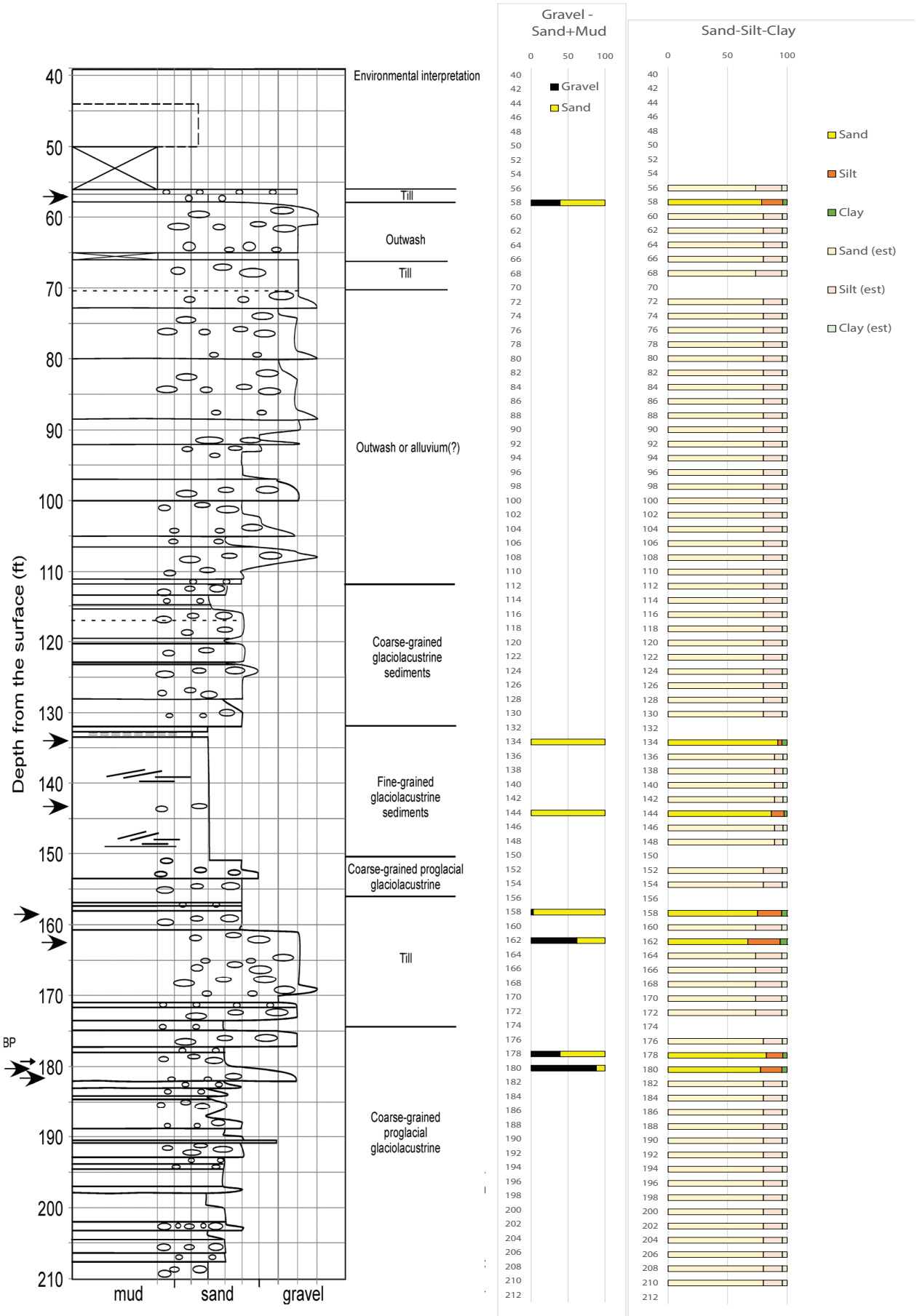
Section 8: Remarks
WELL DRILLED BY PETER CHINIKAYLO AKD

Section 9: Well Log
Geologic Source
112GLCC - GLACIOLACUSTRINE DEPOSITS (PLEISTOCENE)

From	To	Description
0	7	SAND
7	15	COBBLES
15	22	REDDISH BROWN MEDIUM SAND
17	34	SAND AND GRAVEL
22	29	REDDISH BROWN MEDIUM SAND WITH LITTLE MULTICOLORED (BELT) GRAVEL
29	34	REDDISH BROWN MEDIUM SAND AND MULTICOLORED (BELT) FINE GRAVEL
34	39	MULTICOLORED (BELT) MEDIUM TO COARSE GRAVEL WITH FEW COBBLES AND LITTLE REDDISH BROWN SAND
39	65	MULTICOLORED (BELT) MEDIUM TO COARSE SAND AND AND FINE TO MEDIUM GRAVEL WITH SOME COBBLES
65	83	REDDISH BROWN FINE TO MEDIUM SAND WITH LITTLE FINE GRAVEL AND FEW COBBLES
83	84	MEDIUM TO COARSE SAND
84	101	FINE TO COARSE SAND WITH SOME GRAVEL AND FEW COBBLES
101	116	MULTICOLORED (BELT) FINE TO MEDIUM GRAVEL WITH SOME MEDIUM TO COARSE SAND
116	124	MEDIUM TO COARSE SAND WITH SOME FINE MULTICOLORED (BELT) GRAVEL
124	134	MEDIUM TO COARSE SAND WITH LITTLE FINE MULTICOLORED (BELT) GRAVEL
134	178	FINE SAND

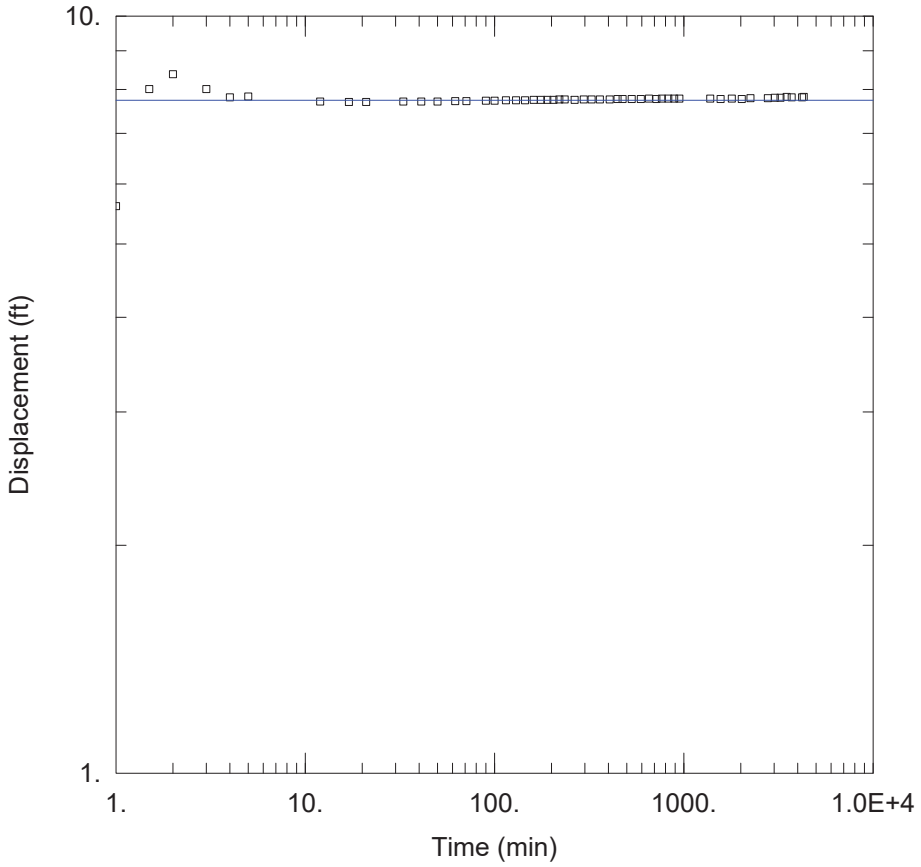
Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MARTIN WILSON
Company: AK DRILLING INC


Depth from the surface (ft)
Environmental interpretation
Till
Outwash
Till
Outwash or alluvium(?)
Coarse-grained glaciolacustrine sediments
Fine-grained glaciolacustrine sediments
Coarse-grained proglacial glaciolacustrine
Till
Coarse-grained proglacial glaciolacustrine
BP
mud
sand
gravel
Gravel - Sand+Mud
Gravel
Sand
Sand-Silt-Clay
Sand
Silt
Clay
Sand (est)
Silt (est)
Clay (est)

APPENDIX D

JESSUP MILL POND CONSTANT-RATE TEST



OTTEY TEST

Data Set: E:\Users\TMyse\Desktop\Ottey\OtteyTest_EastFlathead_PWManuals_hantush.aqt
Date: 06/16/22 Time: 18:18:06

PROJECT INFORMATION

Company: MBMG
Client: East Flathead
Project: BWIPEF
Location: Kalispell, MT
Test Well: 318274
Test Date: 12.7.21

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
318274	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
▫ 318274	0	0

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 7790.9 ft^2/day
r/B = 0.332
b = 220. ft

S = 5.0E-8
Kz/Kr = 0.5689

APPENDIX E

JACQUETTE ROAD WELL LOGS

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View water quality for this site
View scanned well log (7/24/2009 8:32:54 AM)

Site Name: SMITH, KEN
GWIC Id: 82279
DNRC Water Right: 16665

Section 1: Well Owner(s)

1) SMITH, KENNETH W & DANLYNNE K (WELL)
290 JAQUETTE ROAD
KALISPELL MT 59901 [03/23/2015]
2) SMITH, KEN (MAIL)
290 JACQUETTE RD
KALISPELL MT 59901 [03/20/1978]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	13	NW¼ NE¼ NW¼ NE¼

County	Geocode
FLATHEAD	

Latitude	Longitude	Geomethod	Datum
48.196594138888	114.216836033333	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
2948.83	SUR-GPS	NAVD88	1/20/2011

Measuring Point Altitude	Method	Datum	Date Applies
2950.83	SUR-GPS	NAVD88	3/30/2010

Addition	Block	Lot

Section 3: Proposed Use of Water

IRRIGATION (1)

Section 4: Type of Work

Drilling Method: AIR ROTARY
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Monday, March 20, 1978

Section 6: Well Construction Details

There are no borehole dimensions assigned to this well.

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2.8	438.4	10				

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
438	478	10			1/4X2 SLOT SCRN

Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 486
Static Water Level: 37
Water Temperature:

Pump Test *

Depth pump set for test _ feet.
750 gpm pump rate with _ feet of drawdown after 6 hours of pumping.
Time of recovery _ hours.
Recovery water level _ feet.
Pumping water level 180 feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	2	TOPSOIL
2	7	BLACK SANDY SOIL
7	65	TAN SILTY SAND W/FEW GRAVELS- SEEP OF WATER
65	89	GRAY SILTY SAND W/A FEW SMALL GRAVELS
89	117	GRAY SANDY SILT W/A FEW SMALL GRAVELS
117	155	GRAY SILTY CLAY W/SOME SMALL GRAVELS
155	204	TAN SILTY CLAY
204	215	SMALL TAN SILTY GRAVEL- 20 GPM WATER
215	223	LARGE GRAVEL- SOME SAND & SILT- 200 GPM OF WATER
223	239	LARGE TAN SILTY GRAVEL- 150 GPM WATER
239	315	TAN SILTY SAND & GRAVEL - 30 GPM WATER
315	389	LARGE GRAVEL EMBEDDED IN TAN SAND & SILT- 50 GPM WATER.
389	410	LARGE SANDY & SILTY GRAVELS- 200 GPM WATER.
410	453	COARSE TAN SAND & GRAVEL- OVER 200 GPM OF WATER.
453	479	LARGE TAN GRAVEL & COARSE SAND- OVER 400 GPM H2O

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name:
Company: LIBERTY DRILLING & PUMP CO
License No: WWC-52
Date Completed: 3/20/1978

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View water quality for this site
View scanned update/correction (10/5/2011 2:40:25 PM)

Site Name: SMITH, KEN * MBMG_KS_1_INTERMEDIATE
GWIC Id: 262323

Section 1: Well Owner(s)
1) SMITH, KEN (WELL)
JAQUETTE RD
BIGFORK MT 59911 [04/22/2011]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	13	NW¼ NW¼ NE¼ NW¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.196536469444	114.216977347222	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
2949.06	SUR-GPS	NAVD88	6/21/2011

Measuring Point Altitude	Method	Datum	Date Applies
2948.73	SURVEY	NAVD88	6/14/2011 12:15:00 PM

Addition: **Block**: **Lot**:

Section 3: Proposed Use of Water
MONITORING (1)

Section 4: Type of Work
Drilling Method:
Status: NEW WELL

Section 5: Well Completion Date
Date well completed: Wednesday, April 20, 2011

Section 6: Well Construction Details
There are no borehole dimensions assigned to this well.

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	217	6				CASING (TYPE UNKNOWN)

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
217	217	6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 217
Static Water Level: 25.44
Water Temperature:

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks
LITHOLOGY CHANGED BY MBMG HYDROGEOLOGIST

Section 9: Well Log
Geologic Source
Unassigned

From	To	Description
0	1	TOPSOIL, DARK BROWN SILTY LOAM, RICH
1	7	CLAY TO TAN BROWN? SMOOTH, DAMP
7	40	SAND, TAN(RED, GREEN, TAN, CLEAN, BELT) FINE-GRAINED VERY WELL SORTED, VERY WELL ROUNDED. LOOKS LIKE PRESENT NORTH SHORE BEACH. FIRST WATER AT 29'
40	52	SAND, AS ABOVE. AT 40' SAND HEAVING, WATER AT ABOUT 1-2 GPM.
52	75	SAND, GREY, FINE TO MEDIUM GRAINED; SAME AS ABOVE BUT NOT WEATHERED. SHARP CONTACT ABOVE. MAKING WATER.
75	110	SAND AS ABOVE WITH SILT, FINING DOWNWARD. MAKING WATER, BY 80' DRILLER THOUGHT 20 GPM WELL WAS POSSIBLE.
110	140	CLAY, TAN-GREY, SLIGHTLY SILTY, VERY SOFT.
140	160	BROWN CLAY, DRILLING EASY, FEW RETURN CUTTINGS. HEAVY CLAY, LIGHT BROWN. VERY SMOOTH BROWN, GREY CLAY WITH PLASTIC CLAY BALLS, CREAMY-SMOOTH, NO SILTY FEEL. MAKING WATER
160	185	TAN/LT BROWN CLAY SMOOTH TEXTURE, PLASTIC CLAY BALLS. CASING DROPPING IN HOLE, NEED TO WELD EAR TABS ON TO HOLD AT SURFACE.
185	195	LT BROWN/TAN CLAY, FEW RETURN CUTTINGS.
195	200	FEW SMALL GRAVELS IN CLAY, AT 200' IN HEAVY CLAY, GRAVEL HEAVED IN.
200	212	CLAY, TAN, SOFT. HEAVED GRAVEL, NO WATER. SANDY-GRAVEL. GRAVELS ARE RED, GREEN, TAN, GREY, VERY POORLY SORTED. UP TO 1 CM CLASTS, MOD ROUND TO SUBANGULAR.
212	217	GRAVEL, SANDY WITH CLAY, VERY POOR SORTING, CLASTS UP TO 2 CM. NO
217	219	GRAVEL, FG, CLEAN WITH MINOR FINE AND MEDIUM SAND. NO CLAY, LOTS OF

Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: JIM CHAMBERS
Company:
License No: -
Date Completed: 4/20/2011

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View water quality for this site
View scanned update/correction (10/5/2011 2:41:51 PM)

Site Name: SMITH, KEN * MBMG_KS_2 SHALLOW MONITORING
GWIC Id: 262324

Section 1: Well Owner(s)

1) SMITH, KEN (WELL)
JAQUETTE RD
BIGFORK MT 59911 [04/27/2011]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	13	NW¼ NW¼ NE¼ NW¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.196553097222	114.216915619444	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
2948.84	SUR-GPS	NAVD88	6/21/2011

Measuring Point Altitude	Method	Datum	Date Applies
2948.46	SUR-GPS	NAVD88	6/14/2011 12:10:00 PM

Addition: **Block:** **Lot:**

Section 3: Proposed Use of Water

MONITORING (1)

Section 4: Type of Work

Drilling Method:
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Thursday, April 21, 2011

Section 6: Well Construction Details

There are no borehole dimensions assigned to this well.

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	0	6				STEEL
20	66	4				PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
56	66	4			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 66
Static Water Level: 29.68
Water Temperature:

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

LITHOLOGY CHANGED BY MBMG HYDROGEOLOGIST

Section 9: Well Log

Geologic Source

Unassigned

From	To	Description
0	2	CLAY. VERY SANDY-CLAY, LT BROWN, SEMI-PLASTIC CLAY FORMS BALLS IN HAND, FG SAND.
2	35	SAND. MEDIUM TO MEDIUM FINE GRAINED SAND, DAMP TO DRY, IT BROWN. SAND IS WELL SORTED AND LOOSE. WEAKLY COMPACTS IN HANDS.
35	37	SAND. MEDIUM BROWN TO GREY SAND, DAMP PACKS LOOSELY
37	40	SATURATED SAND, SILT MUD. PLUGGING IN CASING AND HEAVING; WATER AT 37'
40	47	SATURATED SAND. GREY TO LT BROWN, MG-MFG SAND. SAND GRAINS ARE GREY, BROWN AND RED WITH BLACK FLECKS OF WOODY, ORGANIC MATERIAL.
47	52	CLAY. STIFF, VERY LT BROWN TO TAN, VERY PLASTIC AND MODERATELY DENSE.
52	53	CLAY? HARD LAYER, USED HAMMER
53	55	SAND. DAMP, BROWN, MG-MFG, WELL SORTED WITH A TRACE OF FINE-GRAINED, SUBROUNDED
55	65	SATURATED SAND. GREY TO LT BROWN, WITH BLACK ORGANIC FRAGMENTS.
65	70	SANDY-CLAY. GREY TO LT BROWN/GREY, MOLDABLE CLAY. LOST WATER; NO WATER
70	77	CLAY. SMOOTH GREY TO LT BROWN, NO GRIT CLAY. CAKE-BATTER CONSISTENCY.

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: JIM CHAMBERS
Company: CHAMBERS DRILLING COMPANY
License No: -
Date Completed: 4/21/2011

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View scanned update/correction (10/5/2011 2:44:44 PM)

Site Name: SMITH, KEN * MBMG_KS_3 DEEP MONITORING WELL
GWIC Id: 262325

Section 1: Well Owner(s)
1) SMITH, KENNETH W & DANLYNNE K (MAIL)
290 JAQUETTE RD
KALISPELL MT 59901 [04/03/2015]
2) SMITH, KEN (WELL)
JAQUETTE RD
BIGFORK MT 59911 [05/23/2011]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	13	NW¼ NW¼ NE¼ NW¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.196591413888	114.217362041667	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
2950.54	SUR-GPS	NAVD88	6/21/2011

Measuring Point Altitude	Method	Datum	Date Applies
2952.02	SUR-GPS	NAVD88	6/14/2011 12:20:00 PM

Addition **Block** **Lot**

Section 3: Proposed Use of Water
MONITORING (1)

Section 4: Type of Work
Drilling Method:
Status: NEW WELL

Section 5: Well Completion Date
Date well completed: Saturday, May 21, 2011

Section 6: Well Construction Details
There are no borehole dimensions assigned to this well.
Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2.25	480	6				CASING (TYPE UNKNOWN)

There are no completion records assigned to this well.
Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 480
Static Water Level: 37.81
Water Temperature:

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks
LITHOLOGY CHANGED BY MBMG HYDROGEOLOGIST

Section 9: Well Log
Geologic Source
Unassigned

From	To	Description
0	40	SAND. LT BROWN, MEDIUM-GRAINED TO MEDIUM-FINE-GRAINED, SLIGHTLY DAMP, LOOSELY PACKS IN HAND. SMALL DIAMETER TWIGS, VERY LITTLE DECAY.
40	50	WET SAND. LT BROWN TO GRAY.
50	51	CLAY. GRAY, PLASTIC, SANDY-CLAY. VERY THIN LAYER
51	54	SATURATED SAND WITH CLAY. SAND WITH CLAY, BORDERLINE FOR SAND AND CLAY AND CLAY AND SAND
54	65	SANDY CLAY. GRAY, TACKY. HOLD WATER IN CUTTINGS. CUTTINGS DO NOT FLOW BUT FORM SLOPE ON LAND SURFACE
65	87	CLAY WITH SAND. SATURATED, FLUID, SMOOTH, GRAY CLAY WITH FG SAND GRIT. MORE WATER THAN ABOVE, FLOW EASILY; FAST DRILLING, EASY ADVANCE, NO HAMMER NEEDED
87	95	CLAY. GRAY, SMOOTH FLUID, NO SAND OR GRIT.
95	96	PLASTIC CLAY. THIN, DENSE, GRAY, PLASTIC CLAY INTERVAL.
96	127	CLAY. LT BROWN-GRAY, FLUID, WITH SOME FG SANDY GRIT AND WITH SOME DENSE, PLASTIC CLAY INTERVALS
127	137	CLAY WITH FG SILTY GRIT. FEW RETURN CUTTINGS, MORE DENSE, SLOWER DRILLING.
137	150	CLAY. LT BROWN WITH TAN STREAKS, MORE FLUID THAN ABOVE, HARDER TO LIFT CUTTINGS.
150	155	CLAY. FLUID, SMOOTH-CREAMY TEXTURE, LT BROWN-TAN WITH PLASTIC CLAY BALLS, CLAY GETS THICKER TO BOTTOM OF INTERVAL. CLAY DOES NOT FLOW IN CUTTINGS AT END OF INTERVAL, THICKER, LESS FLUID, FEW RETURN CUTTINGS.
155	157	CLAY. TAN-YELLOW, GEL-LIKE, THICK CLAY
157	174	CLAY. YELLOW-TAN, SMOOTH, NO GRIT IN CLAY. WITH NUMEROUS TAN, DENSE, PLASTIC CLAY FRAGMENTS/BALLS. THICK CLAY DOES NOT FLOW IN CUTTINGS.
174	177	CLAY. SMOOTH, YELLOW-TAN, MORE FLUID, NO PLASTIC CLAY

Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: JIM CHAMBERS
Company: CHAMBERS DRILLING COMPANY
License No: -
Date Completed: 5/21/2011

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View scanned well log (7/24/2009 8:27:33 AM)

Site Name: FAIR MONT EGAN SCHOOL 3
GWIC Id: 197798

Section 1: Well Owner(s)

1) FAIR MONT EGAN SCHOOL 3 (MAIL)
797 FAIRMONT ROAD
KALISPELL MT 59901 [08/19/2002]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	12	SW¼ SW¼ SW¼

County: FLATHEAD
Geocode:

Latitude	Longitude	Geomethod	Datum
48.196995	114.221201	NAV-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
2940	MAP	NAVD88	7/8/2011

Addition: **Block**: **Lot**:

Section 3: Proposed Use of Water

PUBLIC WATER SUPPLY (1)

Section 4: Type of Work

Drilling Method: ROTARY
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Monday, August 19, 2002

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	300	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-1.5	298	6	0.250			STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
298	300	6			OPEN HOLE

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	0	BENTONITE	

Section 7: Well Test Data

Total Depth: 298
Static Water Level: 38
Water Temperature:

Air Test *

60 gpm with drill stem set at 280 feet for 3 hours.
Time of recovery 0.5 hours.
Recovery water level 38 feet.
Pumping water level _ feet.

** During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	4	MEDIUM GRAVEL SAND
4	20	SAND SILT
20	106	SILTY CLAY
106	144	GRAVEL CLAY
144	160	CEMENTED GRAVEL
160	260	MEDIUM GRAVEL SAND
260	300	LARGE GRAVEL SAND WATER

Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: MARVIN SUDAN
Company: SUDAN DRILLING
License No: WWC-450
Date Completed: 8/19/2002

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is compiled electronically from the contents of the Ground Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Return to menu
Plot this site on a topographic map
View hydrograph for this site
View field visits for this site
View scanned well log (7/24/2009 8:33:22 AM)

Site Name: ARLINT, BILL & LINDA
GWIC Id: 143331

Section 1: Well Owner(s)

1) ARLINT, BILL AND LINDA (WELL)
875 FAIRMONT RD
KALISPELL MT 59901 [05/02/1994]

Section 2: Location

Township	Range	Section	Quarter Sections
28N	21W	13	SW¼ NE¼ SW¼ NW¼

County	Geocode
FLATHEAD	

Latitude	Longitude	Geomethod	Datum
48.1899444	114.2192028	MAP	NAD83

Ground Surface Altitude	Method	Datum	Date
2950	MAP	NAVD88	7/8/2011

Measuring Point Altitude	Method	Datum	Date Applies
2951.5	MAP	NAVD88	7/8/2011 5:40:00 PM

Addition	Block	Lot

Section 3: Proposed Use of Water

DOMESTIC (1)

Section 4: Type of Work

Drilling Method: ROTARY
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Monday, May 02, 1994

Section 6: Well Construction Details

There are no borehole dimensions assigned to this well.

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-1.5	198	6				STEEL

There are no completion records assigned to this well.

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	18	BENTONITE	

Section 7: Well Test Data

Total Depth: 200
Static Water Level: 46
Water Temperature:

Air Test *

25 gpm with drill stem set at _ feet for 2 hours.
Time of recovery _ hours.
Recovery water level _ feet.
Pumping water level 120 feet.

* *During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log

Geologic Source

112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	2	TOPSOIL
2	50	SANDY LOAM
50	103	CLAY
103	162	GRAVEL CLAY
162	194	SAND GRAVEL WATER
194	200	GRAVEL WATER

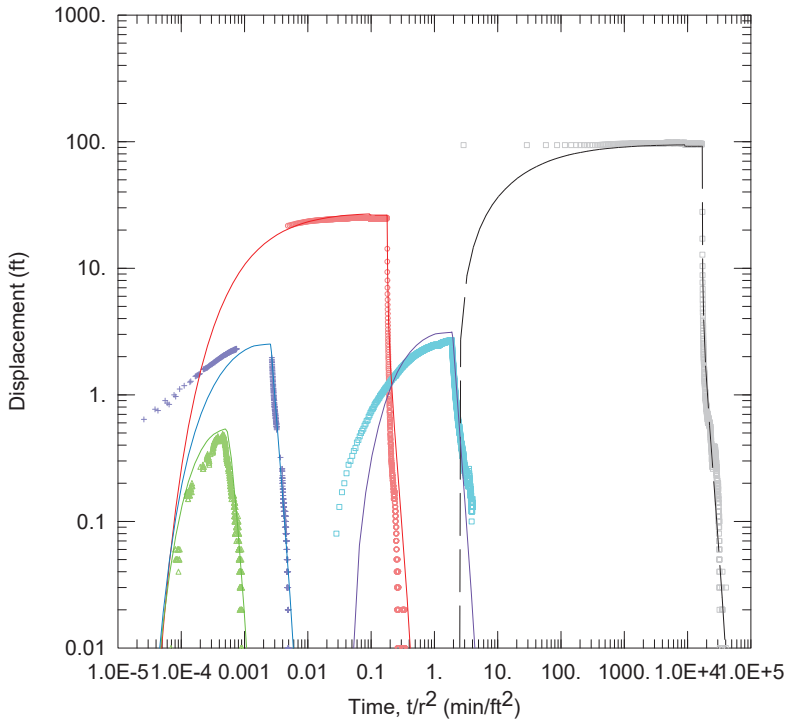
Driller Certification

All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: KELVIN STINGER
Company: STINGER DRILLING
License No: WWC-325
Date Completed: 5/2/1994

APPENDIX F

JACQUETTE ROAD CONSTANT-RATE TEST



KEN SMITH AQUIFER TEST

Data Set: M:\...\Smith_Theis_varied rate_5wells_3.aqt
Date: 06/02/15 Time: 09:16:37

PROJECT INFORMATION

Company: MBMG
Client: BWIPKL
Project: Flathead
Location: Ken Smith
Test Well: KS
Test Date: 9/28/11

AQUIFER DATA

Saturated Thickness: 2483.6 ft
Aquitard Thickness (b'): 300. ft
Anisotropy Ratio (Kz/Kr): 0.03
Aquitard Thickness (b"): 1. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
KS	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
KS	0	0
KS3	-128	7
Arlint	-723	-2387
School	-1060	199
KS1	-35	-19

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 1.7E+4 ft^2/day
1/B = 0.00074 ft^{-1}
C = 0. min^2/ft^5

S = 0.0076
Sw = -4.2
P = 2.

Step Test Model: Jacob-Rorabaugh
Time (t) = 1. min Rate (Q) in cu. ft/min

$s(t) = 0.3174Q + 0.Q^{2.}$
W.E. = 117.8% (Q from last step)