AQUIFER TESTS IN THE UPPER JEFFERSON VALLEY

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Montana Bureau of Mines and Geology

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1 INTRODUCTION

The Upper Jefferson Groundwater Investigation was conducted to evaluate how changes in irrigation management activities and increased residential development may affect water availability in the Upper Jefferson Valley. Five aquifer tests were conducted during this investigation. These tests were conducted in the Upper Jefferson Valley, southwestern Montana, between Silver Star and Cardwell (fig. 1-1). These tests were conducted to provide site-specific aquifer property estimates (e.g., transmissivity and storativity) of the tested aquifers, and to evaluate potential boundary effects. These results were then used in developing groundwater budgets for the model areas

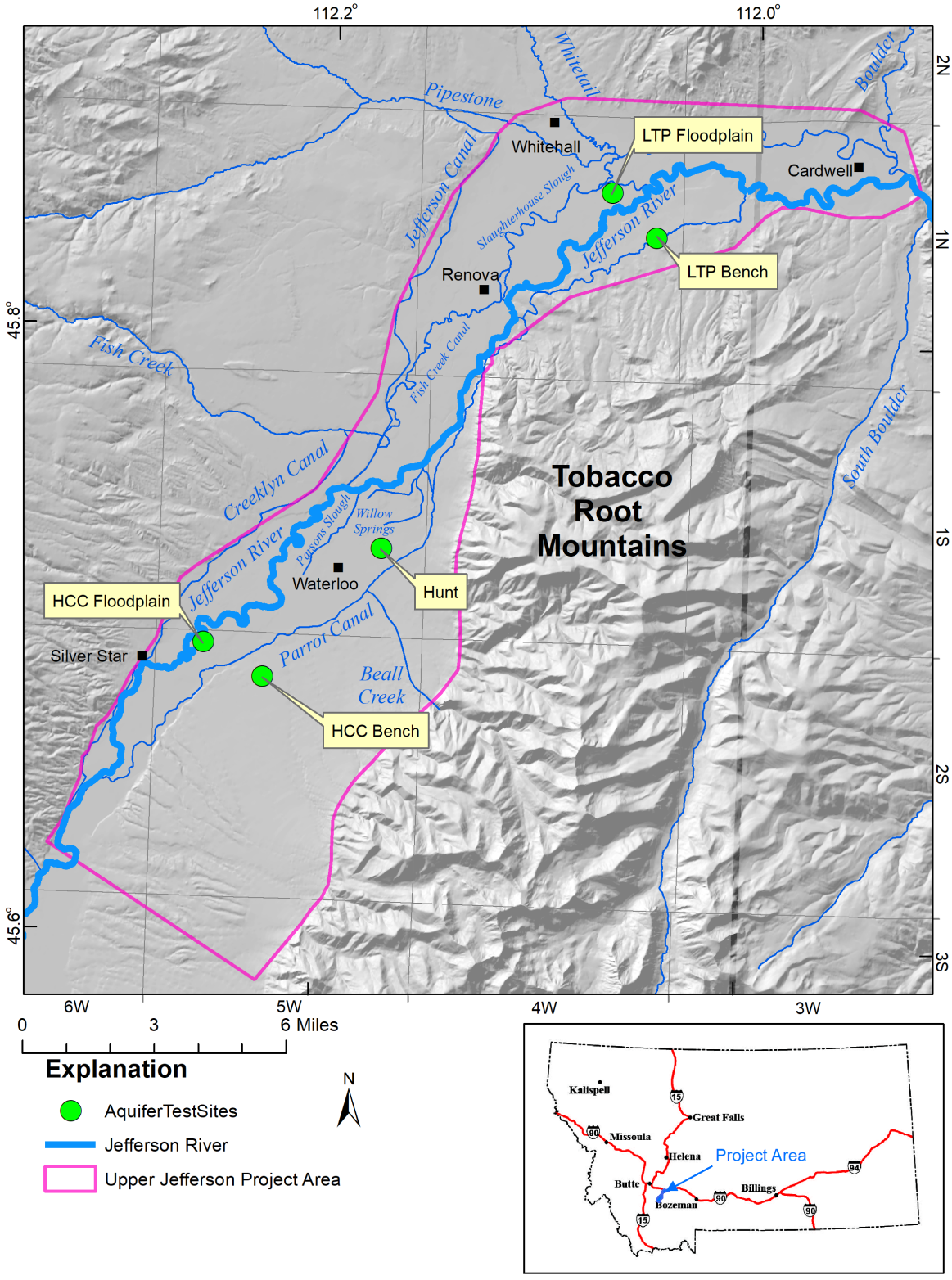

Figure 1-1. Five aquifer tests were conducted for the Upper Jefferson Groundwater Investigation. Four of these tests were in the Tertiary Renova Formation, and one (Hunt) was in the Quaternary alluvium.

near Waterloo and Whitehall, and the values were used to evaluate the reasonableness of aquifer properties used in the calibrated groundwater models (Gebril and Bobst, in preparation, a and b). The results were also used in interpreting the overall hydrologic conditions within the Upper Jefferson Valley (Bobst and Gebril, in preparation).

The Upper Jefferson Valley is an intermontane basin, with the Highland Mountains to the west, and the Tobacco Root Mountains to the east. The valley is filled with sediment transported from both sides and from the overall Jefferson River drainage area to the south. Tertiary and Quaternary pediment gravels occur at the bases of the mountains. Quaternary alluvium underlies the modern floodplain, and is underlain by the relatively fine-grained Tertiary Renova Formation (Vuke and others, 2004). The Renova Formation is characterized by fine-grained strata (>70% fine sand and finer; Kuenzi and Fields, 1971; Vuke, 2004), with channels of immature sandstone (Vuke, 2004). Estimates of the thickness of unconsolidated Tertiary and Quaternary basin-fill material over bedrock in the valley bottom range from about 2,000 to 10,000 ft (Vuke and others, 2004). Four aquifer tests were conducted in the Renova Formation, and one was in the alluvium (table 1-1). The data collected during each test can be accessed from GWIC (http://mbmggwic.mtech.edu/) by using the GWIC ID numbers for the pumping wells.

The local nature of the aquifer and boundaries at each site were evaluated based on drawdown observations and evaluation of derivative plots (Renard and others, 2009). The two tests of the Renova Formation in the floodplain (HCC Floodplain and LTP Floodplain; fig. 1-1) showed a leaky-confined response. This shows that the tested aquifers were hydrologically connected with shallower zones, but that there was some degree of confinement. One of the tests from the Renova Formation on the bench (HCC Bench) showed an unconfined response, and the other Renova Formation bench test (LTP Bench) showed a confined response. The Hunt aquifer test in the Quaternary alluvium showed an unconfined response and the influence of a nearby recharge boundary. Aquifer test solutions for each test were selected based on the hydrogeologic setting and derivative plots, taking into account the degree to which the assumptions inherent in each solution were violated (Fetter, 1994). Sediment types in the completion zones ranged from silty sand to gravel. The results from the aquifer tests reflect these differences in sediment types, with the lowest permeability and storativity occurring in the finest sediments and the highest values occurring in the coarsest grained.

2 HCC FLOODPLAIN TESTS

2.1 Background

2.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Tertiary Renova Formation. The test was also conducted to evaluate interconnections among the Renova Formation, the overlying surficial Quaternary alluvium, and the nearby Jefferson River. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

2.1.2 Test Location

Four wells were installed in the Jefferson River floodplain (T. 2 S., R. 5 W., sec. 5; figs. 2-1 and 2-2, table 2-1; appendix 2A) 1.5 mi northeast of Silver Star. The site is located within a flood-irrigated hay field, and is 0.8 mi from the nearest residence. The Jefferson River is 0.3 mi northwest of the site.

Table 1-1. Aquifer test results.

Test Name	Pumping Well GWIC ID	Aquifer	Transmissivity (T; ft^2/d)	Storativity (S; unitless)	Solution Type
HCC Floodplain	277403	Renova	74–77	1.5×10^{-7} to 1.6×10^{-5}	Leaky-confined
HCC Bench	280980	Renova	255	0.20	Unconfined
Hunt	279259	Alluvium	41,000–44,500	0.14	Unconfined
LTP Floodplain	279262	Renova	310– 440	8×10^{-4} to 2×10^{-3}	Leaky-confined
LTP Bench	280978	Renova	5,800	5.2×10^{-5}	Confined

2.1.3 Test Type

A step-test, a 10-h aquifer test (truncated due to equipment failure), and a 72-h aquifer test were performed. The step-test was performed on 2/4/2015, the 10-h test was conducted on 2/9/2015, and the 72-h test ran from 2/10/2015 to 2/13/2015. Water-level recovery was monitored until 2/18/2015. During the 10-h test the time-weighted average pumping rate was 15.7 gpm, and during the 72-h test the time-weighted average pumping rate was 13.6 gpm. Drawdown and recovery were monitored in the pumping well and in three observation wells.

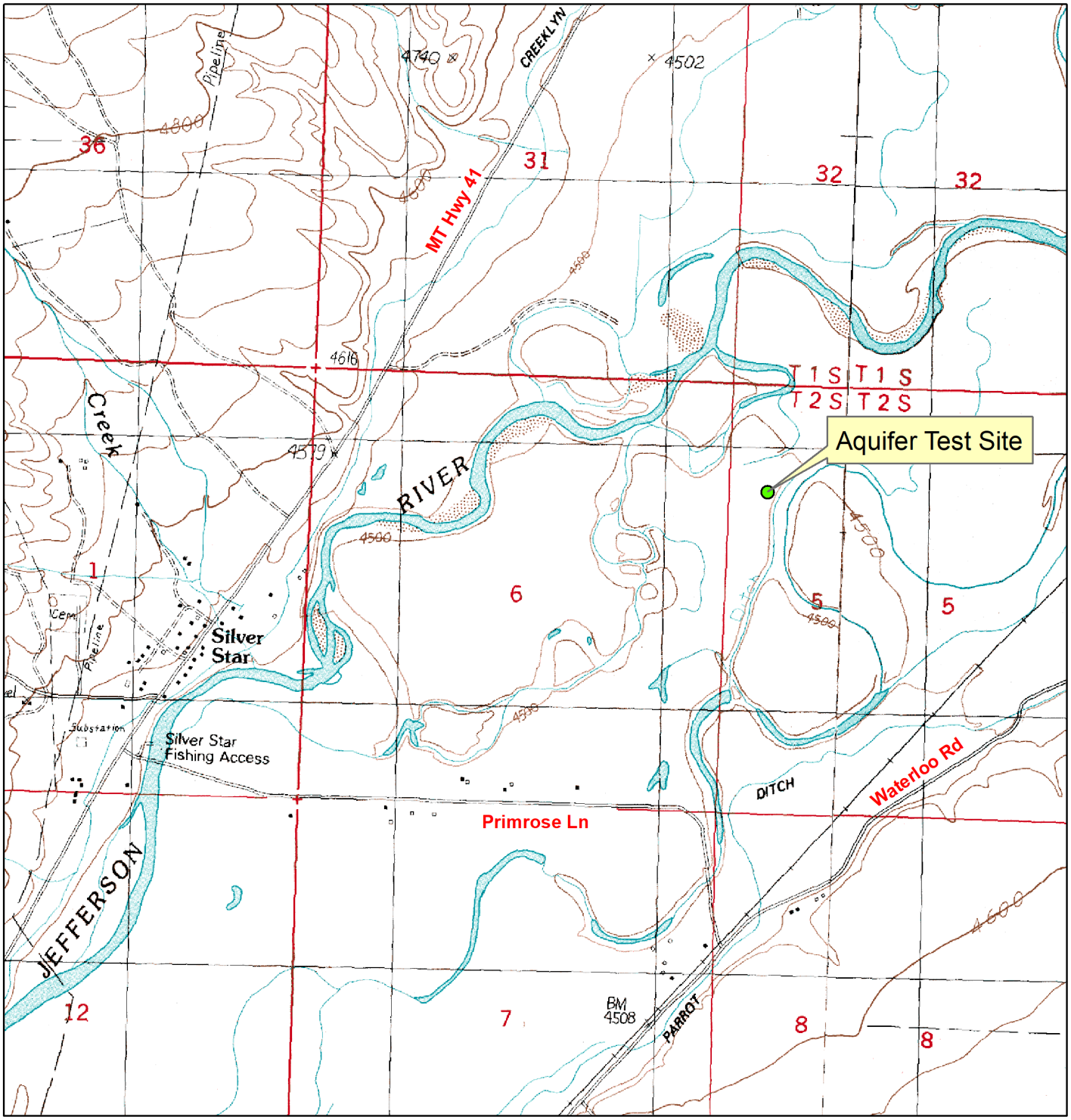

Figure 2-1. The HCC Floodplain aquifer test site is located in the Jefferson River floodplain approximately 1.5 mi north-east of the town of Silver Star, Montana.

Figure 2-2. The HCC Floodplain aquifer test site had a pumping well completed in the Renova Formation (OW1), two observation wells in the Renova Formation (OW2 and PW), and one observation well in the overlying alluvium (OW3). Water was discharged approximately 300 ft northwest of the pumping well.

2.1.4 Hydrogeologic Setting

The stratigraphy is topsoil and silt from 0 to 5 ft, gravel with some silt from 5 to 30 ft, silty clay from 30 to 75 ft, and fine to medium silty sand from 75 to 100 ft. The upper 30 ft is Quaternary alluvium, while the deeper silty clay and silty sand are the Renova Formation (appendix 2A; Vuke and others, 2004).

During longer-term monitoring, from February 2014 to May 2015, groundwater levels fluctuated from about 1.5 to 5.5 ft below ground surface (bgs). The timing of groundwater fluctuations was similar to that of the Jefferson River stage. Groundwater elevation was typically higher in the alluvium than in the Renova Formation; however, this reverses in the late summer when the river stage is low (fig. 2-3).

Table 2-1. Well designations, locations, and completion information, HCC Floodplain Aquifer test site.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from OW1 (ft)	Maximum Drawdown (ft)	Aquifer	Type of Well
277403	OW1	45.695992	-112.254563	4497.2	94	4403–4423	—	43.0	Renova	Pumping
277404	OW2	45.696123	-112.254643	4497.1	103	4394–4416	51.9	5.7	Renova	Observation
277405	PW	45.696076	-112.254497	4497.3	100	4397–4418	34.9	10.6	Renova	Observation
277406	OW3	45.696028	-112.254535	4497.3	30	4467–4478	14.7	0.0	Alluvium	Shallow Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.

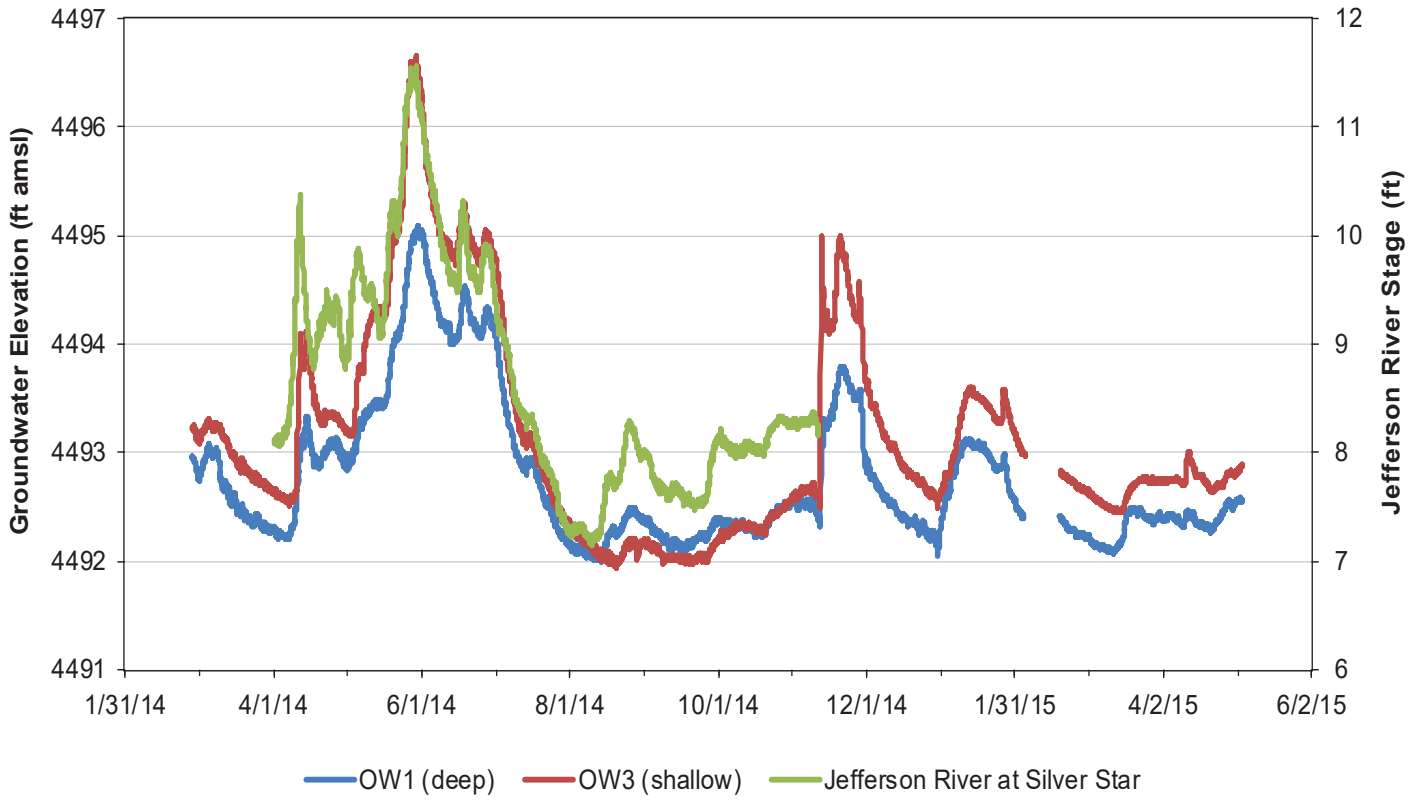

Figure 2-3. Long-term monitoring at the HCC Floodplain site shows that the shallow and deep aquifers both respond to changes in river stage.

2.1.5 Hydrologic Features

The Jefferson River is a significant hydrologic feature in the area, and several secondary channels near the test site flow during high river stages (figs. 2-1 and 2-2). The "Secondary Channel" noted in fig. 2-2 is likely an ancestral channel of the Jefferson River. During the aquifer tests, the secondary channels contained standing water.

2.2 Field Procedure

A step-test was conducted on 2/4/2015 to determine a sustainable pumping rate for the constant-rate test. Well OW1 was used as the pumping well because a crooked casing precluded the installation of the pump in well PW (table 2-1). From the step-test data it was determined that 16 gpm would be a reasonable pumping rate for the 72-h constant-rate test.

During the first attempt at the 72-h constant-rate aquifer test, equipment failure led to the test being terminated after 10 h. A second test started 17 h later, after water levels had recovered and stabilized. The second constant-rate test extended a full 72 h after the restart.

2.3 Data Collection

A vented pressure transducer with data logger was installed in each well on 2/3/2015 and removed on 2/18/2015 (5 days after the end of pumping). Each transducer was programmed to record water levels at a 1-min interval. An e-tape was used to measure water levels in all wells prior to installing transducers, throughout the test, and prior to transducer removal (figs. 2-4 to 2-7). These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a bucket and stopwatch and a totalizing flow meter. During the first 4 hs of the 72-h test we measured flow on average every 9 mins. The maximum interval between discharge measurements was 244 min.

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 2-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech.edu/).

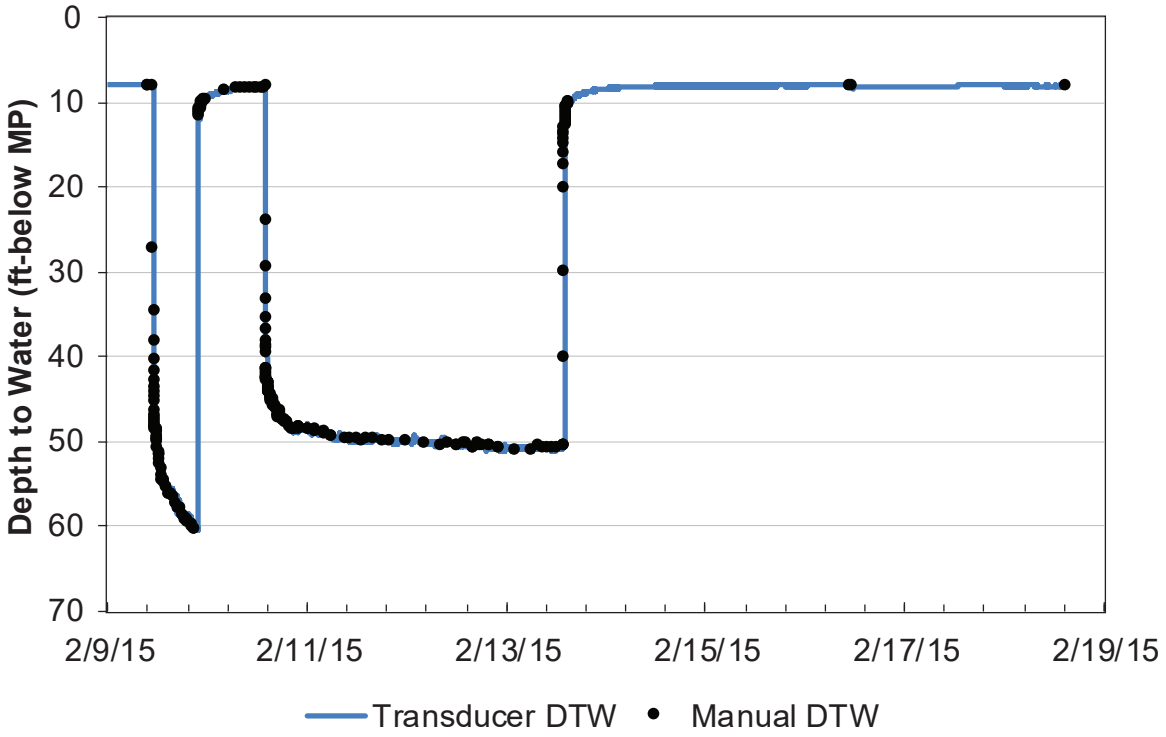

Figure 2-4. Depth to water in the pumping well (OW1) during the aquifer test.

2.4 Results

Data collected before and after the aquifer test show that there were no groundwater level trends during the test period. (figs. 2-4 to 2-7). For example, the depth to water in OW1 was 7.95 ft before the step-test on February 4th, and 7.98 ft at the end of recovery on February 18th. Therefore, no correction was made for antecedent trends.

2.4.1 Water-Level Response

The maximum drawdown in the pumping well (OW1) during the 72-h test was 43.0 ft (table 2-1; fig. 2-4). Drawdown in well OW1 showed a rapid initial decline followed by a gradual leveling out. Drawdown was increasing slightly at the end of the pumping portion of the test. The water level in well OW1 responded rapidly to the cessation of pumping, reaching 90 percent recovery in about 12 min.

Drawdown in the deep observation wells (OW2 and PW) differed from the pumping well in that the drawdowns toward the end of the test were slightly decreasing (figs. 2-5 and 2-6). The maximum drawdown in PW, 10.6 ft, was nearly twice that in OW2, 5.7 ft. The shallow observation well (OW3) showed no measurable response to pumping (fig. 2-7).

2.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a leaky-confined response to the test (appendix 2B). Therefore, aquifer properties were determined using observations from the two deep observation wells (PW and OW2), and a leaky-confined solution (Hantush and Jacob, 1955). AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 74 and 77 ft^2/d, and storativity values between 1.5×10^{-7} and 1.6×10^{-5}.

2.4.3 Aquifer Boundaries

A leaky-confined solution was needed to replicate observations; however, the simulated leakage was relatively small. Long-term monitoring shows that water levels in the deeper aquifer changed in response to short-term variations in river stage. Therefore, even though no drawdown was observed in the shallow observation well on site, the deep aquifer appears to be connected to the shallow aquifer system, and to the Jefferson River. The absence of response in the shallow aquifer during the test is attributed to the slight leakage needed, and the fact that unconfined aquifers have much higher storativity than confined aquifers (specific yield is much larger than specific storage).

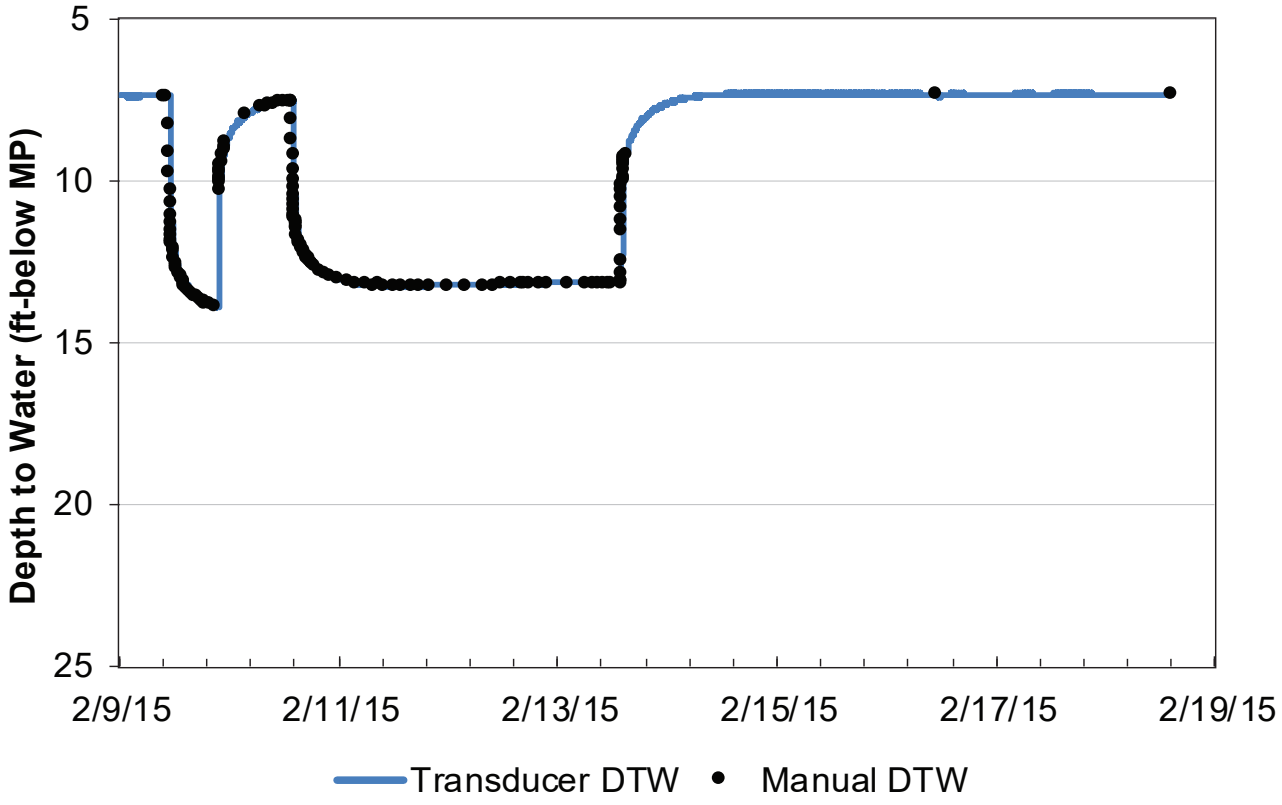

Figure 2-5. Depth to water in observation well OW2 during the aquifer test.

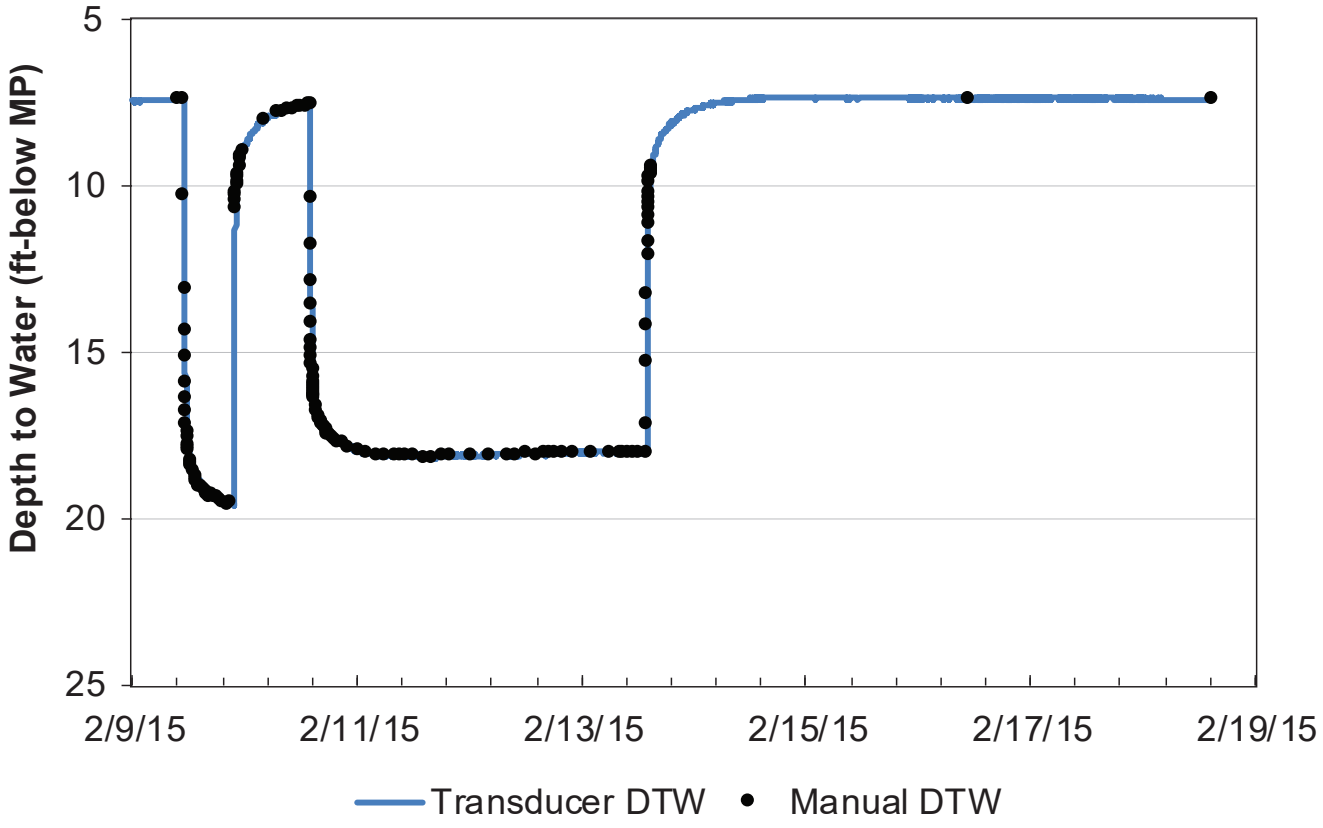

Figure 2-6. Depth to water in observation well PW during the aquifer test.

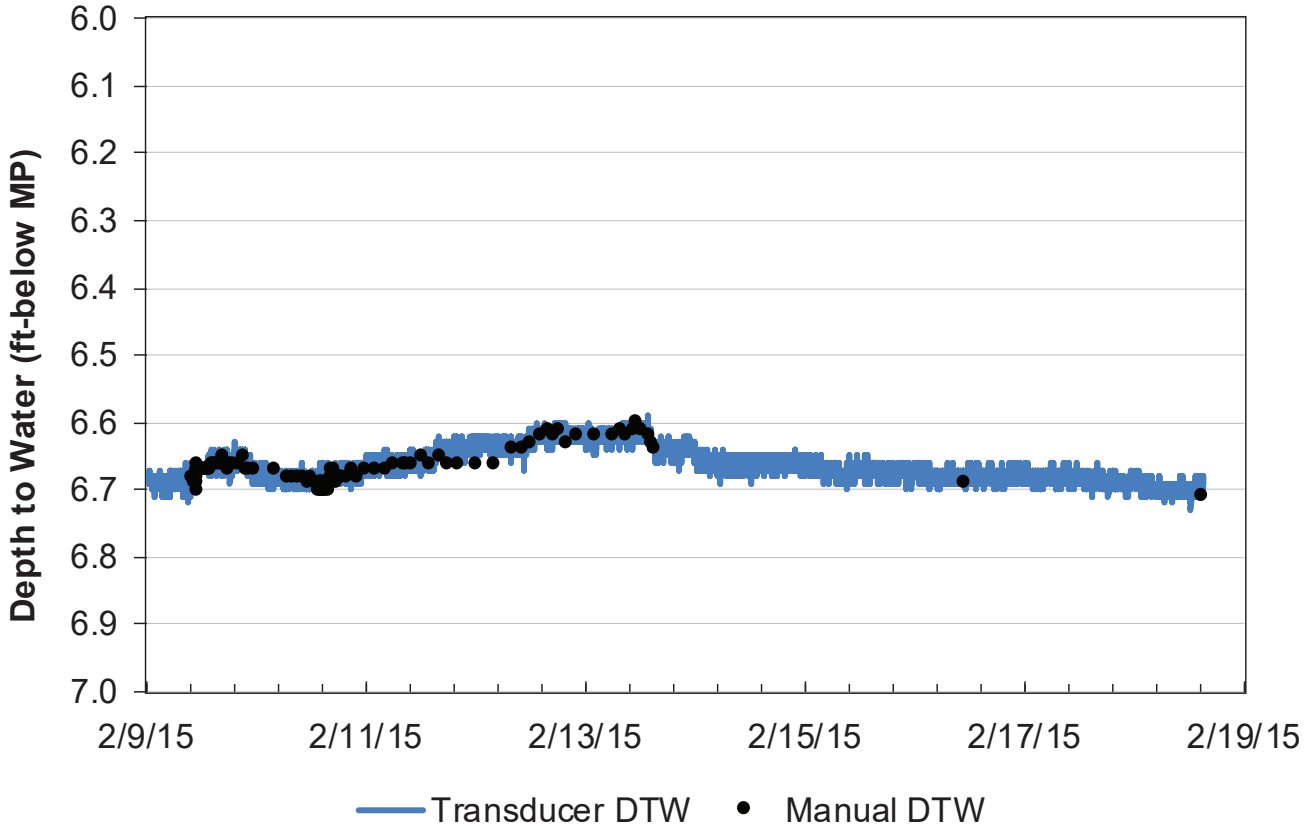

Figure 2-7. Depth to water in observation well OW3 during the aquifer test. Note that this hydrograph is at a different scale than those for the other observation wells.

2.5 Summary

The silty sand of the Renova Formation at this site had a transmissivity of about 75 ft^2/d and an average storativity of about 8 x 10^{-6}. Our interpretation indicates that this portion of the Renova Formation is a leaky-confined aquifer, and appears to be connected to the shallow Quaternary alluvium, and to the Jefferson River.

3 HCC BENCH TESTS

3.1 Background

3.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Tertiary Renova Formation. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

3.1.2 Test Location

Two wells were installed on the bench on the east side of the Jefferson Valley, in T. 2 S., R. 5 W., sec. 9 (figs. 3-1 and 3-2; table 3-1; appendix 3A). This site is 2.7 mi east of Silver Star, and 0.7 mi from the nearest residence.

3.1.3 Test Type

We performed a step-test and a 50-h constant-rate aquifer test. The step-test was performed on 2/16/2015 and the 50-h test ran from 2/17/2015 to 2/19/2015. Water-level recovery data were monitored until 2/23/2015. During the 50-h test the time-weighted average pumping rate was 11 gpm. Drawdown and recovery were monitored in the pumping well and one observation well.

3.1.4 Hydrogeologic Setting

The stratigraphy is interlayered silty sand and silty gravel from 0 to 105 ft, silty clay from 105 to 115 ft, gravel and sandy silt from 115 to 135 ft, and silty gravel with some sand from 135 to 220 ft (appendix 3A). The pumping and observation wells were installed to total depths 220 and 222 ft bgs, respectively, and were constructed with 10-ft screen (table 3-1). These wells are completed within the Renova Formation.

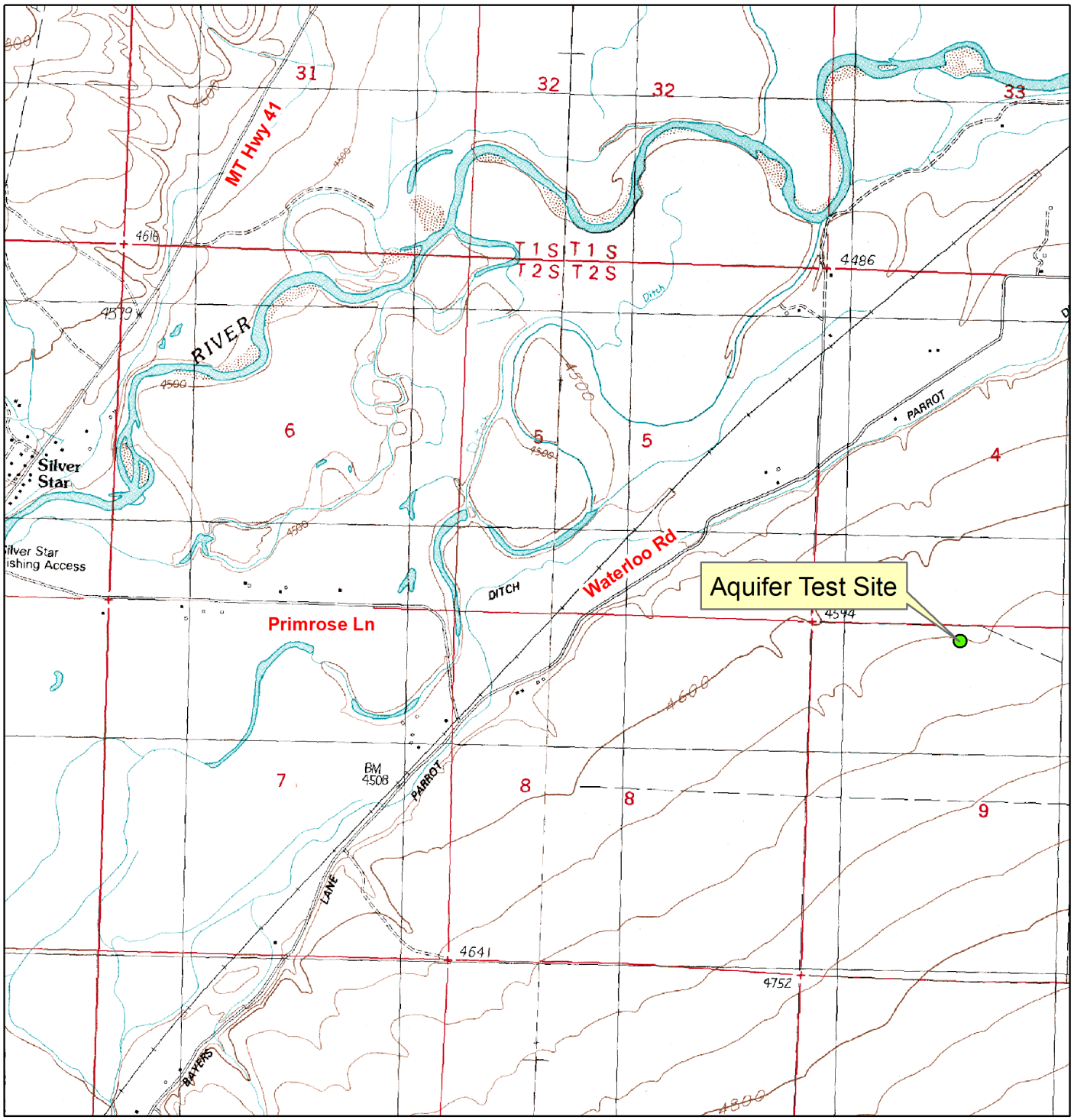

Figure 3-1. The HCC bench aquifer test site is located on the bench east of the Jefferson River approximately 2.7 mi east of the town of Silver Star, Montana.

3.1.5 Hydrologic Features

This site is on a bench above the floodplain, upgradient of all irrigation canals. There are several center-pivot irrigated fields adjacent to this site (fig. 3-2). The test was conducted in February, when there is little potential for influence from irrigation.

3.2 Field Procedure

A step-test was conducted on 2/16/2015 to determine a sustainable pumping rate for the constant-rate test. From the step-test data it was determined that 11 gpm would be a reasonable pumping rate. The constant-rate aquifer test was scheduled to run for 72 h but was terminated after 50 h due to equipment failure.

Figure 3-2. The HCC bench aquifer test site had a pumping well and an observation well completed in the Renova Formation. During the tests, water was discharged approximately 300 ft northwest of the pumping well.

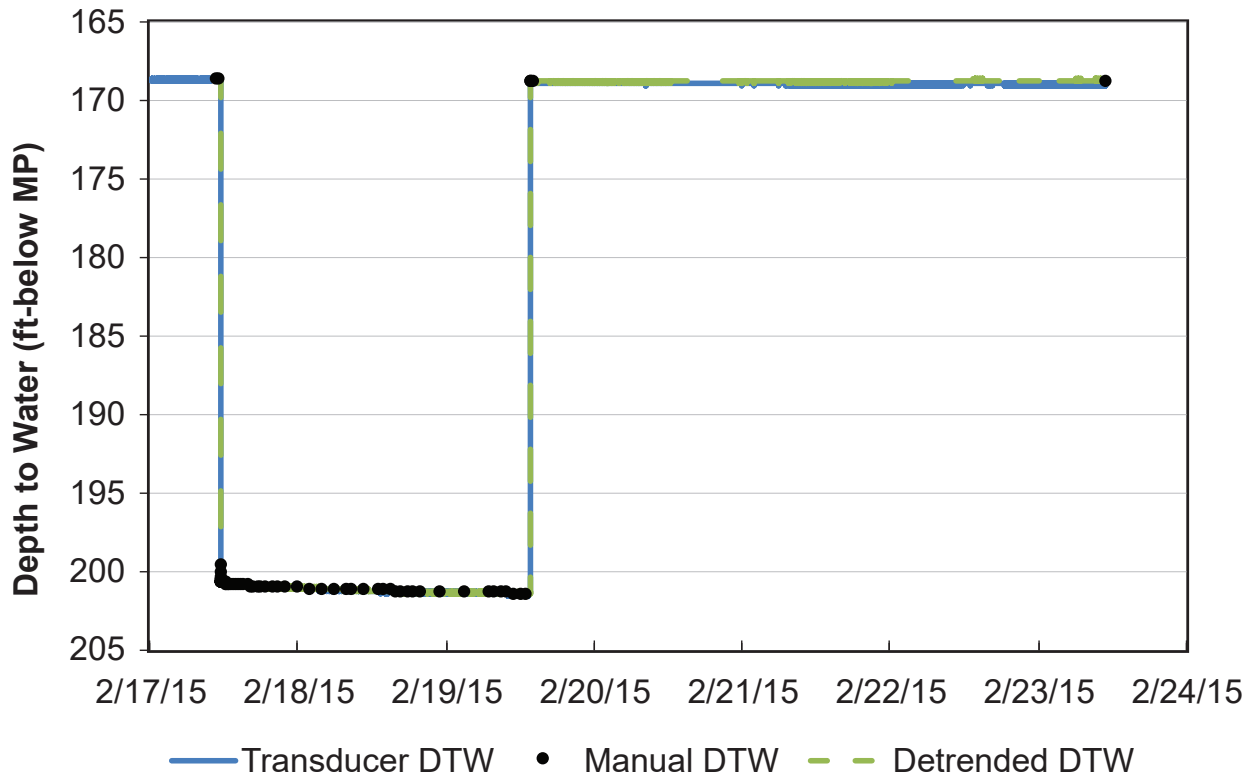

Figure 3-3. The hydrograph for PW showed a slight downward antecedent trend. Time-weighted corrections were applied to remove these effects.

Table 3-1. Well designations, locations, and completion information, HCC Bench Aquifer test site.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from PW (ft)	Maximum Drawdown (ft)	Aquifer	Well Type
280980	PW	45.684520	-112.226762	4644.5	222	4423–4433	—	32.9	Renova	Pumping
280979	OW	45.684633	-112.226694	4643.3	220	4423–4433	44.8	2.4	Renova	Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.

3.3 Data Collection

A vented pressure transducer was installed in each well. The observation well (OW) transducer was installed on 2/11/2015, and the pumping well (PW) transducer was installed along with the pump on 2/16/2015. Each transducer recorded water levels at 1-min intervals. An e-tape was used to collect depth to water (DTW) readings prior to installation of the transducers, throughout the tests, and during the recovery period. These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a bucket and stopwatch and a totalizing flow meter. During the first 4 h of the 72-h test, we measured flow on average every 10 min. The maximum interval between discharge measurements was 230 min (~4 h).

Water-level data and pumping rates are available from GWIC using the wells' GWIC ID numbers (table 3-1), and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech.edu).

3.4 Results

A downward antecedent trend in groundwater levels was noted during the constant-rate test. Time-weighted corrections were applied to results to correct for this trend. Trend-corrected data are shown in figures 3-3 and 3-4.

3.4.1 Water-Level Response

The maximum recorded drawdown in the pumping well (PW) was 32.9 ft (table 3-1; fig. 3-3). Drawdown in PW showed a rapid initial decline followed by gradually declining water levels. The rate of drawdown decreased throughout the test. Well PW exhibited a rapid response to the cessation of pumping, reaching 90% recovery in about 4 min (fig. 3-3).

Drawdown in OW reached a maximum of 2.3 ft. The shape of the hydrograph was similar to that of PW (fig. 3-4).

3.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was an unconfined response to the test (appendix 3B). Therefore, aquifer properties were determined using observations from OW and an unconfined solution

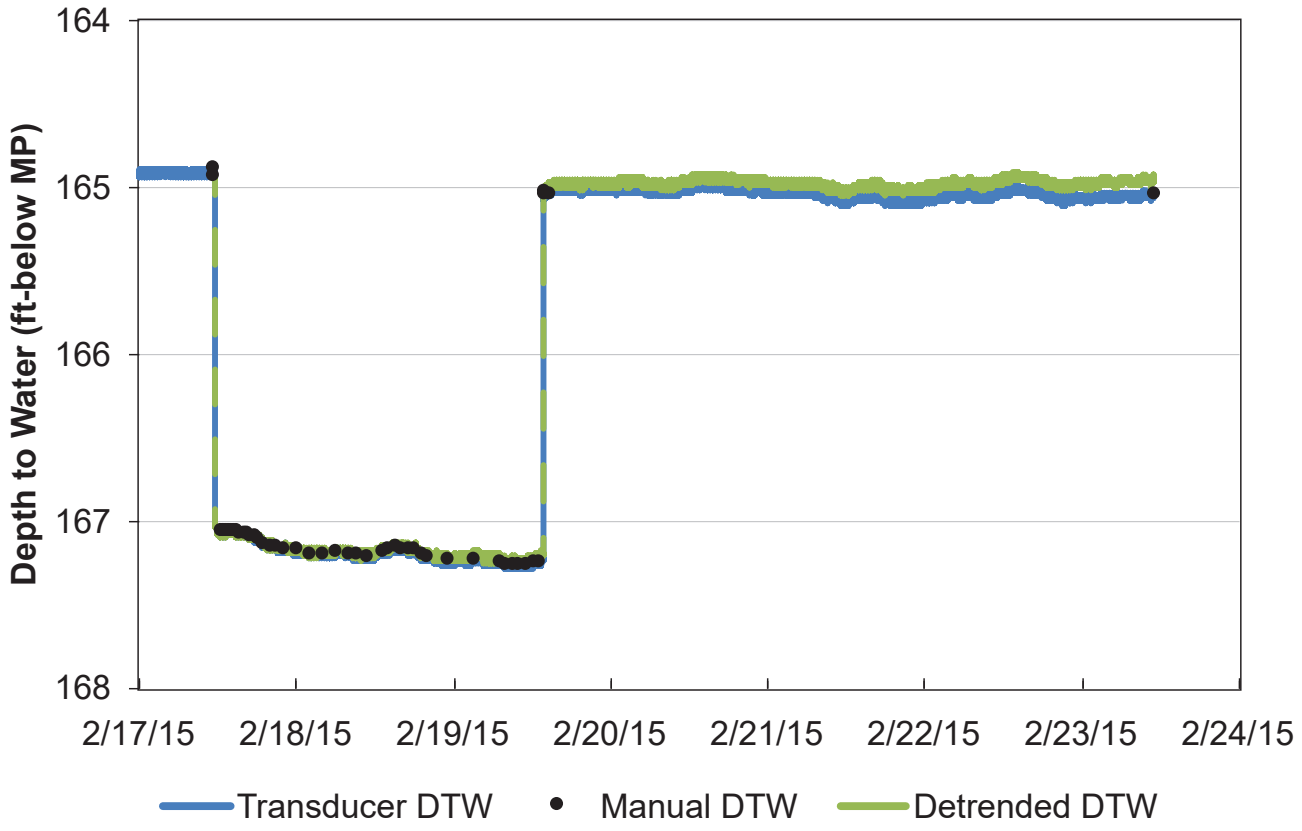

Figure 3-4. The hydrograph for OW showed a slight downward antecedent trend during the 50-h test. Time-weighted correction was used to remove trend.

(Neuman, 1974). AQTESOLV was used to analyze the aquifer test data. These results indicated a transmissivity value of 255 ft^2/d, and a storativity of 0.2.

3.5 Summary

The tested portion of the Renova Formation (silty gravel with some sand) has a transmissivity of about 255 ft^2/d, and a storativity of about 0.2. The aquifer test showed an unconfined response, and did not reveal any boundary effects.

4 HUNT TESTS

4.1 Background

4.1.1 Purpose of Test

This test was designed estimate the transmissivity (T) and storativity (S) of the Quaternary alluvial aquifer. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

4.1.2 Test Location

Three wells were installed in the floodplain east of the Jefferson River, near Waterloo, in T. 1 S., R. 5 W., sec. 24 (figs. 4-1 and 4-2; table 4-1), and 1.6 mi southeast of Parson's Bridge. The site is used as a pasture (fig. 4-2) and is 0.3 mi from the nearest residence.

4.1.3 Test Type

We performed a step-test and a 55-h constant-rate aquifer test. The step-test was performed on 2/23/2015, and the 55-h test ran from 2/24/2015 to 2/26/2015. Water-level recovery was monitored until 3/6/2015. During the 55-h test the time-weighted average pumping rate was 433 gpm. Drawdown and recovery were monitored in the pumping well and two observation wells (table 4-1).

4.1.4 Hydrogeologic Setting

The stratigraphy is silty sand from 0 to 12 ft, clay from 12 to 18 ft, silty sand and gravel from 18 to 20 ft, and gravel with little sand from 20 to 60 ft (appendix 4A). These unconsolidated materials are Quaternary alluvium (Vuke and others, 2004). The pumping and observation wells were installed in the deepest gravel (table 4-1), and the static water level was approximately 7 ft below ground surface. Wells were completed

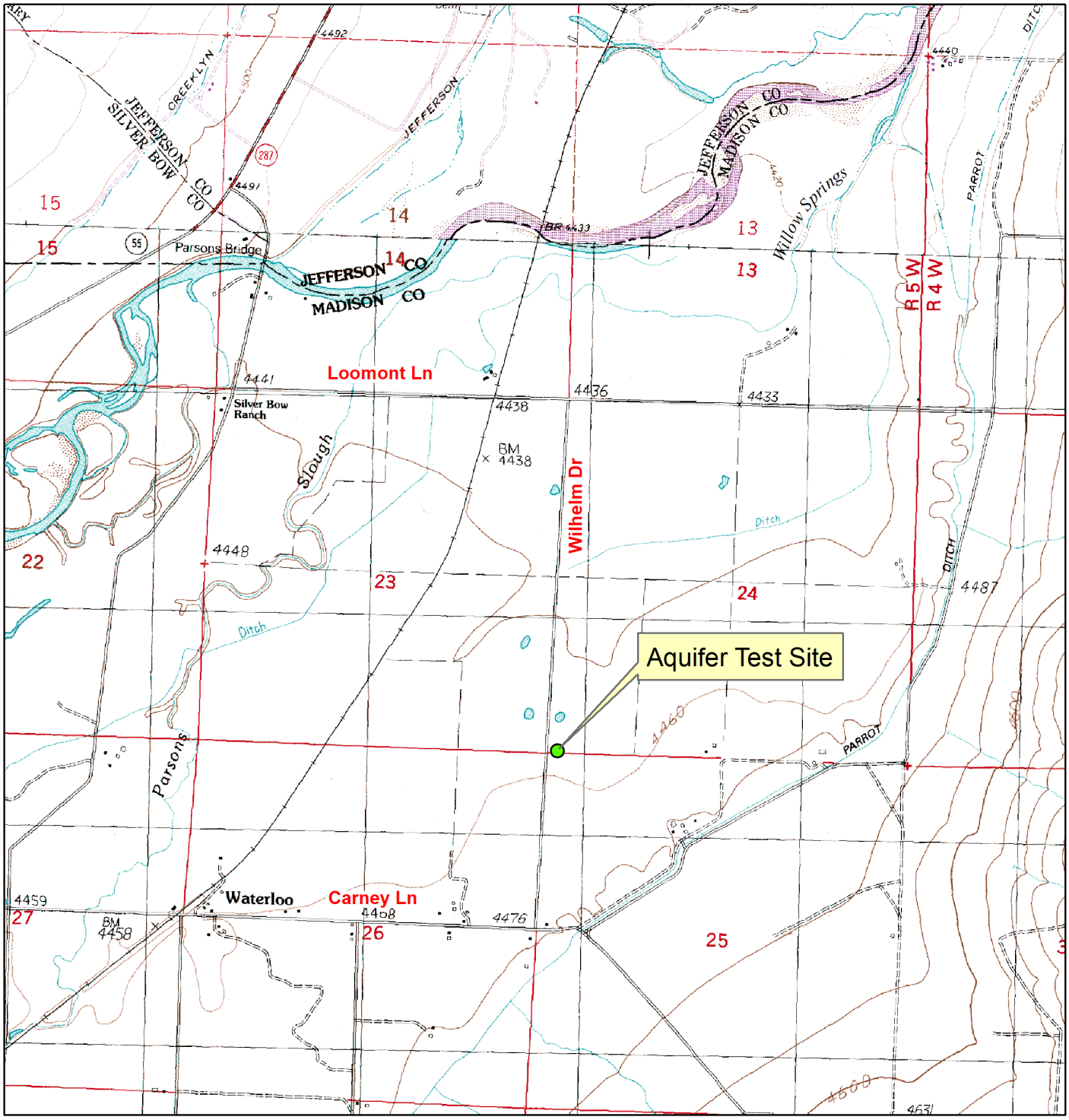

Figure 4-1. The Hunt aquifer test site was located in the floodplain east of the Jefferson River. This site is 1.6 mi southeast of Parson's Bridge.

using steel casing with open bottoms, and perforations (table 4-1; appendix 4A).

4.1.5 Hydrologic Features

This site is a pasture located in the floodplain of the Jefferson River. It is downgradient from the Parrot Canal, and adjacent to irrigated fields. Two groundwater-fed streams (WET, written commun., 2006), Parson's Slough and Willow Springs Creek, are located 1.1 and 0.5 mi from the site. The Jefferson River is approximately 1.8 mi west of the site (fig. 4-1). The

Figure 4-2. At the Hunt aquifer test site one pumping well and two observation wells were completed in the unconsolidated alluvium (table 3-1). During the tests, produced water was discharged approximately 300 ft northeast of the pumping well.

wells were installed adjacent to a wetland area (figs. 4-1 and 4-2).

4.2 Field Procedure

A step-test was conducted on 2/23/2015 to determine a sustainable pumping rate for a constant-rate test. From the step-test data it was determined that a pumping rate of 450 gpm would be appropriate.

Although scheduled for 72 h, the constant-rate aquifer test was terminated after 55 h due to equipment failure. During the constant-rate test, the time-weighted mean pumping rate was 433 gpm. Considerable variation in pumping rates occurred near the end of the test due to pump failure.

4.3 Data Collection

A vented pressure transducer was installed in each well. The observation well transducers were installed on 2/18/2015, and the pumping well transducer was installed along with the pump on 2/23/2015. Each transducer was programmed to record water levels at 1-min intervals. Manual water-level measurements were made using an e-tape prior to placing transducers, during the test, and during recovery. These measurements were used to calibrate transducer response, and to provide a backup in case of transducer malfunction.

Pumping rates were monitored using a totalizing flow meter. Discharge measurements were made more frequently at the start of the test, and near the end when the pump began to fail. The maximum interval between discharge measurements was 273 min (~4.6 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 4-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech.edu/).

Table 4-1. Well designations, locations, and completion information, Hunt Floodplain aquifer test.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Perforated Interval (ft-amsl)	Distance from PW (ft)	Maximum Drawdown (ft)	Aquifer	Well Type
279259	PW	45.728924	-112.171926	4457.0	60	4397–4417	---	15.2	Alluvium	Pumping
279258	OW1	45.728987	-112.171934	4457.1	60	4397–4417	22.8	1.2	Alluvium	Observation
279260	OW2	45.728930	-112.172012	4457.2	60	4397–4407	22.0	1.2	Alluvium	Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.

4.4 Results

Although this test was conducted in February to avoid interference from irrigation practices, static groundwater levels changed slightly during the constant-rate test. Therefore, time-weighted corrections were applied to measurements (figs. 4-3 to 4-6).

4.4.1 Water-Level Response

During the constant-rate test the maximum drawdown in the pumping well (PW) was 15.2 ft (fig. 4-3). Drawdown in PW showed a rapid initial decline followed by gradually declining water levels. Fluctuating water levels observed near the end of the test are attributed to variation in the pumping rate as the pump failed. PW exhibited a rapid recovery after the cessation of pumping, reaching 90% recovery in less than 1 min (fig. 4-3).

The maximum drawdowns in both observation wells were 1.2 ft. These hydrographs were similar to that of PW (figs. 4-5 and 4-6).

4.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was an unconfined response to the test, with a nearby recharge source (appendix 4B). Aquifer properties were determined using observations from the two observation wells (OW1 and OW2), an unconfined solution (Hantush and Jacob, 1955), and a constant head boundary set at the edge of the wetland (100 ft to the north). AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 41,000 and 44,500 ft^2/d, and a storativity value of about 0.14.

4.5 Summary

The transmissivity of the gravel at this site ranges from 41,000 to 44,500 ft^2/d, and has a storativity of about 0.14. An unconfined solution with a nearby constant-head boundary replicates observations, indicating that the clay overlying the gravel aquifer is not laterally continuous, and this aquifer is hydraulically connected to the wetlands.

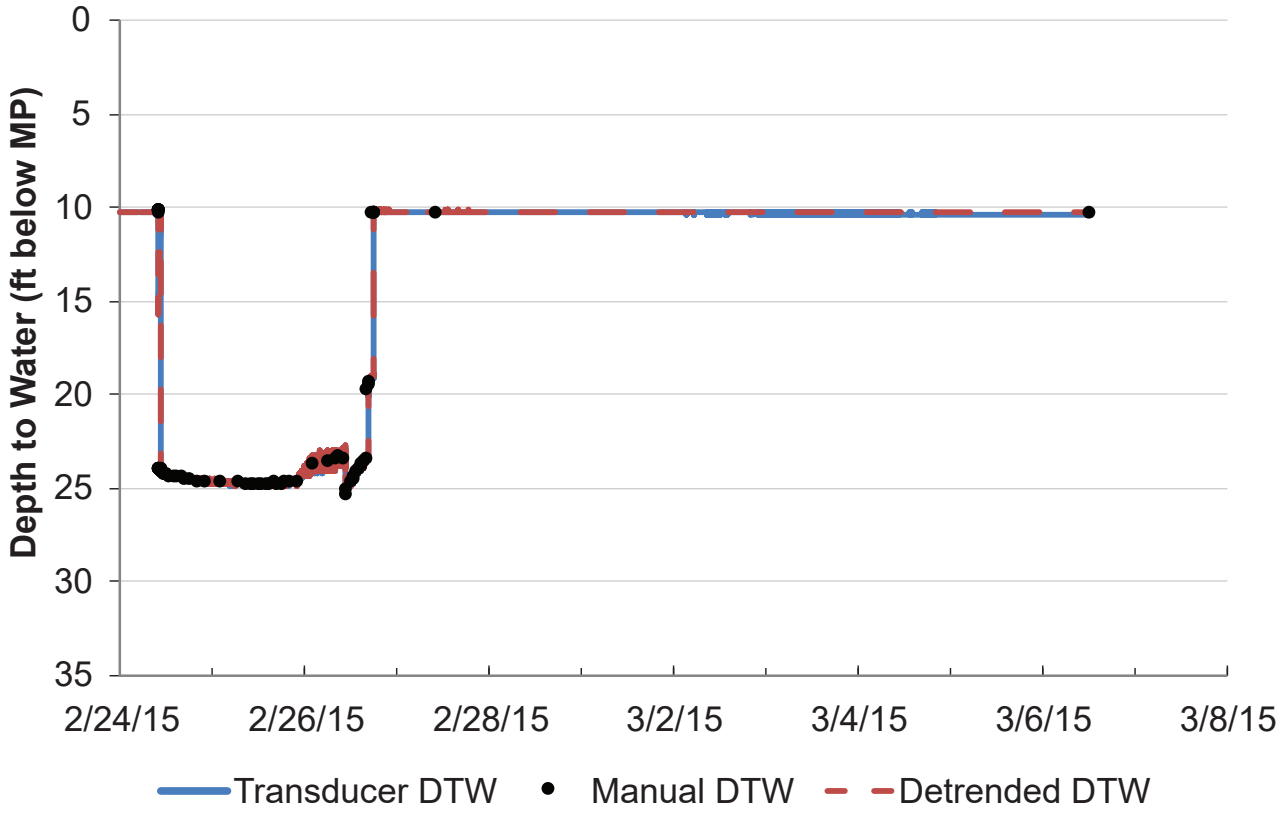

Figure 4-3. The hydrograph for PW shows an antecedent trend in water levels, so a time-weighted correction was applied to remove this effect. This is shown in greater detail in figure 3-4. The maximum drawdown during the constant-rate test (after correction) was 15.2 ft.

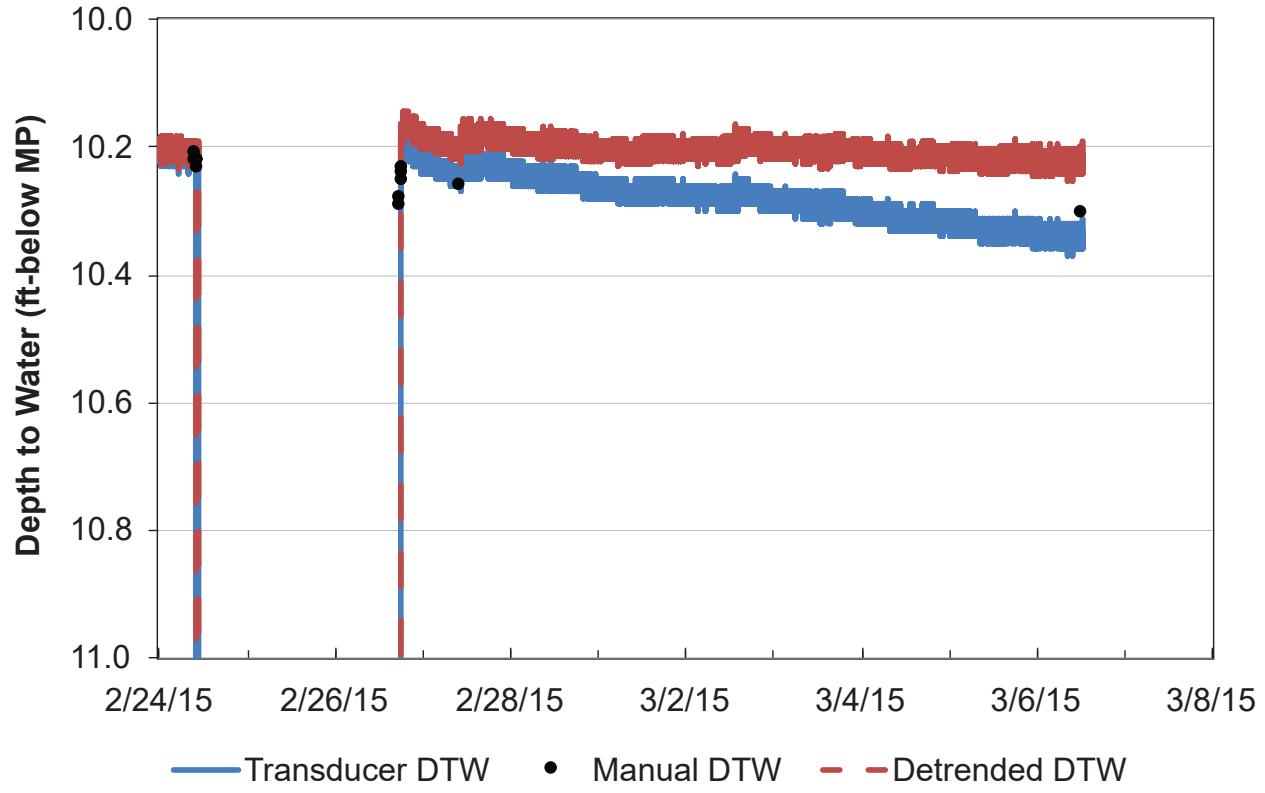

Figure 4-4. The hydrograph for PW shows an antecedent trend in water levels during the aquifer tests. This chart shows the groundwater levels at a higher resolution to illustrate the antecedent trend. For a full scale hydrograph see figure 3-3.

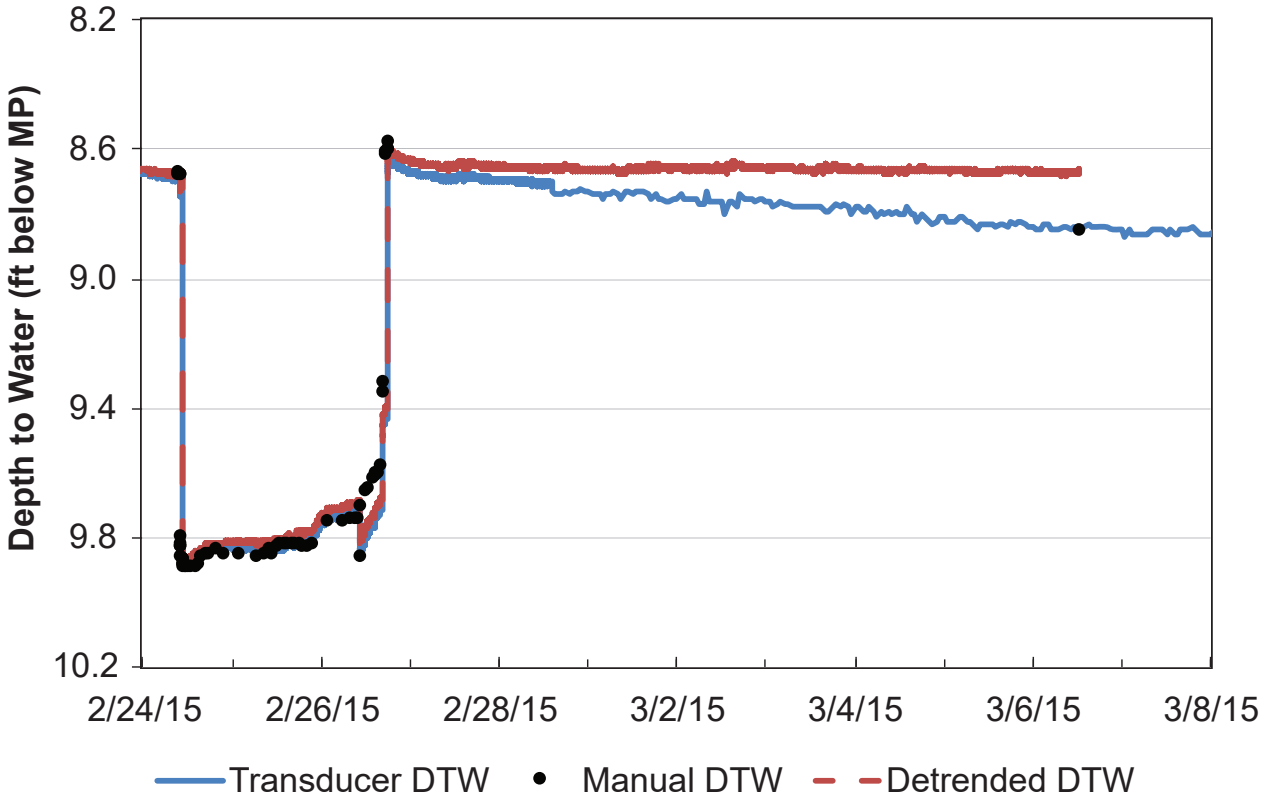

Figure 4-5. This hydrograph shows changes in water levels in OW1 during the aquifer tests. There was a slight downward trend during the test, so a time-weighted correction was applied to remove the effect of this antecedent trend.The maximum drawdown (after correction) during the constant-rate test was 1.2 ft.

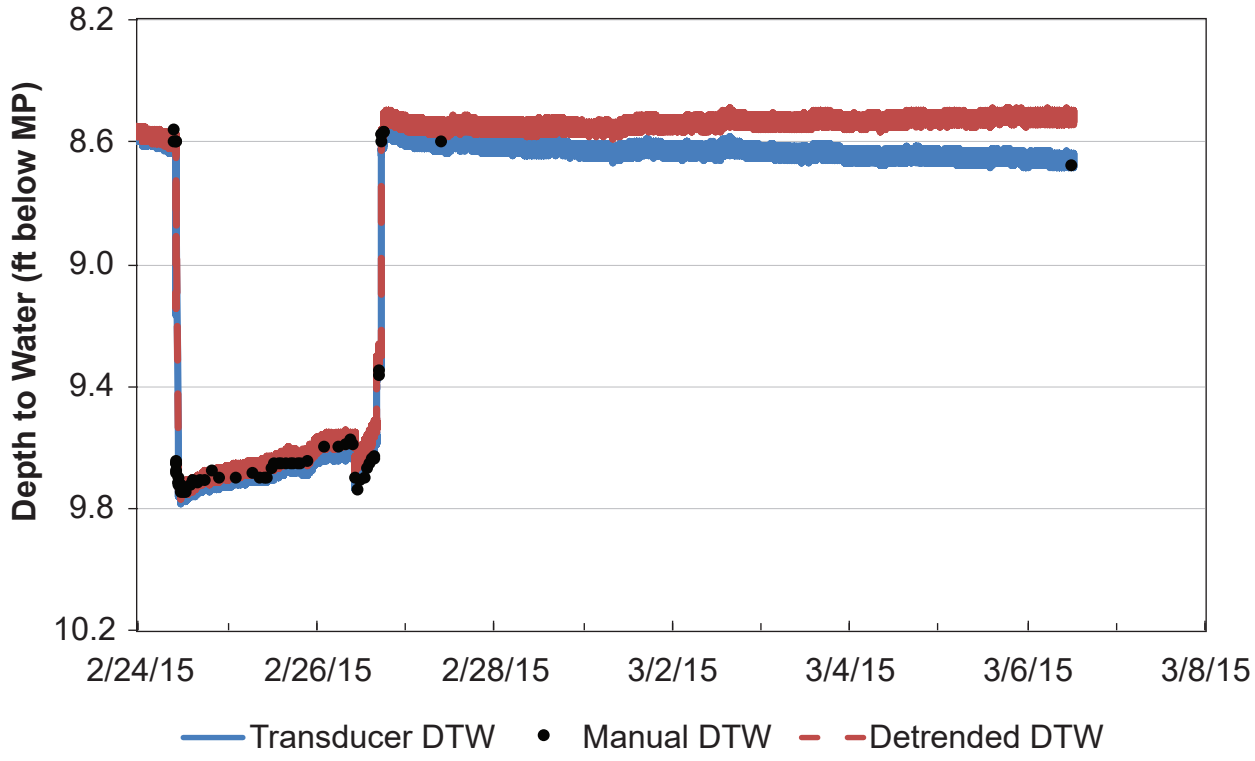

Figure 4-6. This hydrograph shows changes in water levels in OW2 during the aquifer tests. There was a slight downward trend during the test, so a time-weighted correction was applied to remove the effect of this antecedent trend. The maximum drawdown (after correction) during the constant-rate test was 1.2 ft.

5 LAZY TP FLOODPLAIN TESTS

5.1 Background

5.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Renova Formation. Potential hydrologic connection to the overlying alluvial aquifer was also evaluated. These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

5.1.2 Test Location

Three wells were installed in the floodplain between the Jefferson River and Slaughterhouse Slough (fig. 5-1; table 5-1; appendix 5A). The wells are located in T. 1 N., R. 4 W., sec. 11, 2 mi southeast of Whitehall. The site is located next to an inactive flooded gravel pit and an irrigated field (fig. 5-2). It is 0.7 mi from the nearest residence.

5.1.3 Test Type

We performed a step-test and a 72-h constant-rate aquifer test. The step-test was conducted on 3/6/2015, and the 72-h test ran from 3/16/2015 to 3/19/2015. Water-level recovery was monitored until 3/30/2015. During the 72-h test, the time-weighted average pumping rate was 21.3 gpm. Drawdown and recovery were recorded in the pumping well and two observation wells (table 5-1).

5.1.4 Hydrogeologic Setting

The stratigraphy includes gravel and sand from 0 to 20 ft, clay and gravel from 20 to 25 ft, and interbedded sand and mudstone from 25 to 60 ft (appendix 5A). The wells were installed in a sand-dominated portion of the interbedded sand and mudstone zone (table 5-1), and the static water level was approximately 7 ft below ground surface. The wells are completed in the Tertiary Renova Formation (Vuke and others, 2004). The overlying shallow sand and gravel (0–20 ft) is Quaternary alluvium.

5.1.5 Hydrologic Features

This site is in the floodplain of the Jefferson River, approximately 0.4 mi north of the river. The Slaughterhouse Slough (an ancestral channel of the Jefferson River) is located approximately 0.2 mi north of the site (fig. 5-1). Water produced during the aquifer test was

Table 5-1. Well designations, locations, and completion information, Lazy TP Floodplain aquifer test.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from PW (ft)	Maximum Drawdown (ft)	Aquifer	Well Type
279262	PW	45.848671	-112.068528	4334.0	60	4274–4294	—	21.8	Renova	Pumping
279261	OW1	45.848588	-112.068593	4333.8	60	4274–4284	34.6	2.7	Renova	Observation
279263	OW2	45.848703	-112.068626	4334.2	60	4274–4294	27.4	4.2	Renova	Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.

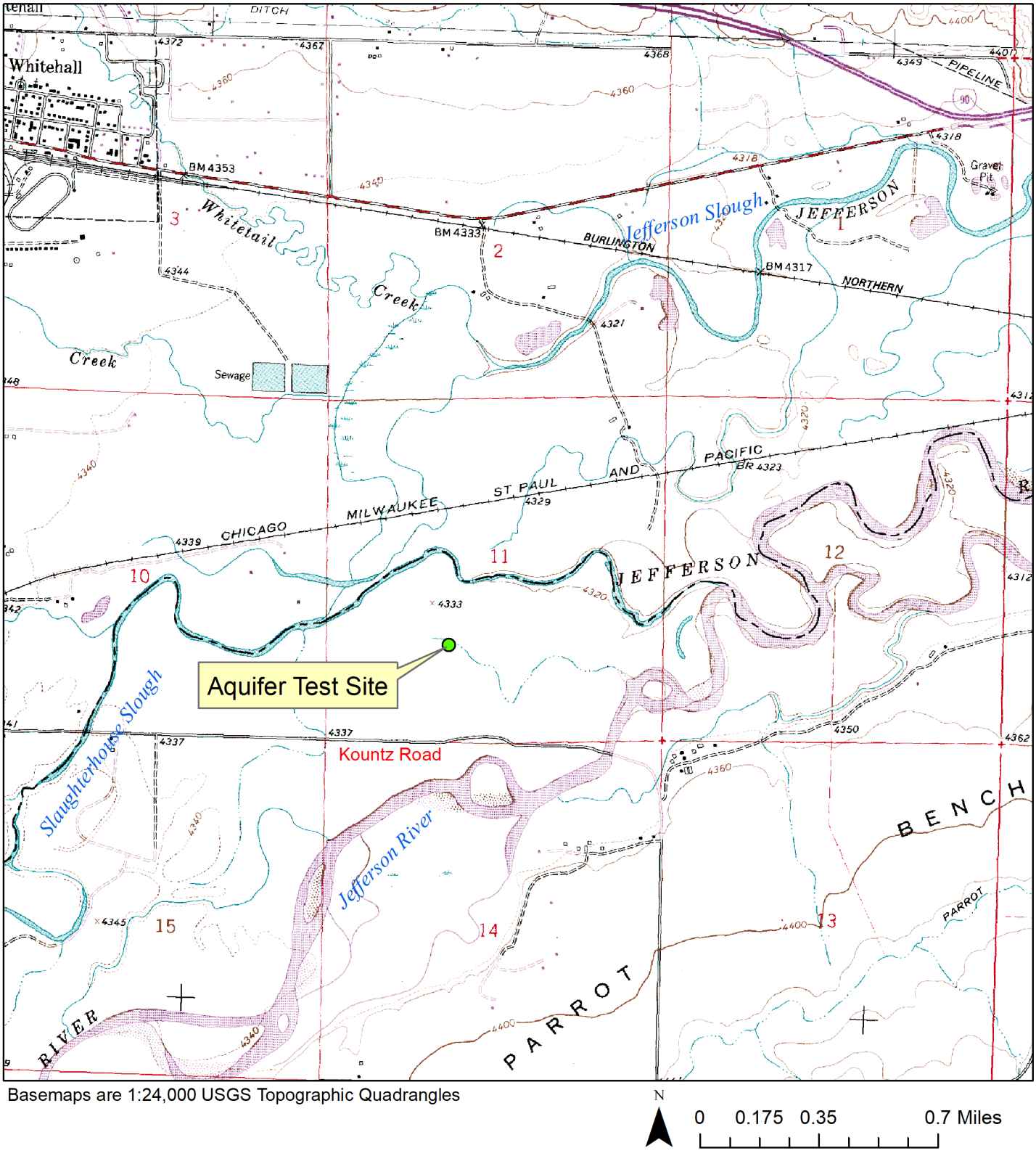

Figure 5-1. The Lazy TP Floodplain test site is located between the Jefferson River and Slaughterhouse Slough. This site is approximately 2 mi southeast of Whitehall.

discharged to the flooded gravel pit, approximately 200 ft north of the site (fig. 5-2).

5.2 Field Procedure

A step-test was conducted to determine a sustainable pumping rate for the constant-rate test. From the step-test data a pumping rate of 22 gpm was selected for the constant-rate test. The constant-rate test ran for 72 h, from 3/16/2015 to 3/19/2015.

Figure 5-2. The Lazy TP Floodplain test site had a pumping well (PW) and two observation wells installed in the Renova Formation. During the tests, water was discharged into the unused flooded gravel pit approximately 225 ft north of the pumping well.

5.3 Data Collection

Manual depth to water measurements were taken at this site using an e-tape from September 2014 to May 2015. A non-vented transducer was installed in OW1 in October 2014 and ran until May 2015 (fig. 5-3). The readings from the non-vented transducer were corrected for barometric pressure variations based on data from a barometric logger located near Cardwell.

A vented pressure transducer was installed in each well prior to the start of the tests. On 2/3/2015 the transducer for OW2 and the pump for PW were installed. The transducers for PW and OW1 were installed before the start of the step-test on 3/6/2015, and at that time all vented transducers were programed to record at 1-min intervals. Manual depth to water readings were made prior to placing the transducers throughout the tests, and during recovery (figs. 5-4 to 5-7). These manual measurements were used to calibrate transducer response and served as a backup in case of transducer malfunction.

Pumping rates were monitored using a totalizing flow meter and bucket and stopwatch. Discharge measurements were made more frequently at the start of the test; during the first 4 h discharge measurements were made on average every 15 min. The maximum interval between discharge measurements was 363 min (~6 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 5-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech.edu/).

5.4 Results

Static groundwater levels changed noticeably during the constant-rate test, coincident with increases in the stage of the Jefferson River. As such, time-

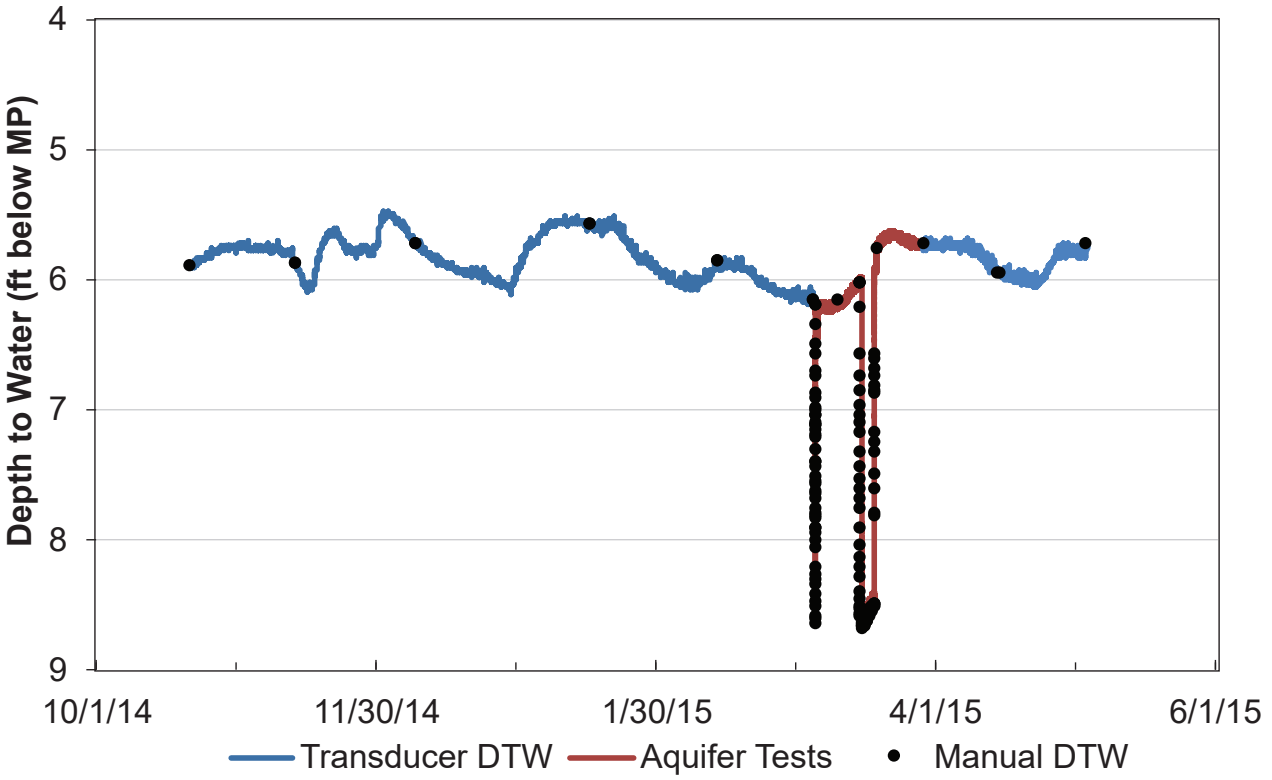

Figure 5-3. Transducer data were collected in OW1 from October 2014 to May 2015. Changes in water levels appear to correlate with changes in stage in the Jefferson River, which are partly due to ice jams in the winter.

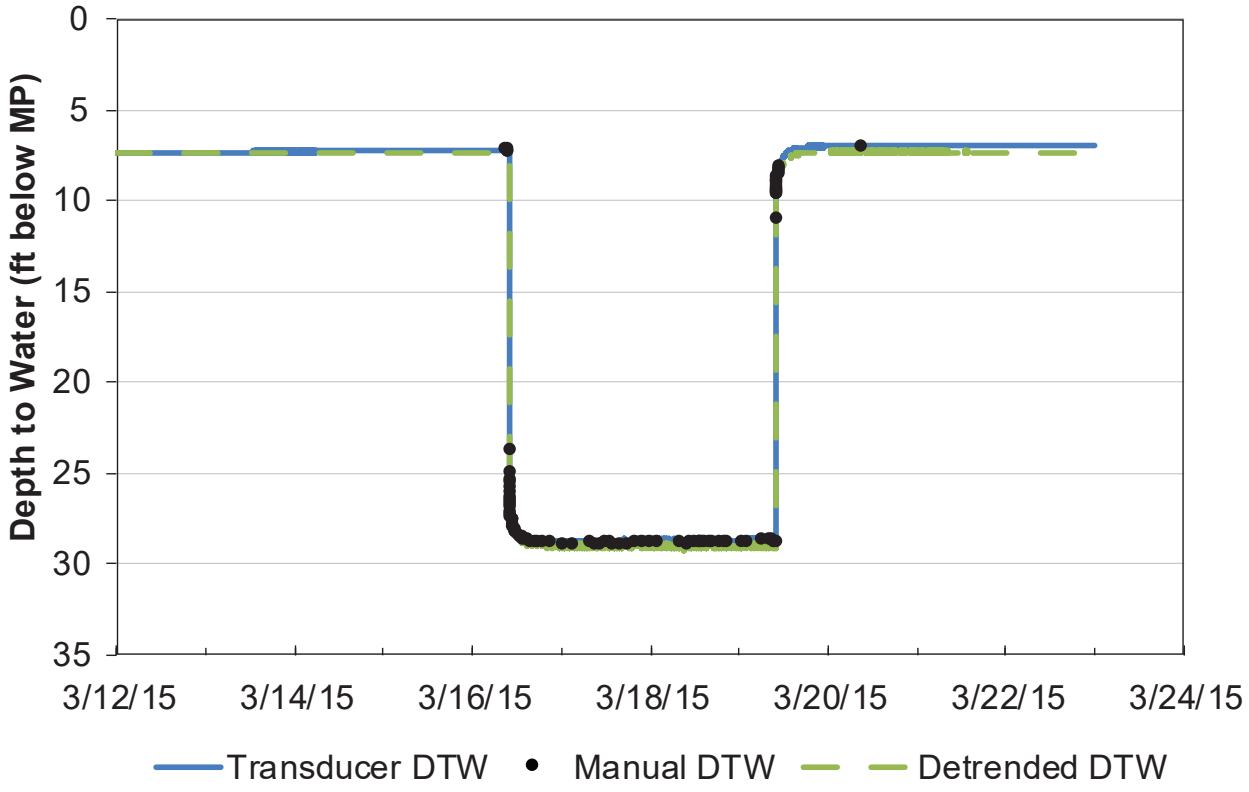

Figure 5-4. The hydrograph for PW during the constant-rate test shows changes in water levels during the aquifer tests; however, at a scale that shows all of the drawdown, the effect of antecedent trends cannot be clearly seen. Figure 5-5 shows the antecedent trend at a higher resolution. Maximum detrended drawdown during the constant rate test was 21.8 ft.

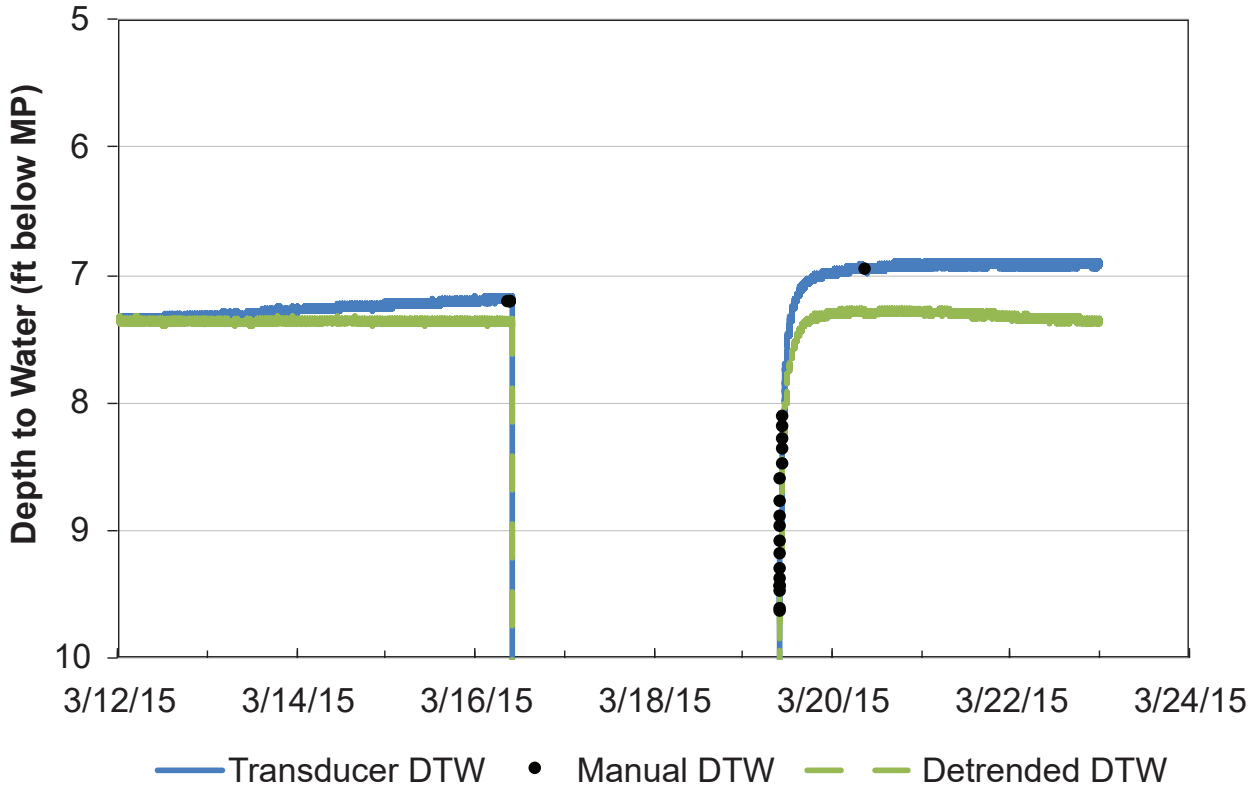

Figure 5-5. The hydrograph for PW shows changes in water levels during the constant-rate aquifer test. This chart shows the groundwater levels at a higher resolution to more clearly illustrate the antecedent trend. For a full scale hydrograph see figure 5-4.

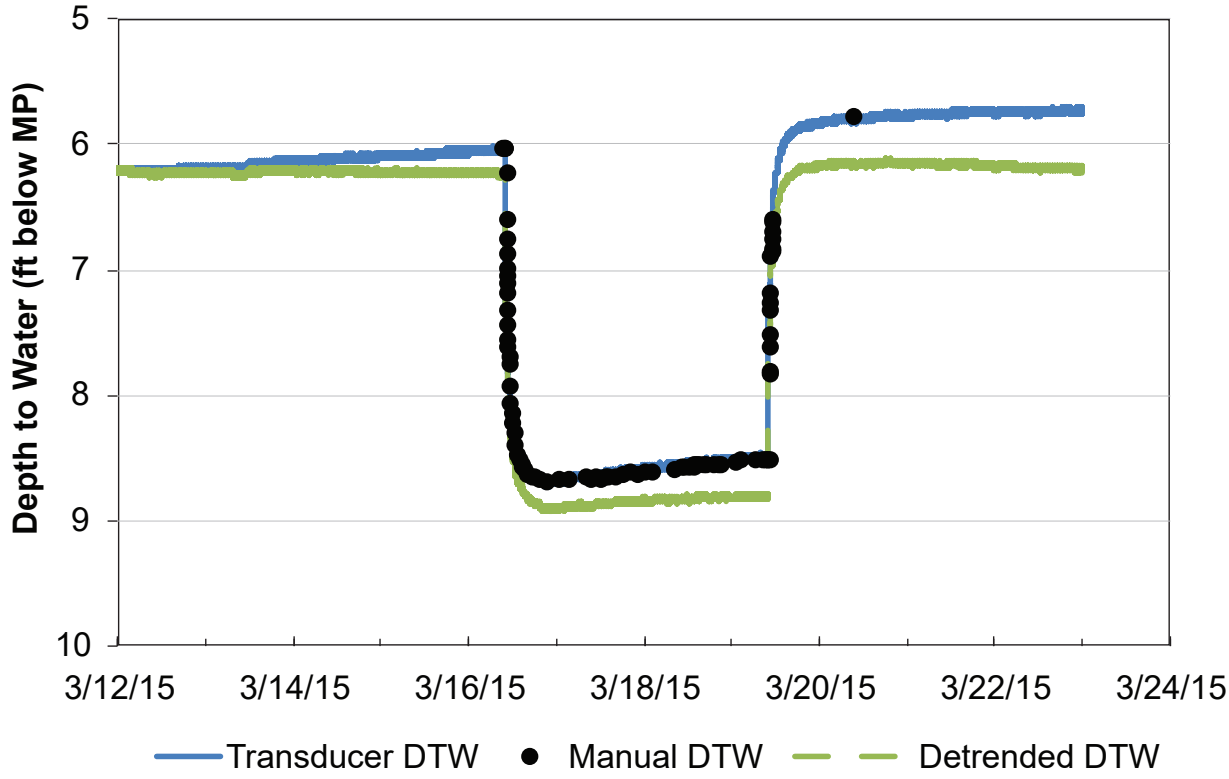

Figure 5-6. This hydrograph shows changes in water levels in OW1 during the constant-rate aquifer test. Maximum detrended drawdown was 2.7 ft.

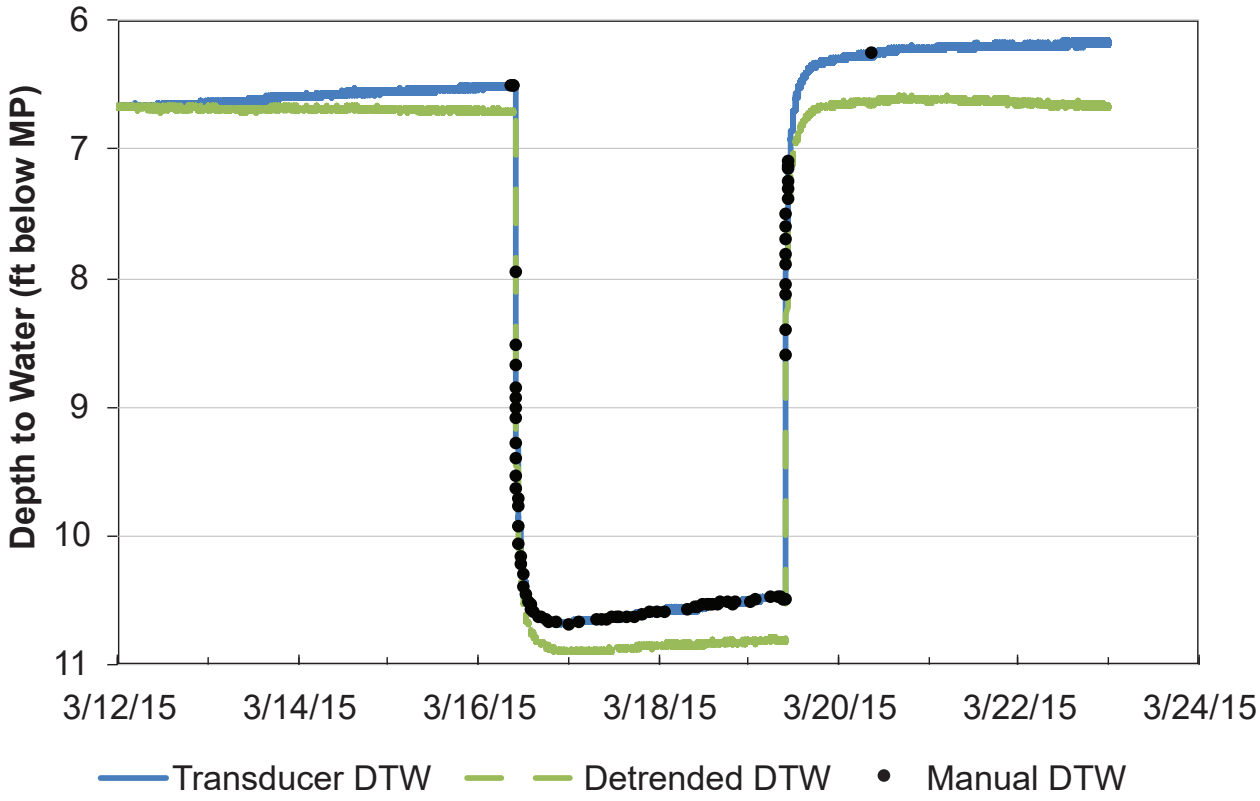

Figure 5-7. This hydrograph shows changes in water levels in OW2 during the constant-rate aquifer test. Maximum detrended drawdown was 4.2 ft.

weighted corrections were applied to account for the antecedent trends (figs. 5-4 to 5-7).

5.4.1 Water-Level Response

The maximum drawdown in the pumping well (PW) was 21.8 ft. Water levels in this well declined rapidly at the start of pumping, followed by gradually increasing water levels (fig. 5-4). This upward trend reflected the overall rise in groundwater levels during the test. Corrections applied to the depth to water measurements removed most of this trend. After pumping ceased, the water level reached 90% recovery in 14 min (figs. 5-4 and 5-5).

The observation well hydrograph shapes are similar to that of PW (figs. 5-6 and 5-7). OW2 showed more drawdown than OW1 (4.2 vs. 2.7 ft).

5.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a leaky-confined response to the test (appendix 5B). Aquifer properties were determined using observations from the two observation wells (OW1 and OW2) and a leaky-confined solution (Hantush and Jacob, 1955). AQTESOLV was used to analyze the aquifer test data. These results indicated transmissivity values between 310 and 440 ft^2/d, and storativity values between 8 x 10^{-4} and 2 x 10^{-3}. The test results support the interpretation of a sand aquifer within the interbedded sand and mudstone of the Renova Formation.

5.5 Summary

The sand aquifer in the Renova Formation had transmissivity values between 310 and 440 ft^2/d. Storativity values ranged from 8 x 10^{-4} to 2 x 10^{-3}. A leaky-confined solution was needed to replicate observations, showing that the Renova Formation and the overlying alluvial aquifer are hydraulically connected. Long-term monitoring also showed that groundwater levels in this aquifer respond to changes in river stage (fig. 5-3).

6 LAZY TP BENCH TESTS

6.1 Background

6.1.1 Purpose of Test

This test was designed to estimate the transmissivity (T) and storativity (S) of the Renova Formation.

These results aided in the development of groundwater flow models to address the objectives of the Upper Jefferson Groundwater Investigation.

6.1.2 Test Location

Two wells were installed on the Parrot Bench, south of the Jefferson River floodplain, in T. 1 N., R. 4 W., sec. 13, 3.5 mi southeast of Whitehall (fig. 6-1; table 6-1). The site is located next to the Parrot Canal, and between two irrigated fields (fig. 6-2). The nearest residence was under construction during the test, and is about 400 ft to the south.

6.1.3 Test Type

We performed a step-test and a 72-h constant-rate aquifer test. The step-test was conducted on 3/20/2015, and the 72-h test ran from 3/23/2015 to 3/26/2015. Water-level recovery was monitored until 3/30/2015. During the 72-h test, the time-weighted average pumping rate was 25.2 gpm. Drawdown and recovery were monitored in the pumping well and one observation well (table 6-1).

6.1.4 Hydrogeologic Setting

The stratigraphy is silt and sand with some gravel from 0 to 105 ft, semi-lithified mudstone from 105 to 145 ft, and medium to fine sand from 145 to 183 ft (appendix 6A). The wells were both installed in the deep sand zone, and the static water level was approximately 100 ft bgs. This material is the Tertiary Renova Formation (Vuke and others, 2004).

6.1.5 Hydrologic Features

This site is approximately 100 ft north of the Parrot Canal, and is located between two center pivots (fig. 6-2). The canal was shut off in October, and the test was conducted in March to minimize the effects of canal leakage. However, long-term monitoring shows that groundwater levels decrease continually while the canal is not on, and rise when it is turned on (fig. 6-3). Monitoring for this test showed that water levels were following a downward antecedent trend for the duration of the test (figs. 6-4 and 6-5). Water levels continued to decrease through late April, and rose when the canal was turned on.

6.2 Field Procedure

A step-test was performed on 3/20/2015 to determine a sustainable pumping rate for the constant-rate

Table 6-1. Well designations, locations, and completion information, Lazy TP Bench aquifer test.

GWIC ID	Name	Latitude (degrees)	Longitude (degrees)	Ground Surface Elevation (ft-amsl)	Total Depth (ft-bgs)	Screened Interval (ft-amsl)	Distance from PW (ft)	Maximum Drawdown (ft)	Aquifer	Well Type
280978	PW	45.834252	-112.047069	4441	160	4281–4291	—	12.0	Renova	Pumping
280977	OW	48.834419	-112.047125	4439	183*	4281–4291	62.4	0.9	Renova	Observation

Note. ft-amsl, feet above mean sea level; ft-bgs, feet below ground surface. All locations and elevations determined by survey. Horizontal Datum, NAD83; Vertical Datum, NAVD88.
*OW was backfilled to 160 ft bgs before completion.

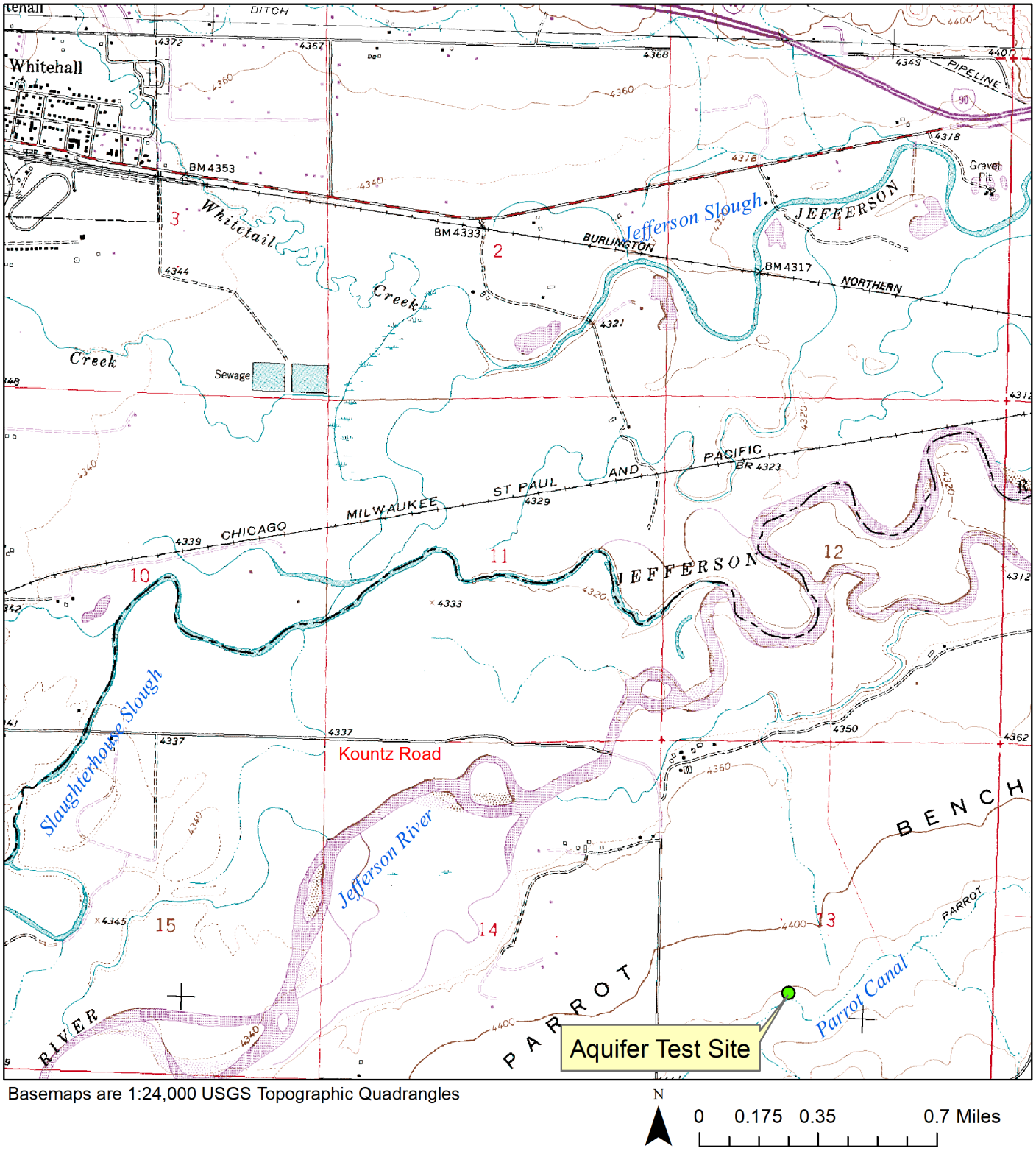

Figure 6-1. The Lazy TP bench test site is located on the Parrot Bench south of the Jefferson River, and approximately 3.5 mi southeast of Whitehall, Montana.

test. From the step-test data we determined that a pumping rate of about 25 gpm would be appropriate for the constant-rate test. The constant-rate test ran for 72-h, from 3/23/2015 to 3/26/2015.

6.3 Data Collection

Vented pressure transducers were used to record water levels at 1-min intervals in the pumping well (PW) and the observation well (OW). The vented transducers were installed with the pump on 3/17/2015, and were removed on 3/30/2015. Manual

Figure 6-2. The Lazy TP bench test site had a pumping well and an observation well completed in the Renova Formation. During the tests, water was discharged approximately 200 ft north, and downhill from the pumping well.

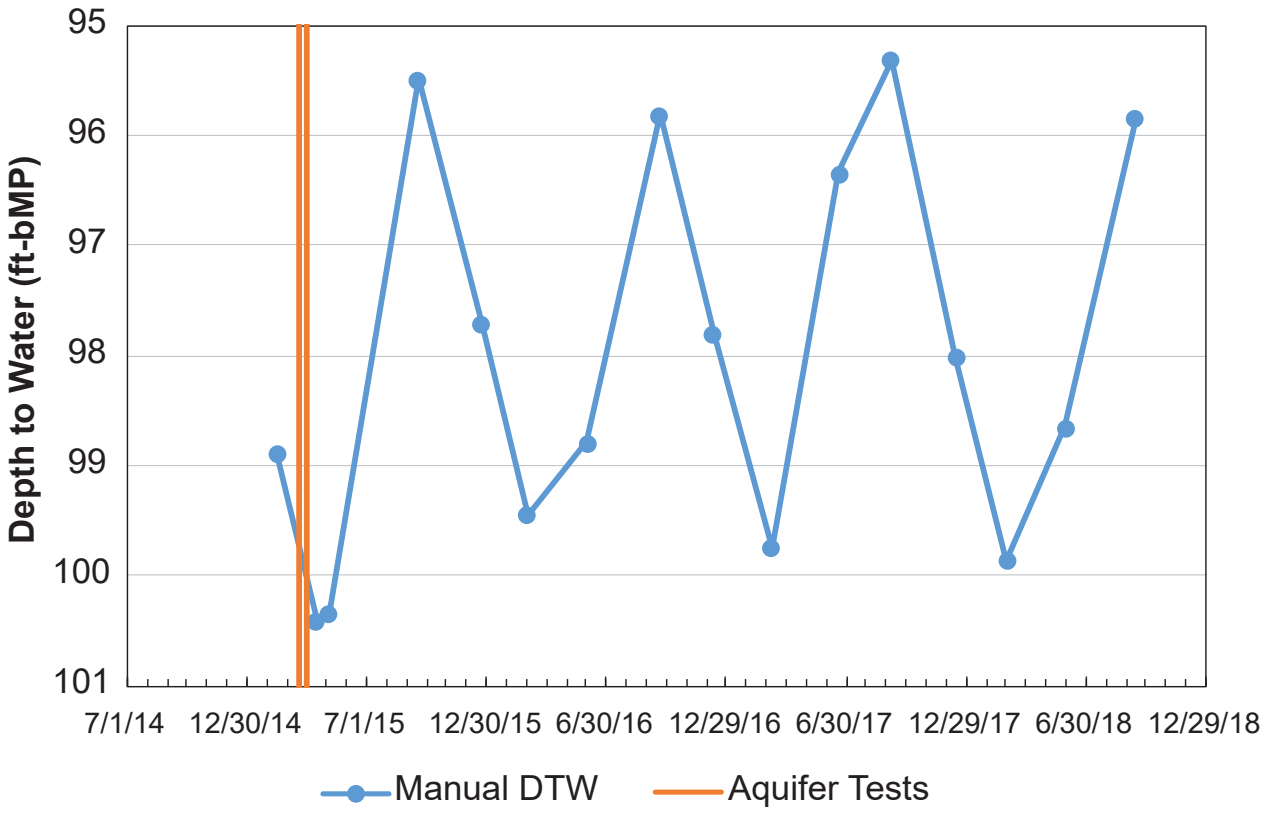

Figure 6-3. Monitoring of PW from 2015 to 2018 shows that each year water levels rise as the Parrot canal is turned on, and then fall after it is shut off. This suggests that the canal and associated irrigation affect the groundwater levels in the well despite the local confinement caused by the overlying mudstone.

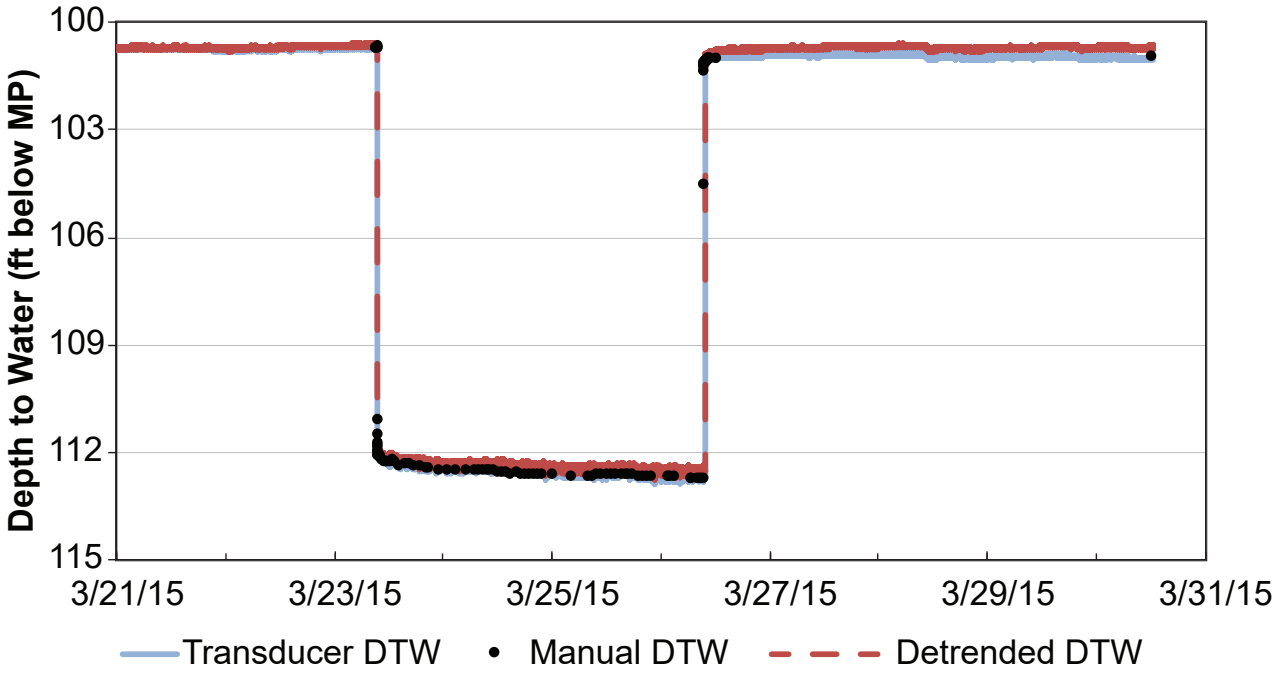

Figure 6-4. The hydrograph for PW during the constant-rate test shows a slight downward trend, so a time-weighted correction factor was applied. The maximum detrended drawdown during the test was 12.0 ft.

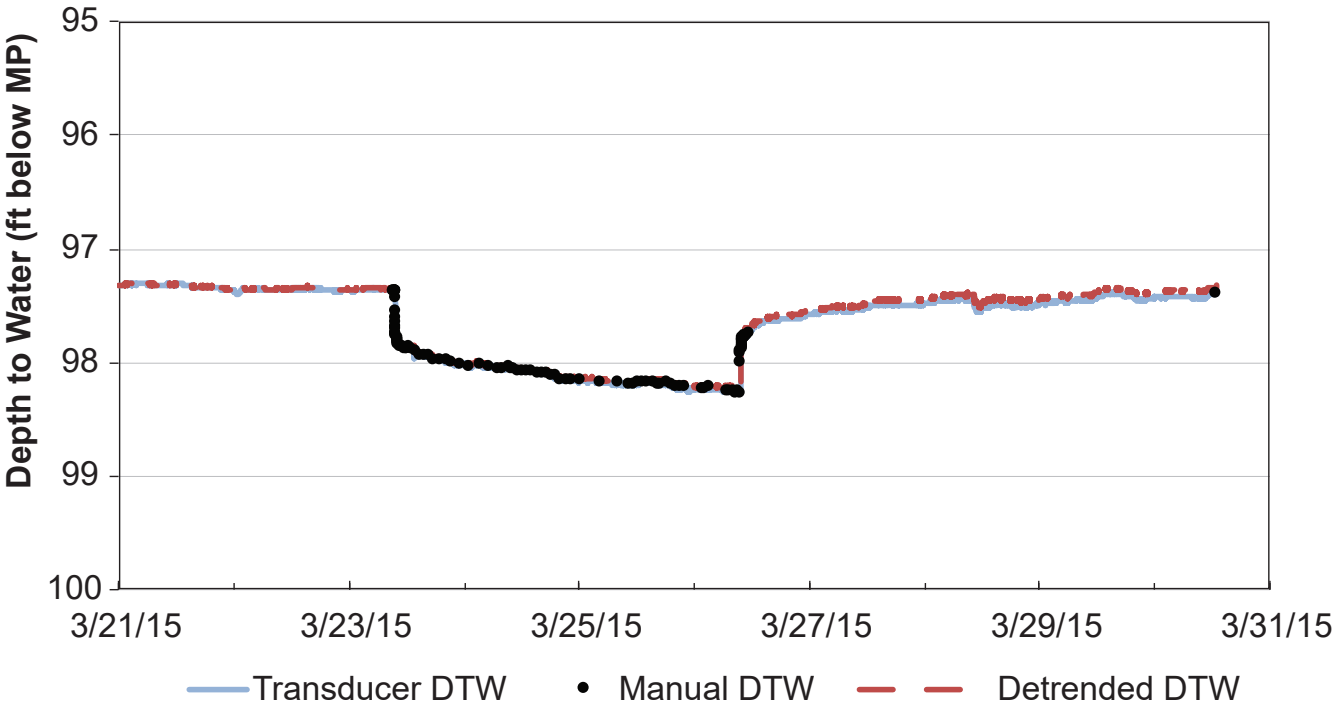

Figure 6-5. The hydrograph for OW during the constant-rate test shows a slight downward trend, so a time-weighted correction factor was applied. The maximum detrended drawdown during the test was 0.9 ft.

readings of water levels were made for all wells using an e-tape prior to placing transducers, during the test, and during recovery. These measurements were used to calibrate transducer response, and provided backup in case of transducer malfunction (figs. 6-4 and 6-5).

Pumping rates were monitored using a totalizing flow meter and bucket and stopwatch. Discharge measurements were made more frequently at the start of the test, with the average interval during the first 4 h being 10 min. The maximum interval between discharge measurements during this test was 246 min (~4 h).

All water-level data and pumping rates are available from GWIC by using the wells' GWIC ID numbers (table 6-1) and accessing the applicable aquifer test information (e.g., Form 633 data; http://mbmggwic.mtech.edu/).

6.4 Results

During the constant-rate test there was a slight downward antecedent trend. As such, a time-weighted correction was applied to the data so that static water levels before and after the test were equal (figs. 6-4 and 6-5).

6.4.1 Water-Level Response

The maximum drawdown in PW was 12.3 ft. Drawdown in this well showed a rapid initial decline followed by gradually decreasing water levels (fig. 6-4). After pumping ceased, PW reached 90% recovery in less than 2 min (fig. 6-4). Drawdown and recovery in the observation well were more gradual, and the maximum drawdown was 0.9 ft (fig. 6-5).

6.4.2 Aquifer Properties

The hydrogeologic setting, known hydrologic features, and derivative plots indicate that there was a confined response to the test (appendix 6B). Aquifer properties were determined using observations from OW and a confined solution (Theis, 1935). AQTESOLV was used to analyze the aquifer test data. These results indicated a transmissivity value of 5,800 ft^2/d and a storativity value of 5.2×10^{-5}.

6.4 Summary

The sand aquifer in the Renova Formation at this site has a transmissivity of about 5,800 ft^2/d, and a storativity of about 5.2×10^{-5}. The test results suggest that the aquifer is confined at this location, but long-term monitoring at this site indicates that this aquifer responds to changes in canal operations, indicating that the confining layer is not laterally continuous.

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Appendix 2A—HCC Floodplain 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
View scanned well log (6/9/2014 8:43:59 AM)

Site Name: HCC * MBMG OW-1
GWIC Id: 277403

Section 1: Well Owner(s)
1) HOYT, MARK (MAIL)
41 JUDD LANE
SILVER STAR MT 59751 [02/14/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	5	SE¼ SW¼ NW¼ NW¼

County	Geocode
MADISON	

Latitude	Longitude	Geomethod	Datum
45.695992448	112.254562866	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4497.24	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4499.96	SUR-GPS	NAVD88	2/14/2014

Addition **Block** **Lot**

Section 3: Proposed Use of Water
MONITORING (1)
STOCKWATER (2)

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

Section 5: Well Completion Date
Date well completed: Friday, February 14, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	94	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	30	8			WELDED	STEEL
0	74	4			THREADED	PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
74	94	4		.040	SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
3	73	SMOOTH GROUT	
73	94	10/20 GRAVEL	

Section 7: Well Test Data

Total Depth: 94
Static Water Level: 7
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
120SDMS - SEDIMENTS (TERTIARY)

From	To	Description
0	1	TOPSOIL
1	5	GREY SILT / CLAY
5	10	COARSE GRAVEL WITH SOME SILT
10	15	MEDIUM GRAVEL WITH SOME SILT
15	30	MEDIUM GRAVEL WITH LITTLE SILT
30	75	REDDISH BROWN SILTY CLAY
75	90	TAN FINE TO MEDIUM SAND WITH LITTLE CLAY
90	100	TAN MEDIUM SAND TO FINE GRAVEL 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: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: MWC-43
Date Completed: 2/14/2014

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 scanned well log (6/9/2014 8:42:28 AM)

Site Name: HCC * MBMG OW-2
GWIC Id: 277404

Section 1: Well Owner(s)
1) HOYT, MARK (MAIL)
41 JUDD LANE
SILVER STAR MT 59751 [02/17/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	5	SE¼ SW¼ NW¼ NW¼

County
MADISON

Geocode

Latitude	Longitude	Geomethod	Datum
45.696123018	112.254642993	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4497.08	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4499.86	SUR-GPS	NAVD88	2/17/2014

Addition **Block** **Lot**

Section 3: Proposed Use of Water
MONITORING (1)
STOCKWATER (2)

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

Section 5: Well Completion Date
Date well completed: Monday, February 17, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	103	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	30	8			WELDED	STEEL
0	81	4			THREADED	PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
81	103	4		.040	SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
3	81	SMOOTH GROUT	
81	103	10/20 GRAVEL	

Section 7: Well Test Data

Total Depth: 103
Static Water Level: 6.8
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	6	GREY SILTY SAND
6	10	FINE GRAVEL WITH SAND
10	16	COARSE GRAVEL WITH SAND
16	22	CLEAN COARSE GRAVEL, GOOD WATER
22	30	SILTY GRAVEL WITH SAND
30	75	MOIST BROWN SILTY CLAY, STICKY, NO WATER PRODUCTION
75	80	MEDIUM GRAVEL WITH SAND, SOME CLAY / SILT, GOOD WATER
80	94	SOFT BROWN CLAY, SOME WATER
94	96	STRINGER OF WEAKLY CEMENTED CLAY
96	100	SOFT BROWN CLAY, SOME 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: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: MWC-43
Date Completed: 2/17/2014

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 scanned well log (6/9/2014 8:41:03 AM)

Site Name: HCC * MBMG PW
GWIC Id: 277405

Section 1: Well Owner(s)
1) HOYT, MARK (MAIL)
41 JUDD LANE
SILVER STAR MT 59751 [02/18/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	5	SE¼ SW¼ NW¼ NW¼

County / **Geocode**
MADISON

Latitude	Longitude	Geomethod	Datum
45.696076144	112.254496537	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4497.28	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4499.79	SUR-GPS	NAVD88	2/18/2014

Addition / **Block** / **Lot**

Section 3: Proposed Use of Water
MONITORING (1)
STOCKWATER (2)

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

Section 5: Well Completion Date
Date well completed: Tuesday, February 18, 2014

Section 6: Well Construction Details
Borehole dimensions

From	To	Diameter
0	100	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	30	8			WELDED	STEEL
0	78	4			THREADED	PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
79	100	4		.040	SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
3	79	SMOOTH GROUT	
79	100	10/20 GRAVEL	

Section 7: Well Test Data

Total Depth: 100
Static Water Level: 6.9
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	5	BROWN SILTY SAND
5	10	GREY TO BLACK SILT AND GRAVEL
10	17	GREY SILTY GRAVEL
17	20	TAN CLEAN SAND AND GRAVEL
20	30	CLEAN GRAVEL
30	50	REDDISH BROWN SILTY CLAY
50	55	FINE TO MEDIUM SAND WITH SOME CLAY
55	60	SAND WITH SOME GRAVEL AND LITTLE CLAY
60	63	FINE TO MEDIUM SAND WITH SOME CLAY
63	65	REDDISH BROWN SILTY CLAY
65	68	FINE TO MEDIUM SAND WITH SOME CLAY
68	85	REDDISH BROWN SILTY CLAY
85	90	FINE TO MEDIUM SAND WITH SOME CLAY
90	100	REDDISH BROWN SILTY 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: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: MWC-43
Date Completed: 2/18/2014

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 scanned well log (6/9/2014 8:39:38 AM)

Site Name: HCC * MBMG OW-3
GWIC Id: 277406

Section 1: Well Owner(s)
1) HOYT, MARK (MAIL)
41 JUDD LANE
SILVER STAR MT 59751 [02/20/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	5	SE¼ SW¼ NW¼ NW¼

County MADISON **Geocode**

Latitude	Longitude	Geomethod	Datum
45.696027873	112.254535351	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4497.33	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4499.53	SUR-GPS	NAVD88	2/20/2014

Addition **Block** **Lot**

Section 3: Proposed Use of Water
MONITORING (1)
STOCKWATER (2)

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

Section 5: Well Completion Date
Date well completed: Thursday, February 20, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	30	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	10	8			WELDED	STEEL
0	18	4			THREADED	PVC

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
19	30	4		.040	SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
3	19	SMOOTH GROUT	
19	30	10/20 GRAVEL	

Section 7: Well Test Data

Total Depth: 30
Static Water Level: 6.3
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

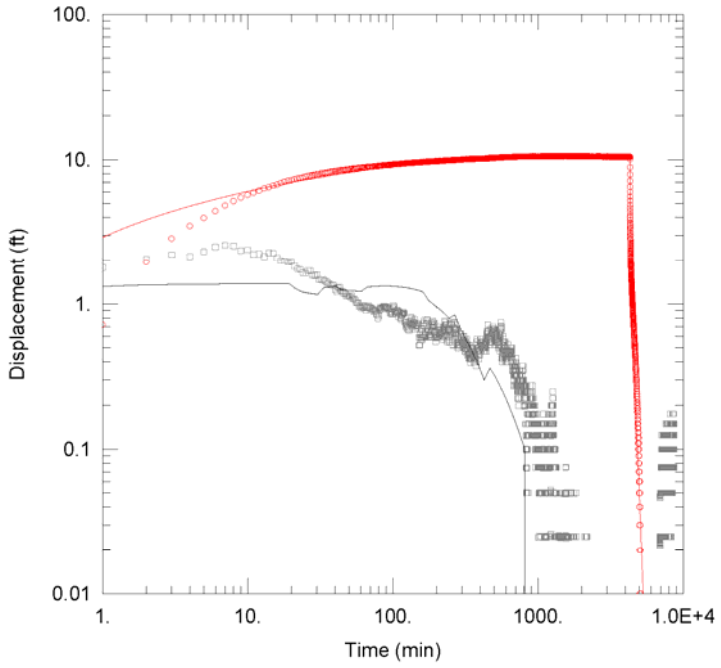
Section 9: Well Log
Geologic Source
Unassigned

From	To	Description
0	5	GREY SILT WITH LITTLE FINE SAND
5	10	GRAVEL WITH SOME GREY SILT
10	17	FINE TO MEDIUM GRAVEL WITH LITTLE SILT
17	23	CLEAN FINE TO MEDIUM GRAVEL
23	28	FINE TO MEDIUM GRAVEL WITH LITTLE SILT
28	30	REDDISH BROWN SILTY 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: DAN OKEEFE
Company: OKEEFE DRILLING CO
License No: MWC-43
Date Completed: 2/20/2014

Appendix 2B—HCC Floodplain Aquifer Test Analysis



HCCA 72HR CONSTANT RATE TEST

Data Set: M:\...\HCCA_72hr_Leaky_PW.aqt
Date: 11/15/19 Time: 13:31:49

PROJECT INFORMATION

Company: MBMG
Client: BWIPUJ
Project: Upper Jefferson
Location: HCCA
Test Well: OW1
Test Date: 2/4/15

AQUIFER DATA

Saturated Thickness: 40. ft
Aquitard Thickness (b'): 80. ft
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b"): 80. ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
OW1 (pumping)	0	0

Observation Wells

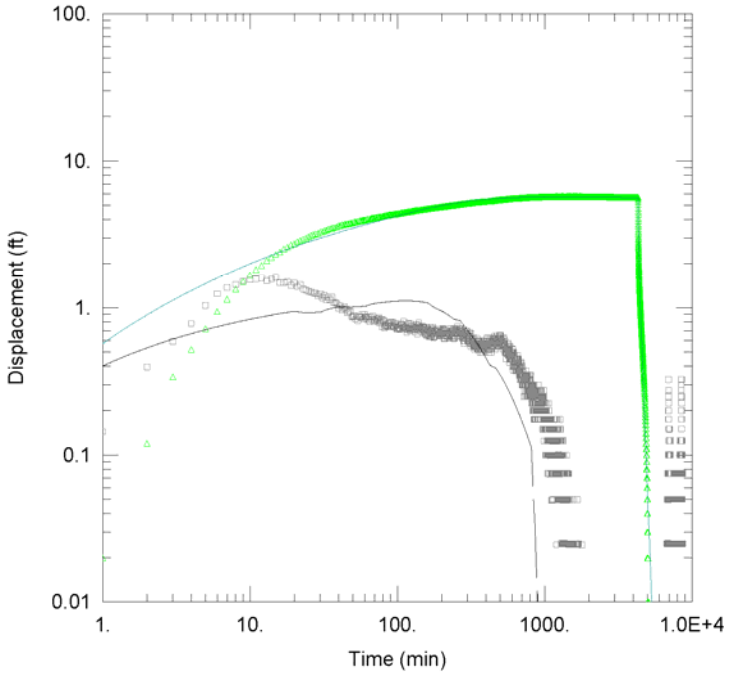
Well Name	X (ft)	Y (ft)
◦ PW	18	29.7

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 76.82 ft^2/day
1/B' = 2.879E-7 ft^{-1}
1/B" = 0.004769 ft^{-1}
S = 1.565E-5
ß'/r = 2.879E-7 ft^{-1}
ß"/r = 0.008027 ft^{-1}

The derivative plot for observation well PW (gray symbols) indicates a leaky confined aquifer, or a nearby recharge boundary (Renard and others, 2009). Testing combinations of confined and leaky-confined solutions with and without nearby recharge boundaries showed that a leaky-confined solution with no constant head boundary was the best fit with observations. Therefore, the Hantush model was used to simulate this test.



HCCA 72HR CONSTANT RATE TEST

Data Set: M:\...\HCCA_72hr_Leaky_OW2.aqt
Date: 11/15/19 Time: 11:24:07

PROJECT INFORMATION

Company: MBMG
Client: BWPUJ
Project: Upper Jefferson
Location: HCCA
Test Well: OW1
Test Date: 2/4/15

AQUIFER DATA

Saturated Thickness: 40. ft
Aquitard Thickness (b'): 80. ft
Anisotropy Ratio (Kz/Kr): 1.
Aquitard Thickness (b''): 80. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
OW1 (pumping)	0	0	OW2	-18.8	48.2

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush

T = 74.13 ft^2/day
1/B' = 5.439E-7 ft^{-1}
1/B'' = 0.008724 ft^{-1}
S = 1.494E-7
ß'/r = 2.879E-7 ft^{-1}
ß''/r = 0.281 ft^{-1}

The derivative plot for observation well OW2 (gray symbols) indicates a leaky-confined aquifer, or a nearby recharge boundary (Renard and others, 2009). Testing combinations of confined and leaky-confined solutions with and without nearby recharge boundaries showed that a leaky-confined solution with no constant head boundary provided the best fit with observations. Therefore, the Hantush model was used to simulate this test.

Appendix 3A—HCC Bench 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: MBMG-HCCB-PW
GWIC Id: 280980

Section 1: Well Owner(s)
1) MBMG-HCCB-PW (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [11/21/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	9	NE¼ NE¼ NW¼

County: MADISON
Geocode:

Latitude	Longitude	Geomethod	Datum
45.684519804	112.226762198	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4644.53	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4646.11	SUR-GPS	NAVD88	11/21/2014

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

Section 3: Proposed Use of Water
STOCKWATER (1)

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

Section 5: Well Completion Date
Date well completed: Friday, November 21, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	140	10
140	222	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	205	8	0.25		WELDED	A53B STEEL
-2	222	4			SPLINE	PVC-SCHED 160

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
212	222	4			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	50	GROUT	Y

Section 7: Well Test Data

Total Depth: 222
Static Water Level: 160
Water Temperature:

Air Test *

7 gpm with drill stem set at 218 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 160 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
120SDMS - SEDIMENTS (TERTIARY)

From	To	Description
0	10	SILT WITH SOME GRAVEL
10	15	GRAVEL
15	25	SILTY GRAVEL
25	40	SILTY GRAVEL AND SAND
40	45	SILTY SAND
45	60	SILTY GRAVEL
60	65	SILTY SAND
65	90	SILTY GRAVEL WITH SOME SAND
90	130	SILT AND FINE SAND WITH SOME GRAVEL
130	135	SILTY SAND WITH SOME GRAVEL
135	220	SILTY GRAVEL WITH SOME 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 11/21/2014

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

Site Name: MBMG-HCCB-OW
GWIC Id: 280979

Section 1: Well Owner(s)
1) MBMG-HCCB-OW (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [11/21/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
02S	05W	9	NE¼ NE¼ NW¼

County: MADISON
Geocode:

Latitude	Longitude	Geomethod	Datum
45.68463308	112.226694266	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4643.26	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4644.24	SUR-GPS	NAVD88	11/21/2014

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

Section 3: Proposed Use of Water
MONITORING (1)

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

Section 5: Well Completion Date
Date well completed: Friday, November 21, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	140	8
140	220	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	205	6	0.25		WELDED	A53B STEEL
-2	220	2			FLUSH THREAD	PVC-SCHED 80

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
210	220	2			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	50	GROUT	Y

Section 7: Well Test Data

Total Depth: 220
Static Water Level: 160
Water Temperature:

Air Test *

7 gpm with drill stem set at 218 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 160 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	10	SILT WITH SOME GRAVEL
10	30	SILTY SAND WITH GRAVEL
30	35	SILTY GRAVEL WITH SOME SAND
35	40	SILTY SAND WITH SOME GRAVEL
40	55	SILTY GRAVEL WITH SOME SAND
55	60	SILTY SAND WITH SOME GRAVEL
60	70	SAND AND GRAVEL
70	80	SILTY GRAVEL WITH SOME SAND
80	90	SILTY SAND WITH LITTLE GRAVEL
90	105	SILTY SAND WITH SOME CLAY AND LITTLE GRAVEL
105	115	SILTY CLAY WITH LITTLE SAND
115	120	SILTY GRAVEL
120	125	ANDY SILT WITH SOME GRAVEL
125	130	GRAVEL
130	135	SANDY SILT AND GRAVEL

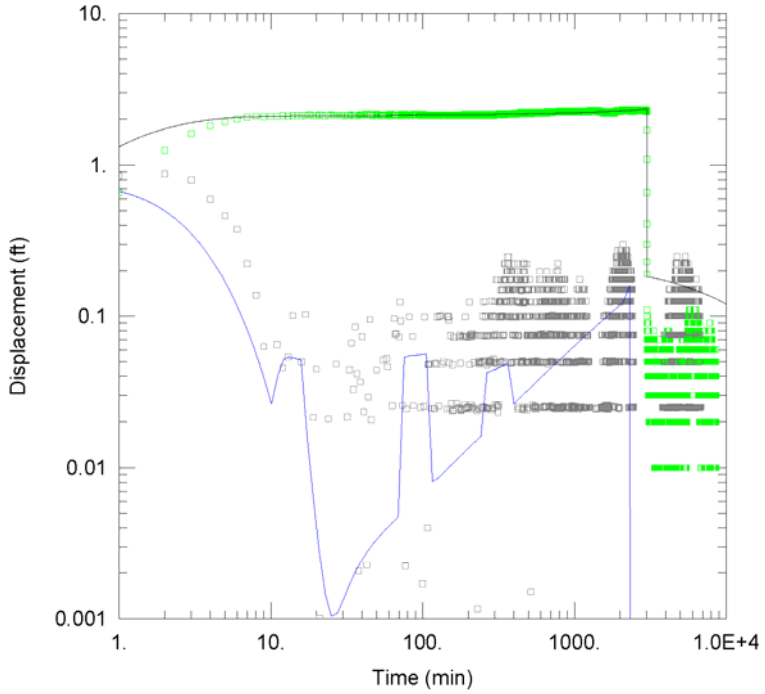
Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 11/21/2014

Site Name: MBMG-HCCB-OW
GWIC Id: 280979
Additional Lithology Records

From	To	Description
135	140	GRAVEL
140	180	SILTY GRAVEL WITH SOME SAND
180	220	SILTY GRAVEL WITH SOME SAND AND FEW COBBLES

Appendix 3B—HCC Bench Aquifer Test Analysis



HCC BENCH AQUIFER TEST

Data Set: M:\...\HCCB CR NeumanUC.aqt
Date: 11/12/19 Time: 10:16:28

PROJECT INFORMATION

Company: MBMG
Client: BWIPUJ
Project: Upper Jefferson
Location: HCC Bench
Test Well: HCCB-PW
Test Date: 2/17/15

AQUIFER DATA

Saturated Thickness: 105. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	OW	0	44.79

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 255. ft^2/day
S = 0.0001
Sy = 0.2
Kz/Kr = 1.

The derivative plot for observation well OW (gray symbols) indicates an unconfined aquifer (Renard and others, 2009). We used the Neuman solution to simulate this test.

Appendix 4A—Hunt 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

Site Name: MBMG-HA-OW1
GWIC Id: 279258

Section 1: Well Owner(s)
1) MBMG-HA-OWL (MAIL)
1300 WEST PARK
BUTTE MONTANA 59701 [07/23/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01S	05W	24	

County MADISON — **Geocode**

Latitude	Longitude	Geomethod	Datum
45.728986597	112.171933642	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4457.06	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4458.49	SUR-GPS	NAVD88	7/23/2014

Addition — **Block** — **Lot**

Section 3: Proposed Use of Water
STOCKWATER (1)

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

Section 5: Well Completion Date
Date well completed: Wednesday, July 23, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	60	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	60	6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
50	60	6	100	3/8	HOLTE PERFORATOR SLOTS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	30	GROUT	Y

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 6
Water Temperature:

Air Test *

200 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 6 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	2	TOPSOIL
2	12	SILTY SAND
12	18	CLAY
18	20	SILTY SAND AND GRAVEL
20	60	GRAVEL WITH LITTLE 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 7/23/2014

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

Site Name: MBMG-HA-OW2
GWIC Id: 279260

Section 1: Well Owner(s)
1) MBMG-HA-OW2 (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [07/28/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01S	05W	24	

County MADISON — **Geocode**

Latitude	Longitude	Geomethod	Datum
45.728929629	112.172011919	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4457.19	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4458.37	SUR-GPS	NAVD88	7/28/2014

Addition — **Block** — **Lot**

Section 3: Proposed Use of Water
STOCKWATER (1)

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

Section 5: Well Completion Date
Date well completed: Monday, July 28, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	60	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	60	6	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
50	60	6	100	3/8	HOLTE PERFORATOR SLOTS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	30	GROUT	Y

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 6
Water Temperature:

Air Test *

200 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 6 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	2	TOPSOIL
2	12	SILTY SAND
12	18	CLAY
18	20	SILTY SAND AND GRAVEL
20	60	GRAVEL WITH LITTLE 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 7/28/2014

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: MBMG-HA-PW
GWIC Id: 279259

Section 1: Well Owner(s)
1) MBMG-HA-PW (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [07/24/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01S	05W	24	

County: MADISON **Geocode:**

Latitude	Longitude	Geomethod	Datum
45.72892428	112.171926249	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4456.98	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4458.6	SUR-GPS	NAVD88	7/24/2014

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

Section 3: Proposed Use of Water
STOCKWATER (1)

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

Section 5: Well Completion Date
Date well completed: Thursday, July 24, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	60	10

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	60	10	0.25		WELDED	A53B STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
40	60	10	150	3/8	HOLTE PERFORATOR SLOTS

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	30	GROUT	Y

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 6
Water Temperature:

Air Test *

400 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 6 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

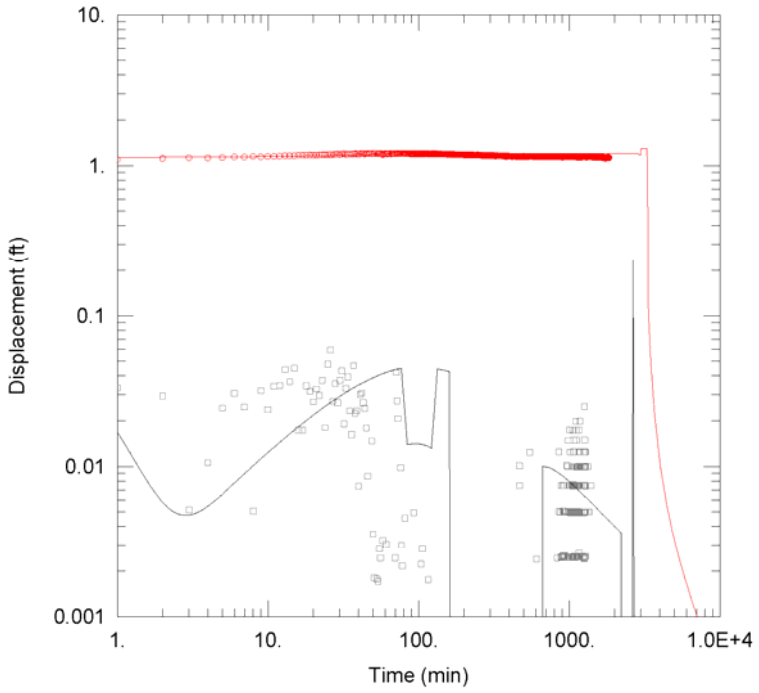
Section 9: Well Log
Geologic Source
120SDMS - SEDIMENTS (TERTIARY)

From	To	Description
0	2	TOPSOIL
2	12	SILTY SAND
12	18	CLAY
18	20	SILTY SAND AND GRAVEL
20	60	GRAVEL WITH LITTLE 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 7/24/2014

Appendix 4B—Hunt Aquifer Test Analysis



HUNTA AQUIFER TEST

Data Set: M:\...\HuntA_CR_OW1_UC_CHB.aqt
Date: 11/19/19 Time: 09:11:05

PROJECT INFORMATION

Company: MBMG
Client: HuntA
Project: BWIPUJ
Location: Upper Jefferson
Test Well: PW
Test Date: 2/24/15

AQUIFER DATA

Saturated Thickness: 100. ft

WELL DATA

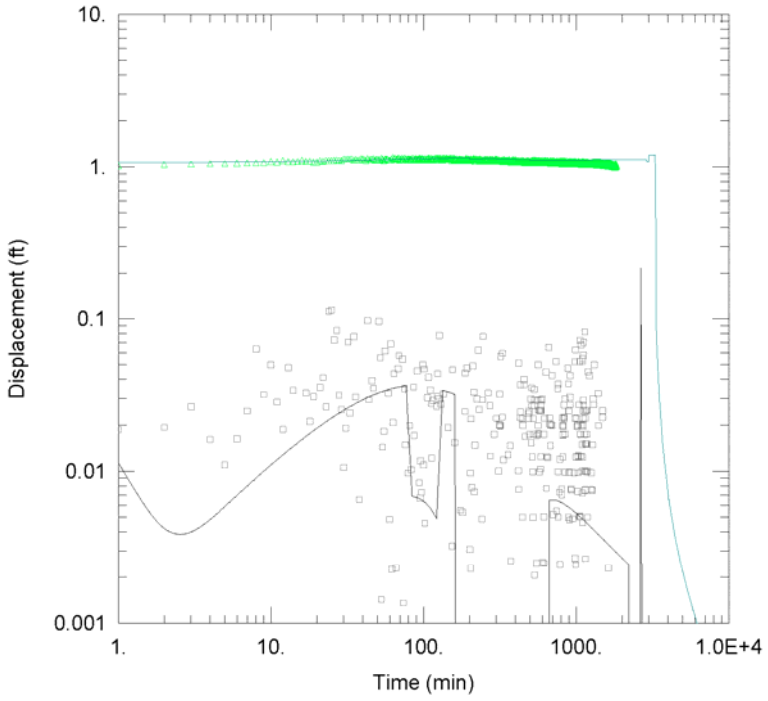
Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	○ OW1	-1.112	22.767

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 4.1E+4 ft^2/day
S = 0.0013
Sy = 0.14
Kz/Kr = 0.2

The derivative plot for observation well OW1 (gray symbols) indicates an unconfined aquifer, with a nearby recharge boundary (Renard and others, 2009). The Neuman unconfined solution was used along with a constant head boundary 100 ft to the west, representing the wetland near the site.



HUNTA AQUIFER TEST

Data Set: M:\...\HuntA_CR_OW2_UC_CHB.aqt
Date: 11/19/19 Time: 09:11:16

PROJECT INFORMATION

Company: MBMG
Client: HuntA
Project: BWIPUJ
Location: Upper Jefferson
Test Well: PW
Test Date: 2/24/15

AQUIFER DATA

Saturated Thickness: 100. ft

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
PW	0	0	△ OW2	-21.792	2.695

SOLUTION

Aquifer Model: Unconfined Solution Method: Neuman

T = 4.45E+4 ft^2/day S = 0.0013
Sy = 0.14 Kz/Kr = 0.2

The derivative plot for observation well OW2 (gray symbols) indicates an unconfined aquifer, with a nearby recharge boundary (Renard and others, 2009). The Neuman unconfined solution was used along with a constant head boundary 100 ft to the west, representing the wetland near the site.

Appendix 5A—LTP Floodplain 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

Site Name: MBMG-TPA-OW1
GWIC Id: 279261

Section 1: Well Owner(s)
1) MBMG-TPA-OW1 (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [08/05/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	04W	11	SW¼ NE¼ SW¼

County MADISON — **Geocode**

Latitude	Longitude	Geomethod	Datum
45.848587583	112.068593201	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4333.8	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4335.36	SUR-GPS	NAVD88	8/5/2014

Addition — **Block** — **Lot**

Section 3: Proposed Use of Water
MONITORING (1)

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

Section 5: Well Completion Date
Date well completed: Tuesday, August 05, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	60	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	40	6	0.25		WELDED	A53B STEEL
-2	60	2			FLUSH THREAD	PVC-SCHED 80

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
50	60	2			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	45	GROUT	Y
45	60	GRAVEL PACK	

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 7
Water Temperature:

Air Test *

30 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 7 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	4	TOPSOIL
4	20	GRAVEL AND SAND
20	25	CLAY AND GRAVEL
25	60	MUDSTONE WITH SAND SEAMS

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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 8/5/2014

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: MBMG-TPA-PW
GWIC Id: 279262

Section 1: Well Owner(s)
1) MBMG-TPA-PW (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [08/05/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	04W	11	SW¼ NE¼ SW¼

County: MADISON
Geocode:

Latitude	Longitude	Geomethod	Datum
45.84867114	112.06852844	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4333.95	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4335.22	SUR-GPS	NAVD88	8/5/2014

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

Section 3: Proposed Use of Water
STOCKWATER (1)

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

Section 5: Well Completion Date
Date well completed: Tuesday, August 05, 2014

Section 6: Well Construction Details
Borehole dimensions

From	To	Diameter
0	60	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	35	8	0.25		WELDED	A53B STEEL
-2	60	4			FLUSH THREAD	PVC-SCHED 80

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
40	60	4			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	35	GROUT	Y
33	38	BENTONITE CHIPS	
38	60	GRAVEL PACK	

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 7
Water Temperature:

Air Test *

30 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 7 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
120SDMS - SEDIMENTS (TERTIARY)

From	To	Description
0	4	TOPSOIL
4	20	GRAVEL AND SAND
20	25	CLAY AND GRAVEL
25	60	MUDSTONE WITH SAND SEAMS

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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 8/5/2014

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

Site Name: MBMG-TPA-OW2
GWIC Id: 279263

Section 1: Well Owner(s)
1) MBMG-TPA-OW2 (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [08/05/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	04W	11	SW¼ NE¼ SW¼

County	Geocode
MADISON	

Latitude	Longitude	Geomethod	Datum
45.848702902	112.068625817	SUR-GPS	NAD83

Ground Surface Altitude	Method	Datum	Date
4334.21	SUR-GPS	NAVD88	1/12/2015

Measuring Point Altitude	Method	Datum	Date Applies
4335.76	SUR-GPS	NAVD88	8/5/2014

Addition	Block	Lot

Section 3: Proposed Use of Water
MONITORING (1)

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

Section 5: Well Completion Date
Date well completed: Tuesday, August 05, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	60	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	35	6	0.25		WELDED	A53B STEEL
-2	60	2			FLUSH THREAD	PVC-SCHED 80

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
40	60	2			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	30	GROUT	Y

Section 7: Well Test Data

Total Depth: 60
Static Water Level: 7
Water Temperature:

Air Test *

30 gpm with drill stem set at 58 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 7 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

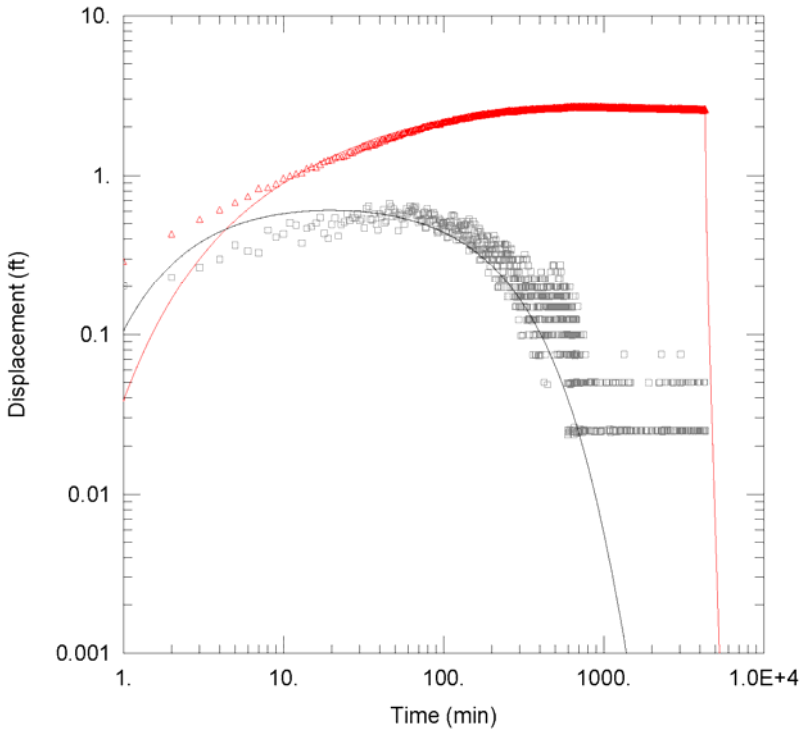
Section 9: Well Log
Geologic Source
Unassigned

From	To	Description
0	4	TOPSOIL
4	20	GRAVEL AND SAND
20	25	CLAY AND GRAVEL
25	60	MUDSTONE WITH SEAMS OF 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 8/5/2014

Appendix 5B—LTP Floodplain Aquifer Test Analysis



DEVELOPMENT STEP TEST

Data Set: M:\...\LTPA_CR_OW1_leaky.aqt
Date: 11/19/19 Time: 10:24:56

PROJECT INFORMATION

Company: MBMG
Client: TPA
Project: BWIPUJ
Location: Upper Jefferson
Test Well: PW
Test Date: 8/6/14

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW	17.5	29.9

Observation Wells

Well Name	X (ft)	Y (ft)
△ OW1	0	0

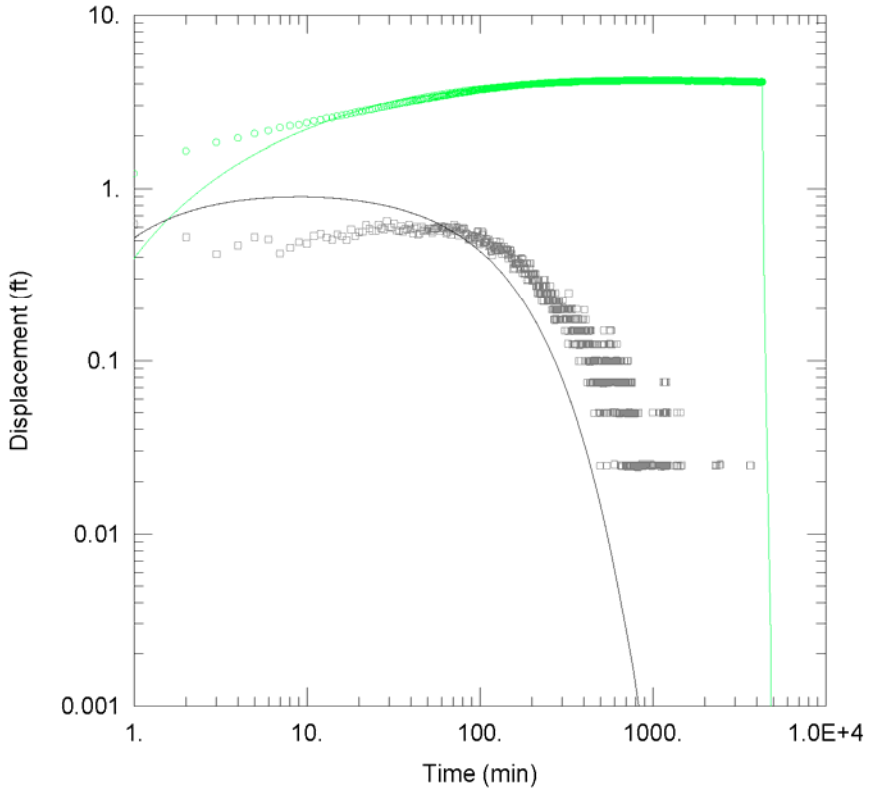
SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 440. ft^2/day
1/B = 0.0057 ft^{-1}
b = 20. ft

S = 0.002
Kz/Kr = 1.

The derivative plot for observation well OW1 (gray symbols) indicates a leaky-confined aquifer (Renard and others, 2009). We used the Hantush-Jacob leaky-confined solution, without aquitard storage, to simulate this test.



DEVELOPMENT STEP TEST

Data Set: M:\...\LTPA_CR_OW2_leaky.aqt
Date: 11/19/19 Time: 10:24:03

PROJECT INFORMATION

Company: MBMG
Client: TPA
Project: BWIPUJ
Location: Upper Jefferson
Test Well: PW
Test Date: 8/6/14

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
PW	17.5	29.9

Observation Wells

Well Name	X (ft)	Y (ft)
○ OW2	-6.9	42.3

SOLUTION

Aquifer Model: Leaky
Solution Method: Hantush-Jacob

T = 310. ft^2/day
1/B = 0.0057 ft^{-1}
b = 20. ft

S = 0.0008
Kz/Kr = 1.

The derivative plot for observation well OW1 (gray symbols) indicates a leaky-confined aquifer (Renard and others, 2009). We used the Hantush-Jacob leaky-confined solution, without aquitard storage, to simulate this test.

Appendix 6A—LTP Bench 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

Site Name: MBMG-LTPB-OW1
GWIC Id: 280977

Section 1: Well Owner(s)
1) MBMG (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [10/22/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	04W	13	SE¼ NE¼ SW¼

County MADISON — **Geocode**

Latitude	Longitude	Geomethod	Datum
45.834444	112.046944	NAV-GPS	NAD27

Ground Surface Altitude	Method	Datum	Date
4439	DEM	NAVD88	8/21/2015

Measuring Point Altitude	Method	Datum	Date Applies
4440.5	MAP	NAVD88	10/22/2014

Addition — **Block** — **Lot**

Section 3: Proposed Use of Water
MONITORING (1)

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

Section 5: Well Completion Date
Date well completed: Wednesday, October 22, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	100	8
100	183	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	183	6	0.25		WELDED	A53B STEEL
-2	160	2			FLUSH THREAD	PVC-SCHED 80

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
150	160	6	50	3/8	HOLTE PERFORATOR SLOTS
150	160	2			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	50	GROUT	Y

Section 7: Well Test Data

Total Depth: 183
Static Water Level: 92
Water Temperature:

Air Test *

40 gpm with drill stem set at 160 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 72 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	2	TOPSOIL
2	15	LIGHT TAN SILT AND FINE SAND WITH LITTLE GRAVEL
15	20	FINE TO MEDIUM GRAVEL
20	30	LIGHT TAN SILT AND FINE SAND WITH SOME GRAVEL
30	65	LIGHT TAN SILT WITH SOME FINE SAND
65	70	LIGHT TAN SILT WITH SOME FINE SAND AND LITTLE GRAVEL
70	80	LIGHT TAN SILT WITH SOME FINE SAND
80	90	LIGHT TAN SILT WITH SOME FINE SAND AND SOME GRAVEL
90	98	FINE TO MEDIUM GRAVEL
98	105	MDIUM SAND WITH LITTLE SILT
105	120	SEMI-LITHOFIED MUDSTONE WITH LITTLE SAND
120	130	SEMI-LITHOFIED MUDSTONE WITH TRACE SAND
130	135	SEMI-LITHOFIED MUDSTONE WITH SOME SAND
135	145	SEMI-LITHOFIED MUDSTONE WITH TRACE SAND
145	183	FINE TO MEDIUM 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-607
Date Completed: 10/22/2014

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: MBMG-LTPB-PW
GWIC Id: 280978

Section 1: Well Owner(s)

1) MBMG-LTPB-PW (MAIL)
1300 WEST PARK
BUTTE MONTANA N/A [10/22/2014]

Section 2: Location

Township	Range	Section	Quarter Sections
01N	04W	13	SW¼ NE¼ SW¼

County	Geocode
MADISON	

Latitude	Longitude	Geomethod	Datum
45.834444	112.046944	NAV-GPS	NAD27

Ground Surface Altitude	Method	Datum	Date
4441	DEM	NAVD88	8/21/2015

Measuring Point Altitude	Method	Datum	Date Applies
4442.5	MAP	NAVD88	10/22/2014

Addition	Block	Lot

Section 3: Proposed Use of Water

STOCKWATER (1)

Section 4: Type of Work

Drilling Method: ROTARY
Status: NEW WELL

Section 5: Well Completion Date

Date well completed: Wednesday, October 22, 2014

Section 6: Well Construction Details

Borehole dimensions

From	To	Diameter
0	100	10
100	158	8

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
-2	100	8	0.25		WELDED	A53B STEEL
-2	158	4			SPLINE	PVC-SCHED 160

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
148	158	4			SCREEN-CONTINUOUS-PVC

Annular Space (Seal/Grout/Packer)

From	To	Description	Cont. Fed?
0	50	GROUT	Y

Section 7: Well Test Data

Total Depth: 158
Static Water Level: 72
Water Temperature:

Air Test *

40 gpm with drill stem set at 156 feet for 1 hours.
Time of recovery 1 hours.
Recovery water level 72 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

120SDMS - SEDIMENTS (TERTIARY)

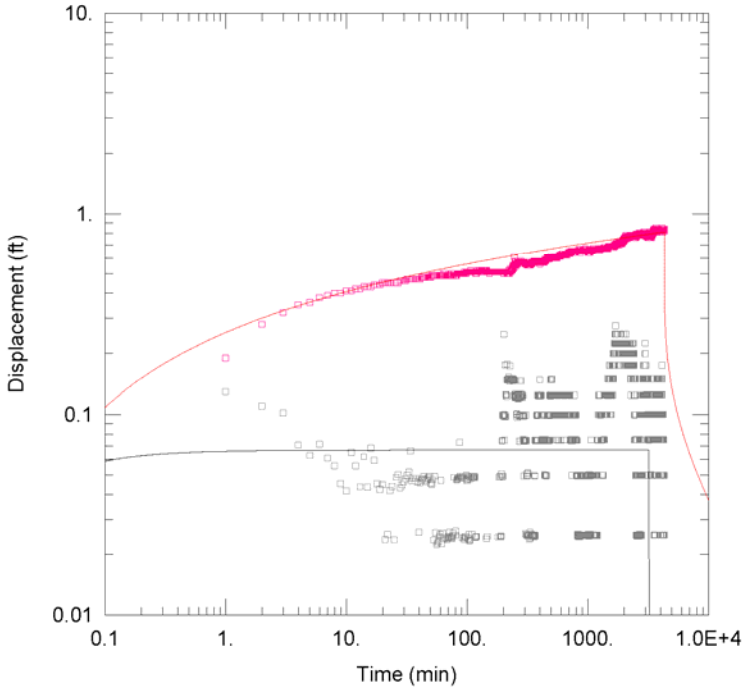
From	To	Description
0	2	TOPSOIL
2	20	SILT WITH SOME MEDIUM GRAVEL
20	35	TAN FINE SAND AND SILT WITH SOME MEDIUM GRAVEL
35	45	FINE SAND WITH SOME SILT AND CLAY
45	70	SILT AND CLAY WITH SOME SAND AND GRAVEL
70	90	SILT AND SAND WITH SOME MEDIUM GRAVEL
90	95	SAND AND GRAVEL
95	105	GRAVEL WITH SOME SAND
105	120	SEMI-LITHOFIED MUDSTONE WITH SOME MEDIUM SAND
120	125	SEMI-LITHOFIED MUDSTONE WITH SOME SAND AND GRAVEL
125	140	SEMI-LITHOFIED MUDSTONE
140	145	MEDIUM TO COARSE SAND WITH LITTLE MUDSTONE
145	160	FINE TO MEDIUM 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: RYAN LINDSAY
Company: LINDSAY DRILLING CO INC
License No: WWC-807
Date Completed: 10/22/2014

Appendix 6B—LTP Bench Aquifer Test Analysis



LAZY TP BENCH AQUIFER TEST

Data Set: M:\...\LTPB_CR_OW.aqt
Date: 11/19/19 Time: 10:48:54

PROJECT INFORMATION

Company: MBMG
Client: BWIPUJ
Project: Upper Jefferson
Location: Lazy TP Bench
Test Well: LTPB-PW
Test Date: 3/20/15

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (ft)	Y (ft)	Well Name	X (ft)	Y (ft)
LTPB-PW	0	0	LTPB-OW	15.12	60.58

SOLUTION

Aquifer Model: Confined Solution Method: Theis

T = 5793.3 ft^2/day S = 5.189E-5
Kz/Kr = 1. b = 40. ft

The derivative plot for the observation well OW (gray symbols) indicates a confined aquifer (Renard and others, 2009). We used the Theis solution to simulate this test.