Big Sky County Water and Sewer District No. 363

MOUNTAIN TEST WELL DRILLING PROJECT 2019 - 2022

September 2022

Western Groundwater Services, LLC
6595 Bear Claw Lane
Bozeman, MT 59715
(406) 585-5947
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WESTERN GROUNDWATER SERVICES

PROJECT SUMMARY

Big Sky County Water and Sewer District No. 363 (District) completed a test well drilling project in Mountain Village from 2019 to 2022 (**Figure 1**). Drilling contractor services were bid for 2019 including two test wells, and for 2020 including nine test wells. The 2019 work was awarded to Potts Drilling Inc. The 2020 work was awarded to Bridger Drilling Inc. Western Groundwater Services, LLC provided hydrogeology services to the District for both drilling phases and a planning project prior to drilling.

The 2019 work was amended to include a pumping test in test well TW#2. The 2020 work was also amended to include pumping tests in test wells TW#7 and TW#8. Potts Drilling Inc. completed the TW#2 and TW#7 pumping tests. Bridger Drilling Inc. completed the TW#8 pumping test.

Prior to drilling, a test well plan was prepared to identify target aquifers and drill sites. Drilling and testing work is documented in four subsequent memorandums. The test well plan and test well memorandums are provided in Attachments A thru E. All of the drill sites were located on Big Sky Resort LLC property.

Total drilled footage was 6,103 feet completing 11 test wells designated TW#1 through TW#11. Test well TW#9 was terminated prior to total depth when Middle Fork Properties, LLC refused access to the drill site across their property as a means to obstruct drilling of the well. This well has been capped and may be re-entered at a later date.

Drilling contractor services including three pumping tests have a total fee of $244,253. Consulting services from initial planning work through site work and documentation total $114,416. The combined total expense for contractor and consultant services was $358,669.

Test wells were located to target three different aquifer formations: 1) recent alluvium deposits; 2) intrusive igneous rock; and 3) sedimentary rock of the Kootenai formation. At this time, none of the test well sites are targeted for permanent production wells. Each memorandum provides details as to the findings of drilling and testing work and the potential yields of production wells at the sites were applicable.

The TW#9 site appears to have good water production potential based on testing in neighboring wells. There is iron and manganese in the groundwater at this location that may require treatment. Water right permitting of wells at this location may be more difficult due to proximity of the Middle Fork channel.

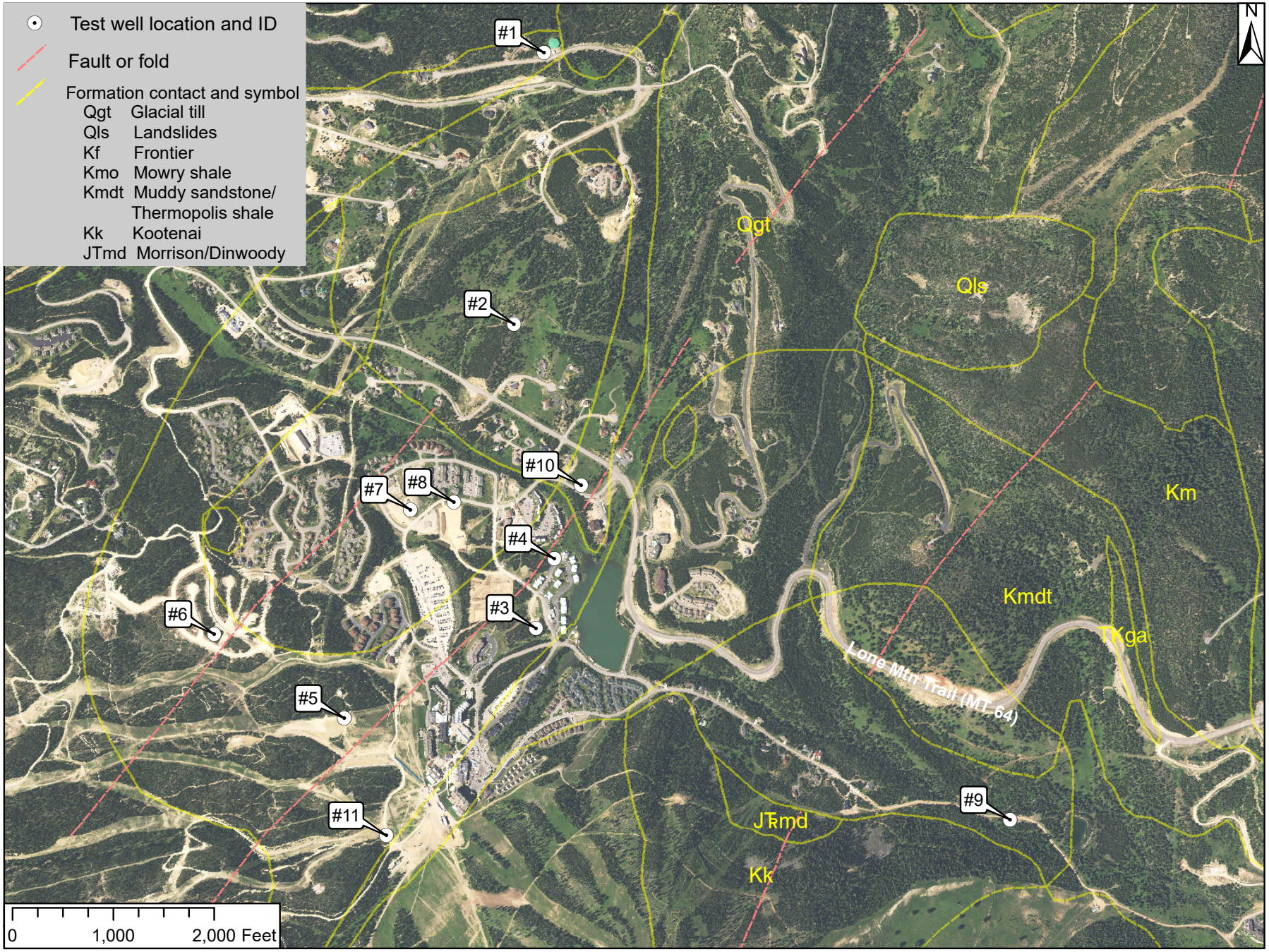


Figure 1. Test Well Location Map

ATTACHMENT A – TEST WELL PLAN

MEMORANDUM

WESTERN GROUNDWATER SERVICES
6595 Bear Claw Lane • Bozeman, MT 59715
(406) 585-5947

To: Ron Edwards, Jim Muscat
Big Sky County Water and Sewer District No. 363
Fr: Mark Cunnane
Re: Mountain Village Test Well Plan
Date: June 28, 2019

This memo provides locations, depths and cost data for constructing test boreholes to evaluate water well sites at Mountain Village. It also includes cost data for production wells, including controls, treatment, and transmission infrastructure. Modifications to two existing wells at Mountain Village and a new Madison aquifer well are also considered.

1. SUMMARY

- The well sites identified can be used to construct wells into the Kootenai aquifer using the air-rotary method. Test boreholes can be installed to verify conditions prior to construction of full size production wells. Treatment for hydrogen sulfide gas and iron may be required.

- Deepening of wells MTN-5 and MTN-6 is an option to use these wells for exploration of deeper groundwater. It is possible to drill into the Kootenai aquifer at the location of MTN-5, and to a sandstone interval in the Thermopolis shale in MTN-6. The completion work is technically difficult, however, and it is more advisable to construct replacement wells at both locations for slightly greater costs.

- A Madison well constructed at one of the identified drill sites has an estimated depth of 3,000 ft. There is potential for greater well capacity from the Madison aquifer than from shallower bedrock aquifers. The yield and quality are, however, uncertain.

2. WELL SITES

The Water System Source Capacity Update[1] identified candidate drill sites based on bedrock geology and the occurrence of an anticline fold located in proximity to existing Mountain Village Wells #5 and #6 (MTN-5, MTN-6). The anticline fold is concave down and has been informally designated the Middle Fork Anticline by the U.S. Geological Survey.[2] Anticline folds generally can have associated tension fractures along the hinge, which may enhance permeability. The hinge location also provides the shallowest drilling depths to deeper formations. Test wells, and if successful, the production wells, are planned to be drilled into the anticline hinge for these reasons.

There is no guarantee that the hinge area will result in successful well sites, but only that the test well sites are being located based on geological considerations that have been favorable at other locations. It does not appear that other bedrock wells owned by the District (MTN-4 thru MTN-7) were targeting a geologic structure.

1 Western Groundwater Services, LLC (2015) Water System Source Capacity Update, report to Big Sky County Water and Sewer District No. 363

2 Tysdal, R. G. et al. (1986) GSA Bull., v. 97, p. 859-868; Kellogg, K. S. et al. (1992) AAPG Bull., v. 79, no. 8, p. 1117-1137.

The anticline fold was evaluated by inspection of rock outcrops and measurement of rock orientation using standard geological practices (**Figure 1**). Measurements taken in the Highway 64 (MT64) roadcut at White Otter Road show the fold to be upright and symmetrical. The axial surface of the fold is subvertical with possibly an easterly dip. The fold continues north for about 2,000 feet, where is blends into a large syncline fold (concave up) with an axis oriented northwesterly (see below). To the south, the fold is faulted with left-lateral movement, resulting in a shift in the fold axis of about 200 ft east.

The bedrock occurring in the fold hinge at the intersection of White Otter Road and MT64 is the basal sandstone of the Thermopolis Shale (**Figure 2**). This formation directly overlies the Kootenai Formation, which has a basal sandstone aquifer utilized at other locations in the Big Sky area. Based on well logs for existing Kootenai wells, it is shown to be the most consistently productive of shallower bedrock formations, with initial test rates reaching 450 gpm, but not always. The water quality also can require treatment for hydrogen sulfide gas and iron. The aquifer has not been drilled in the vicinity of the Middle Fork Anticline structure. The purpose of test borings is to assess yield and water quality potential of the Kootenai at the planned drill sites.

The drill sites shown vary in land surface elevation by about 100 ft. The northerly site is estimated to penetrate the Kootenai at a depth of 650 feet, and the southerly site at 550 ft. These drilling depths are accessible by the air-rotary method and can be completed by several local drilling firms. The northerly site is located on land owned by Big Sky Resort, LLC, and the southerly site is also privately owned. Access through easements or land purchase is required to build the well projects.[3]

One of the special conditions occurring at Big Sky is the occurrence of volcanic intrusive rocks, which occur in Lone Peak, Fan Mountain, Pioneer Mountain, and numerous sills (parallel to bedding) and dikes (cross-cutting bedding) of the sedimentary rocks of the area. It is possible the test wells could intercept intrusive sills at the drill sites. The intrusive rock could provide favorable conditions for groundwater development or could increase the required drilling depth. Both MTN-4 and MTN-7 produce groundwater from intrusive sills in the Mowry Formation.

Groundwater recharge to wells located in the Middle Fork Anticline would be primarily derived from the upland area to the north (**Figure 3**). The outcrop belt for the Kootenai aquifer is estimated to have an effective recharge area of about 450 acres. If only infiltration of precipitation onto the land surface is considered, total annual recharge would be in the range from about 450 to 900 acre-feet. Surface waters that flow across the outcrop area can add to this quantity, however, there are few of such streams present. This information indicates the recharge quantity could be small and could be indicating limited capacity of the aquifer. The occurrence of the Big Sky syncline between the Middle Fork Anticline and the recharge area is also considered unfavorable, as groundwater recharge must flow through the syncline. Syncline hinge areas are not considered favorable for permeability and could limit flow. This structure could have been a factor in the poor production from the Blue Grouse well that also penetrates the Kootenai.

3 Based on discussion with MDT the large right-of-way for MT64 is not likely available for above ground utilities, such as a wellhead or control building, however, this could be further evaluated. One drawback to locating facilities in the State right-of-way is the requirement to move the facility upon request and pay 25% of the moving costs.

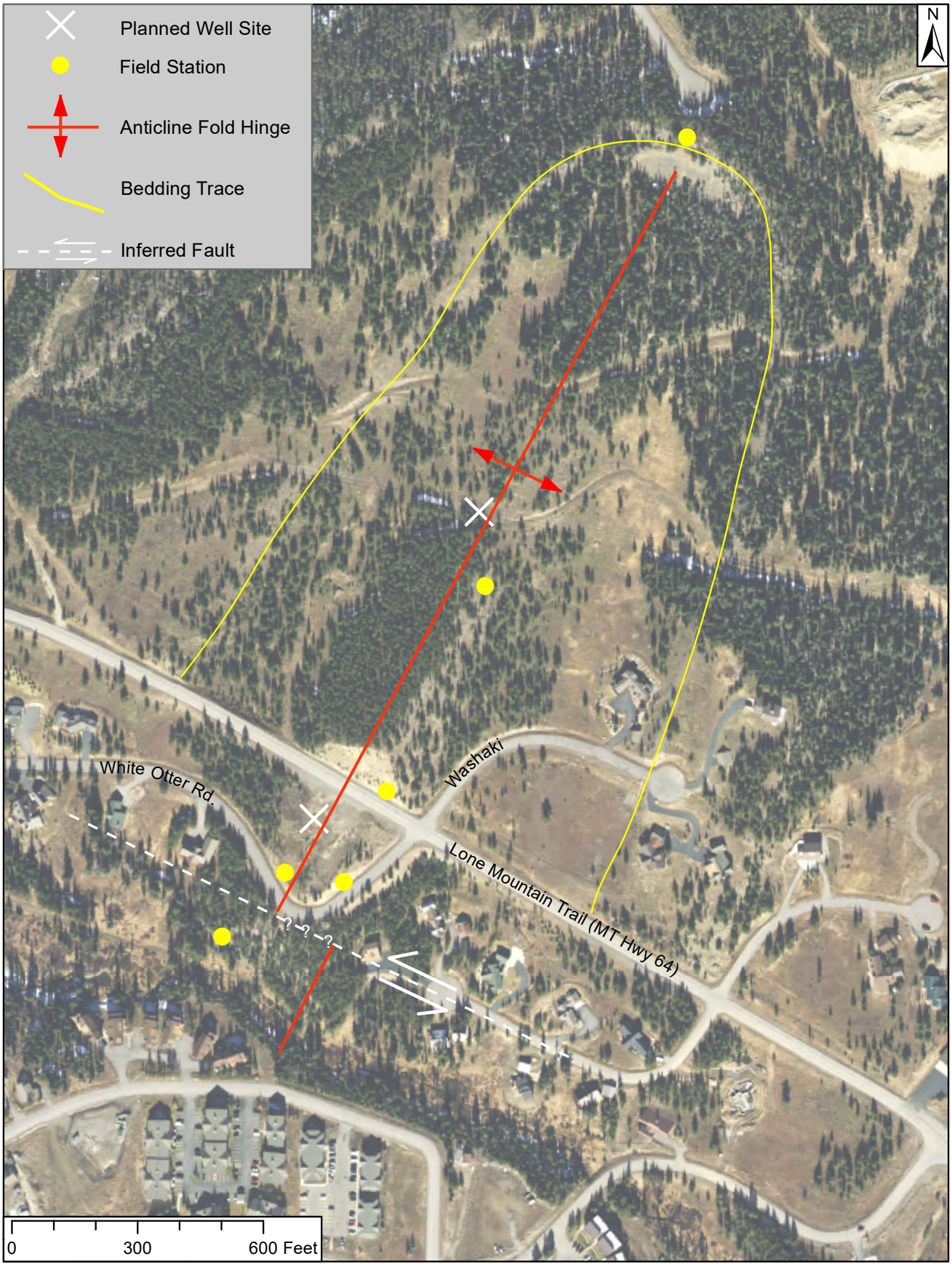


Figure 1. Geology Evaluation Map

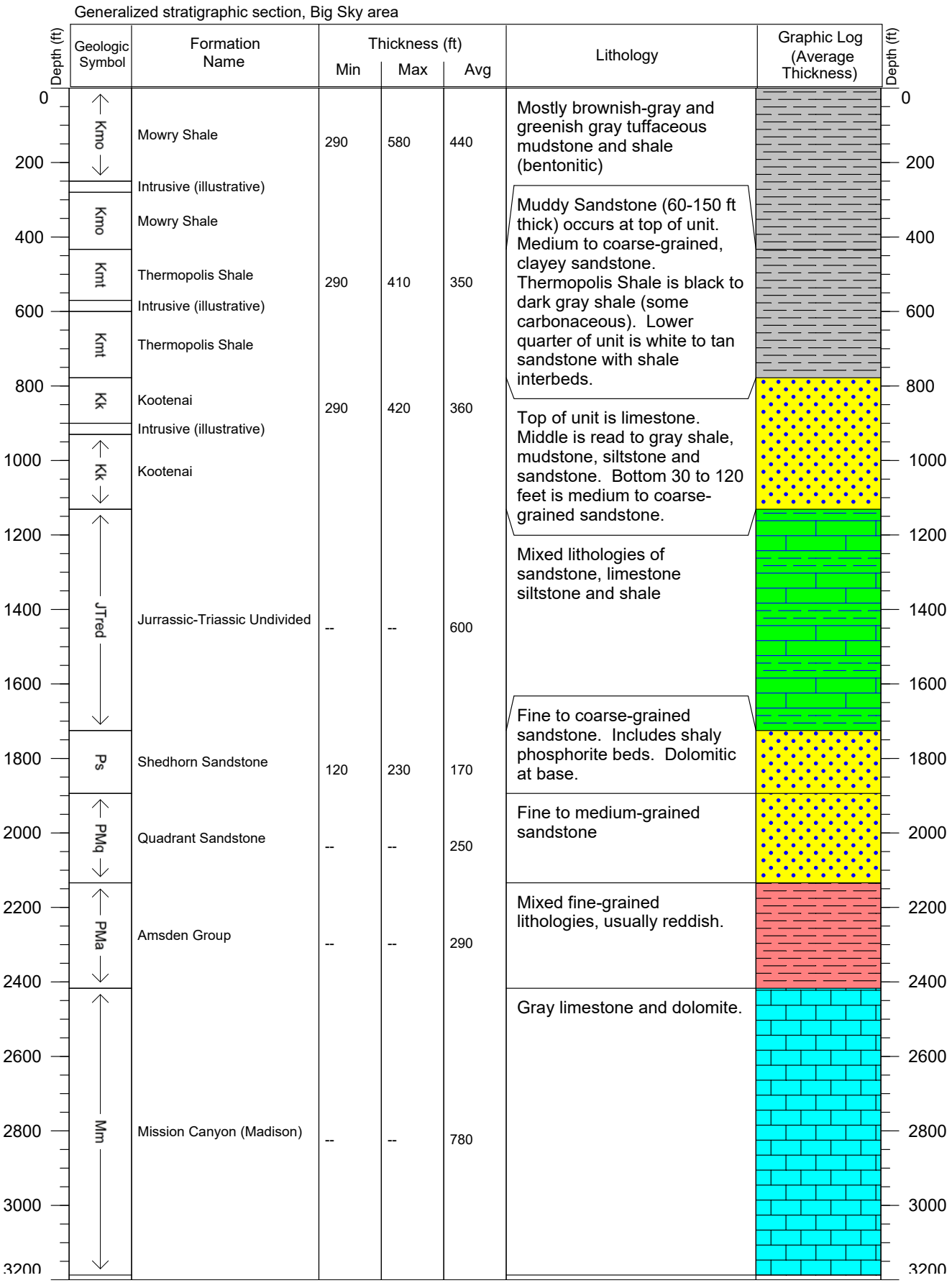


Figure 2. Rock Types and Thicknesses

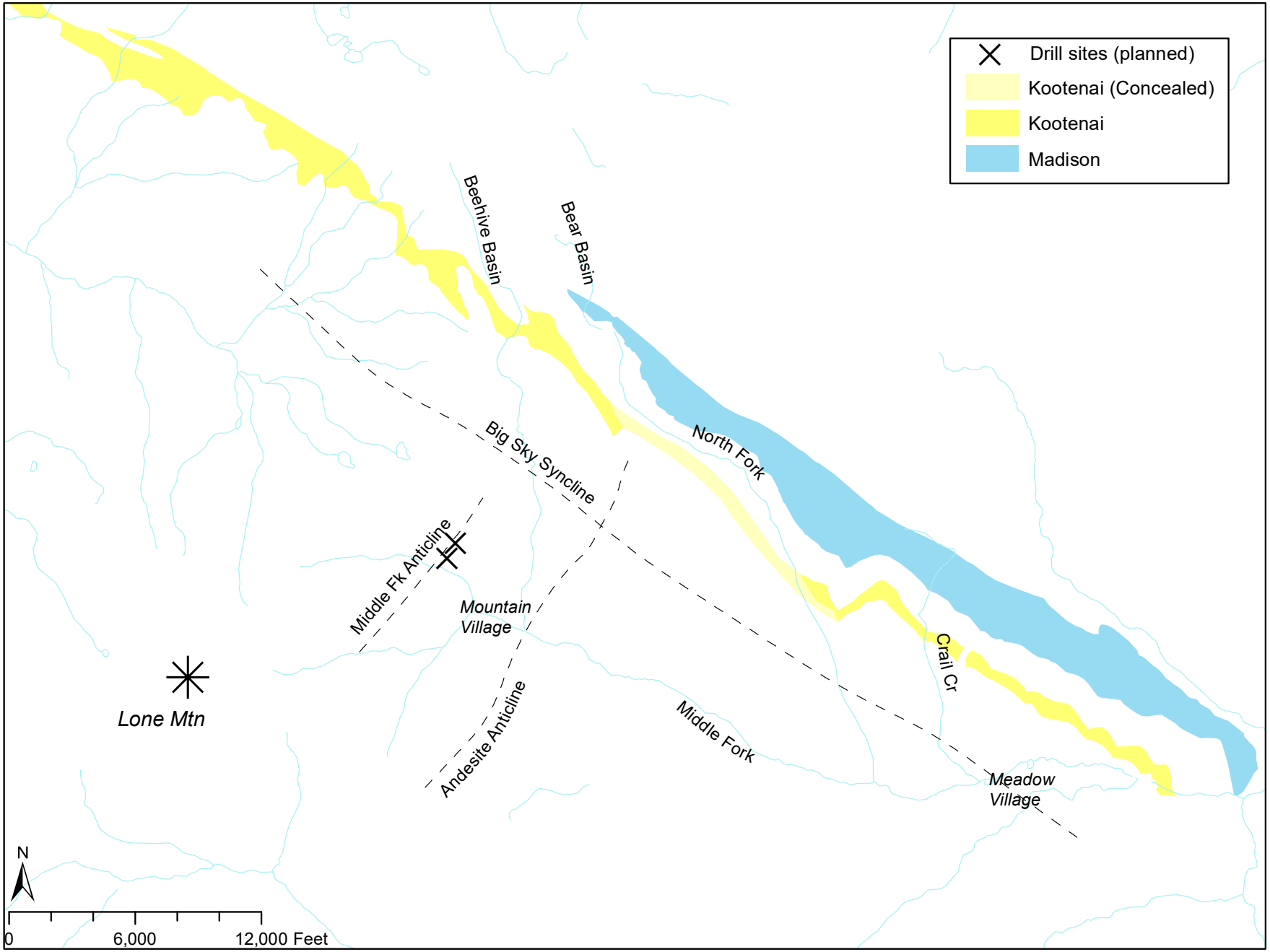


Figure 3. Aquifer Formation Outcrop Areas

3. KOOTENAI AQUIFER WELLS

Cost data was developed for a project to construct two Kootenai aquifer wells at the sites identified on the Middle Fork Anticline. The project includes the construction of two test wells that would be used as pilot boreholes for production wells. A common control building would be constructed and treatment for hydrogen sulfide gas odor by chlorination is included. Based on discussion with Northwestern Energy, it was considered that three-phase power is present in the MT64 right-of-way. A cost summary is provided in **Table 1** and a detailed cost estimate is attached. The infrastructure plan is shown on **Figure 4**. One advantage to evaluating the Kootenai aquifer at the identified drill sites is the ability to use the air-rotary method and local drilling companies. The installation of test wells also enables a limited investment to be made to verify conditions ahead of production wells.

Table 1. Kootenai Well Project (Two Wells) Cost Summary

Description	Total
Test/Pilot Boreholes	$ 47,400
Production Well MTN-8	$ 144,350
Production Well MTN-9	$ 163,850
Well Completion (pumps, controls, treatment, transmission)	$ 615,400
Subtotal	$ 971,000
Engineering (25%)	$ 242,750
Contingency (10%)	$ 121,375
Total	$ 1,335,125
SRF Reserve (10%)	$ 133,513
SRF Loan Fees (counsel, admin)	$ 30,000
Total with SRF Funding	$ 1,498,638

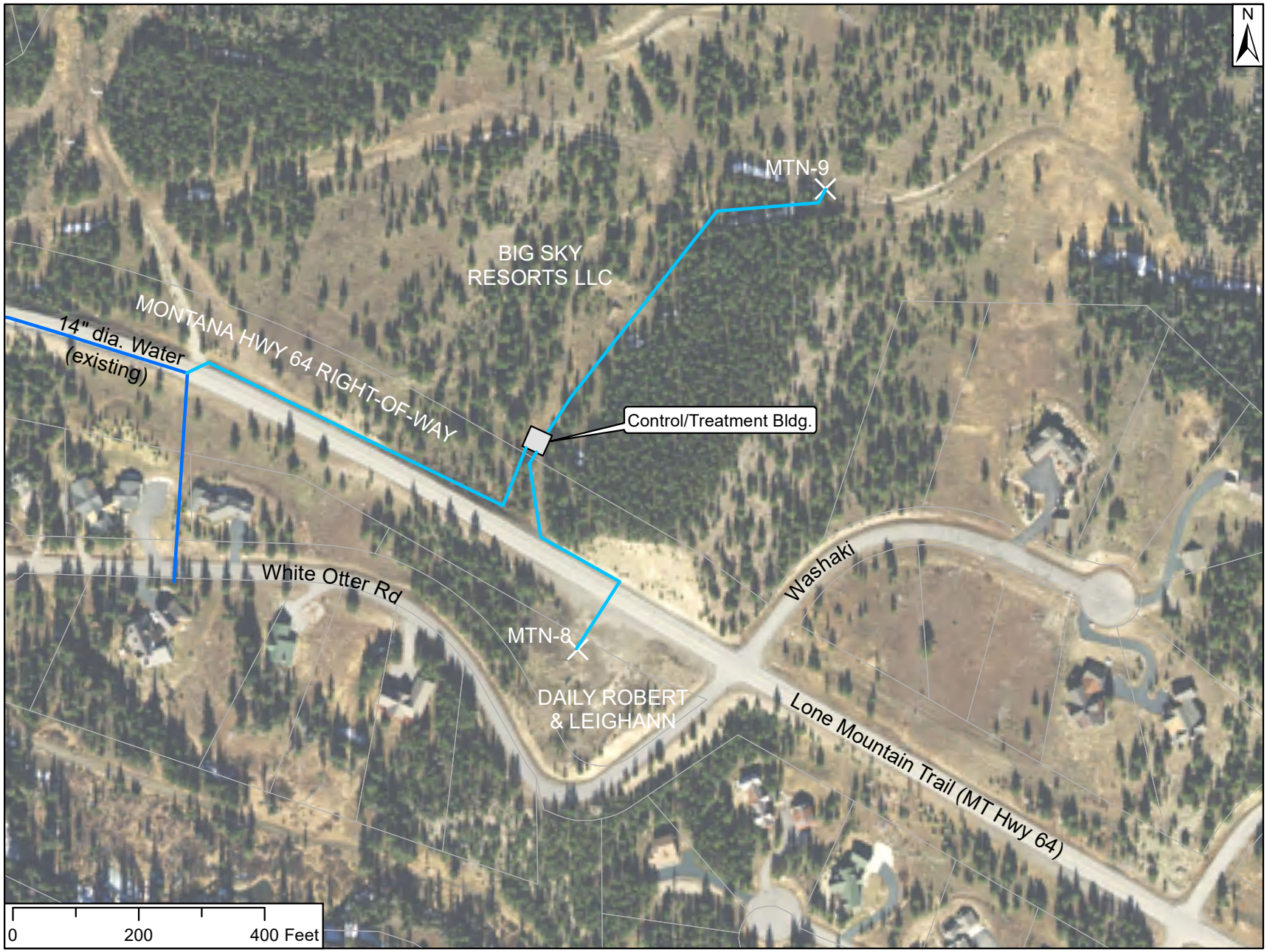


Figure 4. Infrastructure Plan

4. MODIFICATION OF WELLS MTN-5 AND MTN-6

Both MTN-5 and MTN-6 are located on the west limb of the Middle Fork Anticline south of the fault that offsets the anticline hinge. MTN-5 appears to be drilled into the upper part of the Kootenai, whereas MTN-6 appears to be in the Thermopolis shale. MTN-5 is producing groundwater from fractured sandstone; MTN-6 is producing groundwater from fractured shale. Both wells produce water of objectional aesthetic quality caused by hydrogen sulfide gas. It is uncertain that deepening of one or both wells would result in improved water capacity or quality.

Rock orientation measured in an outcrop of the Thermopolis basal sandstone at the location of MTN-5 determined a westerly dip of 35°. Assuming this dip applies to the general area of MTN-5 and MTN-6 drill depths to modify both wells to fully penetrate the Kootenai aquifer were calculated. MTN-5 is estimated to fully penetrate the Kootenai at a depth of 625 ft. MTN-6, located 830 ft west, is estimated to penetrate the basal sandstone of the Thermopolis at 700 ft. MTN-6 would fully penetrate the Kootenai at about 1,200 ft but that project would require mud-rotary drilling, and so is not considered at this time. At both well sites it is also possible to penetrate intrusive sills.

MTN-5 and MTN-6 are both constructed with 8-inch diameter steel well casing. The casing of MTN-5 extends to 180 ft with the lower 20 ft of the well completed as open hole. The casing of MTN-6 extends to the total depth of 200 ft and is perforated below 160 ft. Both wells have seals compliant with public water rules and could be modified by drilling deeper.

A water right filing may not be required to deepen the wells depending on if DNRC considers the Kootenai and shallower aquifers as one system. The requirement for this filing needs to be verified with DNRC.[4] Any work to deepen the wells will however require review and approval by DEQ. This submittal requires an engineering report, plans and specifications. The site ownership and control zone could be evaluated and result in a requirement for a deviation request due to surface water within 100 ft of the wellhead.[5]

Construction work to deepen the wells would include: 1) accessing the wells by removing pumps and disconnecting the wells from the water system; 2) drilling a 7-7/8 inch diameter borehole to total depth; 3) running a wireline log to identify the sandstone intervals; 4) setting and cementing a 5-inch diameter liner casing into the well; 5) conducting development and pump testing; and 6) re-connecting the well to the water system. The use of a 5-inch diameter liner will limit the pump setting depth in these wells. The top of the liner in MTN-5 would be at about 160 ft. The top of liner in MTN-6 would be about 150 ft. The pump would be set with the motor a couple feet above the top of the liner.

A cost summary for this work is provided in **Table 2**, and a detailed estimate is attached. The installation of a liner casing set from a liner hanger and with cement pumped down the inside of the well casing is a routine oil field technique but is not routinely completed by local drillers. This aspect of the project adds to uncertainty in the quality of the completed well and the cost estimate. A completely new replacement well adjacent to the existing wells is a slightly more expensive alternative but is technically more feasible for local drilling firms.

4 Because the water right for MTN-5 and MTN-6 has a completion date of 12/31/2032, a change filing should not encounter much difficulty, as the water right is still being perfected. This status also allows for new wells to be added to the water right for uses up to the appropriated rate and volume.

5 DEQ could limit their review to the downhole work in which case they may not address the control zone. Alternatively, they could use this project to enforce the present rules requiring a 100-ft radius control zone centered on the wellhead or approved deviation.

Table 2. MTN-5 and MTN-6 Modifications Cost Summary

Description	Total
MTN-5 Kootenai Sandstone	$ 114,509
MTN-6 Thermopolis Sandstone	$ 123,960
Total	$ 238,469

5. MADISON AQUIFER WELL

Source capacity planning has identified the Madison aquifer as a potential target for new District wells. The planning process, however, has first considered development of shallower aquifers. This section is providing an updated cost estimate for a Madison aquifer well drilled at the southerly site located on the Middle Fork Anticline. Full penetration of the aquifer at the drill site is estimated at 3,000 ft. A project of this scale requires an approximately 1-acre site to complete. A cost summary is provided in **Table 3** and detailed cost data are attached.

As described for the Kootenai aquifer, the Madison aquifer also has apparent limitations in the size of the recharge area and the well site is located south of the Big Sky syncline hinge area, a location that also could negatively impact recharge. The ability to stimulate well production by acidization is favorable and can be used if needed. Given the depth of the formation, a less expensive test well was not considered. An approximately 10% savings of the production well item can be realized by using a 7-inch diameter liner casing but could reduce well capacity.

Table 3. Madison Well Cost Summary

Description	Total
Production Well (9-5/8" Casing)	$ 944,000
Acid Stimulation	$ 222,400
Completion (no treatment)	$ 519,400
Subtotal	$ 1,685,800
Engineering (15%)	$ 252,870
Contingency (10%)	$ 193,867
Total	$ 2,132,537
SRF Reserve (10%)	$ 213,254
SRF Loan Fees (counsel, admin)	$ 30,000
Total with SRF Funding	$ 2,375,791

KOOTENAI AQUIFER WELLS (2)				
8-5/8" Dia. Well, Pump & Motor, Control/Treatment Building, Transmission				
TEST/PILOT BOREHOLES (650', 550')	Qty	Unit	Rate	Total
Mobe	1	LS	$ 2,200	$ 2,200
6" Drilling with casing	80	LF	$ 40	$ 3,200
6" Drilling open hole	1120	LF	$ 30	$ 33,600
Development	16	HR	$ 275	$ 4,400
Wireline Logging	2	EA	$ 2,000	$ 4,000
			Subtotal	$ 47,400
PRODUCTION WELL, 650 LF	Qty	Unit	Rate	Total
Mobe	1	LS	$ 7,500	$ 7,500
12" Drilling open hole	600	LF	$ 120	$ 72,000
Set and cement 8-5/8" casing	600	LF	$ 75	$ 45,000
Drill out open hole 7-7/8 in	50	LF	$ 75	$ 3,750
Development	24	HR	$ 275	$ 6,600
Pump Testing Mobe	1	LS	$ 10,000	$ 10,000
Pump Testing Hourly	76	HR	$ 250	$ 19,000
			Subtotal	$ 163,850
PRODUCTION WELL, 550 LF	Qty	Unit	Rate	Total
Mobe	1	LS	$ 7,500	$ 7,500
12" Drilling open hole	500	LF	$ 120	$ 60,000
Set and cement 8-5/8" casing	500	LF	$ 75	$ 37,500
Drill out open hole 7-7/8 in	50	LF	$ 75	$ 3,750
Development	24	HR	$ 275	$ 6,600
Pump Testing Mobe	1	LS	$ 10,000	$ 10,000
Pump Testing Hourly	76	HR	$ 250	$ 19,000
			Subtotal	$ 144,350
CONTROL/TREATMENT BLDG.	Qty	Unit	Rate	Total
6" C900 pipe and ductile fittings	1100	LF	$ 55	$ 60,500
10" C900 pipe and ductile fittings	600	LF	$ 110	$ 66,000
Building 24' x 24'	576	SF	$ 150	$ 86,400
Power service (480 VAC, 3p)	250	LF	$ 70	$ 17,500
Pumping system (300 gpm, 60 hp)	2	LS	$ 50,000	$ 100,000
Variable frequency drive	2	LS	$ 15,000	$ 30,000
Electrical	1	LS	$ 15,000	$ 15,000
Mechanical	1	LS	$ 30,000	$ 30,000
SCADA	1	LS	$ 15,000	$ 15,000
Auxilliary power (200 KW, diesel)	1	LS	$ 85,000	$ 85,000
Reclamation, landscaping	1	LS	$ 5,000	$ 5,000
Cl2 treatment system for sulfide	1	LS	$ 105,000	$ 105,000
			Subtotal	$ 615,400
		Construction Total		$ 971,000
ENGINEERING	1	LS	25%	$ 242,750
CONTINGENCY	1	LS	10%	$ 121,375
		TOTAL (Two Wells)		$ 1,335,125
SRF reserve funds	1	LS	10%	$ 133,513
SRF loan fees (counsel, admin.)	1	LS	$ 30,000	$ 30,000
		TOTAL PROJECT		$ 1,498,638

MTN-5 DEEPENING TO KOOTENAI AQUIFER, 625 FT				
Description	Qty	Unit	Rate	Total
Well Access	1	EA	$ 7,500	$ 7,500
7-7/8 Inch Drilling Open Hole	425	LF	$ 53	$ 22,667
Wireline logging	1	EA	$ 3,000	$ 3,000
5" x 8" Liner Hanger Installed	1	EA	$ 20,000	$ 20,000
5" Liner Casing Set and Cemented	450	LF	$ 52	$ 23,513
Development	24	HR	$ 275	$ 6,600
Subtotal				83,279
Engineering			25%	20,820
Contingency			10%	10,410
Total				114,509
MTN-6 DEEPENING TO THERMOPOLIS BASAL SANDSTONE, 700 FT				
Description	Qty	Unit	Rate	Total
Well Access	1	EA	$ 7,500	$ 7,500
7-7/8 Inch Drilling Open Hole	500	LF	$ 53	$ 26,667
Wireline logging	1	EA	$ 3,000	$ 3,000
5" x 8" Liner Hanger Installed	1	EA	$ 20,000	$ 20,000
5" Liner Casing Set and Cemented	505	LF	$ 52	$ 26,386
Development	24	HR	$ 275	$ 6,600
Subtotal				90,153
Engineering			25%	22,538
Contingency			10%	11,269
Total				123,960

MADISON AQUIFER WELL				
3000' x 9-5/8" Dia. Well, Pump & Motor, Control Building, Transmission				
PRODUCTION WELL, 3000 LF	Qty	Unit	Rate	Total
Mobe	1	LS	$ 250,000	$ 250,000
Drill for, set and cement 13-3/8" casing	200	LF	$ 565	$ 113,000
14" gate valve	1	LS	$ 5,000	$ 5,000
Drill 12-1/4" borehole	2300	LF	$ 75	$ 172,500
Set and cement 9-5/8" casing	2500	LF	$ 100	$ 250,000
Drill 8-3/4" open hole	500	LF	$ 96	$ 48,100
Development	40	HR	$ 690	$ 27,600
Pump Testing Mobe	1	LS	$ 55,000	$ 55,000
Pump Testing Hourly	76	HR	$ 300	$ 22,800
			Subtotal	$ 944,000
ACID STIMULATION	Qty	Unit	Rate	Total
Acid treatment service company	1	EA	$ 75,000	$ 75,000
Drilling contractor fees	1	EA	$ 75,000	$ 75,000
Produce water disposal	3200	BBL	$ 2	$ 6,400
Produce water hauling	22	150BBL	$ 3,000	$ 66,000
			Subtotal	$ 222,400
COMPLETION	Qty	Unit	Rate	Total
8" C900 pipe and ductile fittings	700	LF	$ 85	$ 59,500
10" C900 pipe and ductile fittings	600	LF	$ 110	$ 66,000
Building 24' x 24'	576	SF	$ 150	$ 86,400
Power Service (480 VAC, 3p)	250	LF	$ 70	$ 17,500
Pumping system (600 gpm, 125 hp)	1	LS	$ 100,000	$ 100,000
Variable frequency drive	1	LS	$ 30,000	$ 30,000
Electrical	1	LS	$ 15,000	$ 15,000
Mechanical	1	LS	$ 30,000	$ 30,000
SCADA	1	LS	$ 10,000	$ 10,000
Auxilliary power (300 KW, diesel)	1	LS	$ 100,000	$ 100,000
Reclamation, Landscaping	1	LS	$ 5,000	$ 5,000
			Subtotal	$ 519,400
			Construction Total	$ 1,685,800
ENGINEERING	1	LS	15%	$ 252,870
CONTINGENCY	1	LS	10%	$ 193,867
			TOTAL	$ 2,132,537
SRF Reserve Funds	1	LS	10%	$ 213,254
SRF Loan Origination Fees	1	LS	$ 30,000	$ 30,000
			TOTAL PROJECT	$ 2,375,791

ATTACHMENT B – TEST WELLS TW#1 AND TW#2

MEMORANDUM

To: Ron Edwards, Jim Muscat
Big Sky County Water and Sewer District No. 363

Fr: Mark Cunnane

Re: 2019 Mountain Village Test Wells

WESTERN GROUNDWATER SERVICES
6595 Bear Claw Lane • Bozeman, MT 59715
(406) 585-5947

Big Sky County Water and Sewer District No. 363 (District) owns and operates the public water system for Big Sky, Montana. Two test wells were constructed to evaluate potential sites for new water supply wells to serve the Cascade pressure zone (**Figure 1**). This memorandum is documenting the results of the test wells.

1. SUMMARY

- Test Well MtnTW-1 did not penetrate a viable aquifer for a water supply well within the upper 820 ft of formation drilled. There is potential to drill a well to the Kootenai formation basal sandstone at the tank site. This well would be drilled to 1,700 ft and has a drilling contractor feasibility cost estimate of $521,100. Construction of a Kootenai formation well at this location is not presently recommended due to water production uncertainty, costs, and potential to develop groundwater at other locations.

- Test Well MtnTW-2 was drilled through the Kootenai formation and was found to be located in a substantially bounded aquifer. A well at this location is estimated to have a maximum sustained pumping rate of 85 gpm and annual volume of 45 acre-feet (28 gpm). The actual sustained capacity could be less. The discharge was measured to have non-detectable hydrogen sulfide and arsenic, but iron and manganese were measured above the secondary standards and could require treatment to prevent fixture staining. Construction of a Kootenai formation production well is not at this time recommended. This site may be considered for a future well pending the outcome of additional test well drilling.

- The Cascade pressure zone water demand was evaluated based on analysis of parcels. Parcel data were obtained from the State Library in a GIS database and also reviewed using a 2017 air-photo. This analysis found potential for 464 residences consisting of single-family homes, condominiums, and townhouses, resulting in 1,183.2 SFEs. Maximum day demand to serve these users was estimated at 329 gpm. To comply with DEQ source capacity standards, and assuming 125 gpm/well, four wells would need to be available to supply the water system.

- A preliminary test well drilling plan is provided that includes eight drill sites located on property owned by Big Sky Resort, LLC. Test wells are included that target alluvium, intrusive rocks, and the Kootenai aquifer. Alluvium test wells are estimated to be drilled up to 70 ft. Intrusive and Kootenai test wells are budgeted based on a drilling depth of 800 ft. Assuming two wells are pump tested and including engineering services the total cost for the eight test wells is estimated at $248,500.

2. CONTRACTOR SERVICES

Test well drilling was procured by soliciting quotes from local drillers. Five local drillers with experience in the Big Sky area were contacted to bid the project, of which four submitted bids. A bid tabulation is

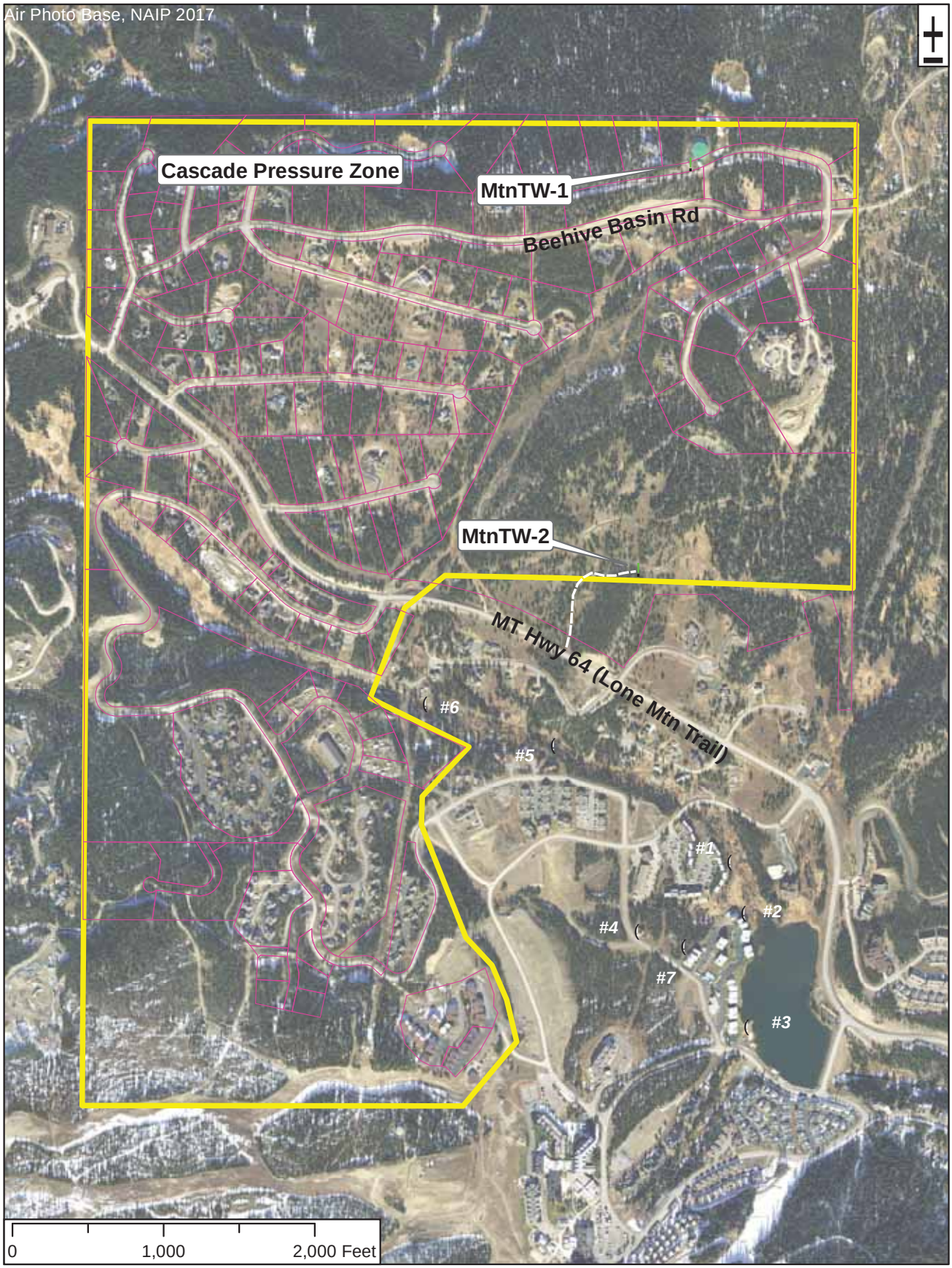


Figure 1. Location Map

provided in **Attachment A**. Potts Drilling, Inc. was selected based on the low bid and completed the work. Drilling work to construct both test wells cost $36,896. Test Well MtnTW-2 was pump tested for a drilling contractor fee of $7,779, bringing the total drilling contractor fees to $44,675. Geophysical logging of the wells was completed by Hawkins CBM Logging of Cody, WY for a fee of $4,759.

3. TEST WELL MTNTW-1

This test well is located at the 1.5 Mgal Cascade Water Storage Tank and was drilled in mid-September to a depth of 820 ft below ground (**Figure 2, Attachment B**). This site was selected solely for the reduced costs to tie a well into the water system at this location.

The Frontier formation sandstone was encountered to a depth of about 40 ft, where the borehole entered the Mowry formation. The Mowry consisted of mostly claystone varying in color from gray to green, but also including thin sandstone and siltstone beds. At 580 ft the borehole entered the Muddy Sandstone, which drilled as very fine chips of hard sandstone. From 600- to 740-ft the borehole penetrated a gabbro sill, and then from 740- to 780-ft re-entered the lower Muddy Sandstone. At 780-ft the borehole entered the Thermopolis Shale (dark gray shale) and stayed in it until the borehole was terminated at 820 ft.

Muddy Sandstone consisted of silica cemented sandstone with primarily angular sand grains consisting of clean quartz, measuring about 0.2- to 0.4-mm (**Figure 3**). The gabbro sill consisted mostly of augite clinopyroxene and plagioclase feldspar, and mica that appears to be a secondary mineral formed in relation to plagioclase. This slide confirms the intrusive rock as a gabbro sill rather than a dacite sill, as the mineralogy is distinctly different. Dacite is the intrusive rock of Lone Mountain and is the primary water bearing interval in Mountain Village Wells #4 and #7, where it occurs as sills intruding the Mowry formation.

Air-lift water production during drilling had a maximum rate of about 40 gpm. Static water level of the well on 11/14/2019 was 163 ft below ground. Wireline logging on the same day encountered a squeezed borehole at 215 ft, which the tools could not penetrate. Due to the low water production from the well, pump testing is not presently recommended.

The Thermopolis Shale is not an aquifer target, except possibly for the basal sandstone, which is estimated in the interval from about 1,000 to 1,100 ft below ground. The next aquifer target is the basal sandstone of the Kootenai formation, estimated at 1,600- to 1,700-ft below ground. A Madison aquifer well would be drilled to a depth of about 3,000- to 3,300-ft to penetrate the Mission Canyon formation. The occurrence of instrusive rocks in these formations could increase drilling depths. Each of these deeper targets should be drilled using the mud-rotary method in order to prevent borehole cave-ins.

A feasibility level cost estimate was made for drilling a Kootenai water supply well at the Tank site (**Attachment E**). This well would be drilled at 12-1/4 inch diameter to total depth, and then completed with 8-5/8 inch diameter steel casing to the top of the sandstone (1,600 ft, cemented). For cost estimation, it was assumed the basal sandstone could be left as an open hole completion. The estimated drilling contractor fee to construct the well is $521,100. The total drilling project cost is $630,531, which includes engineering ($52K) and contingency ($57K) fees. Additional costs are required to complete the well for use in the water system.

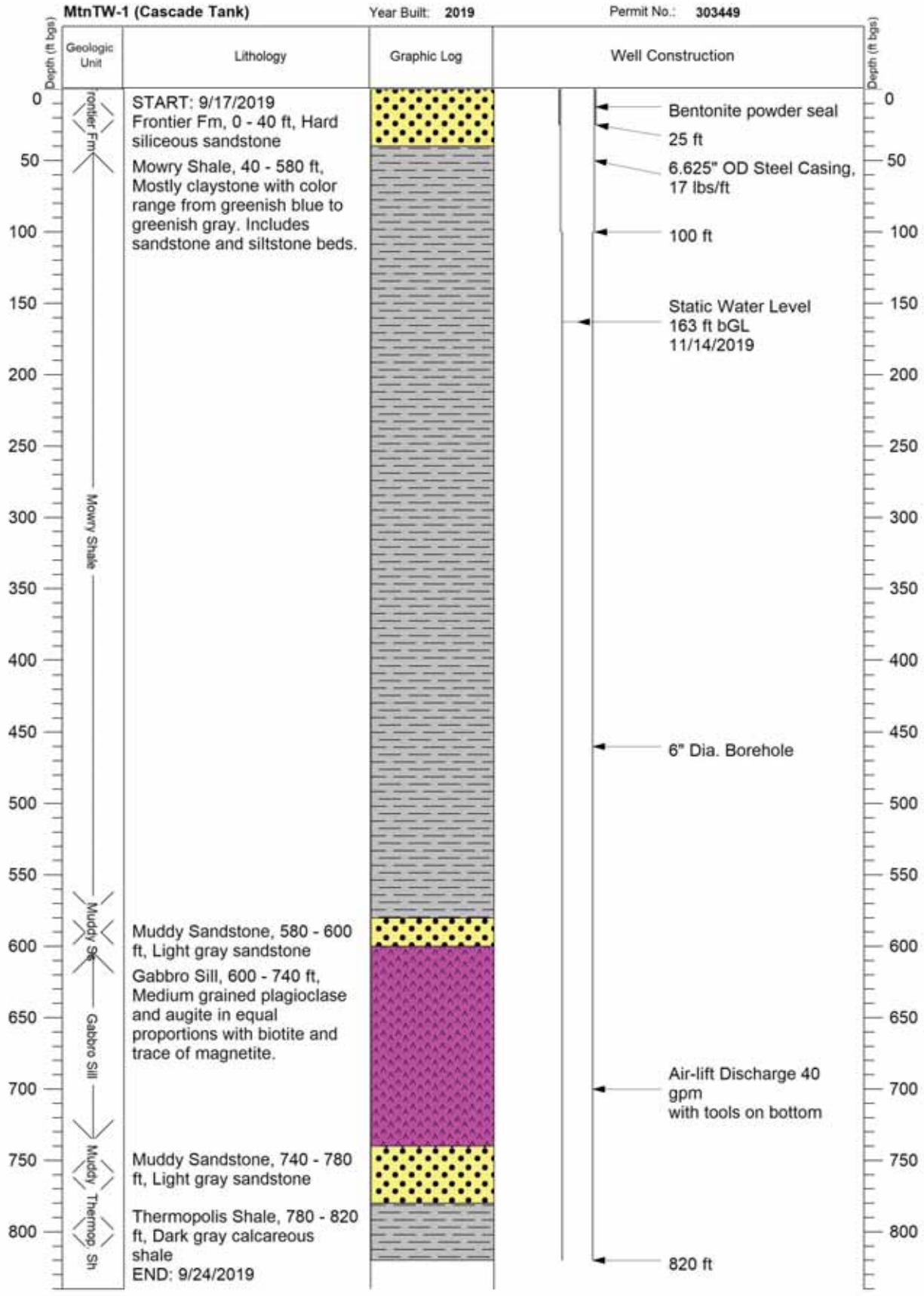
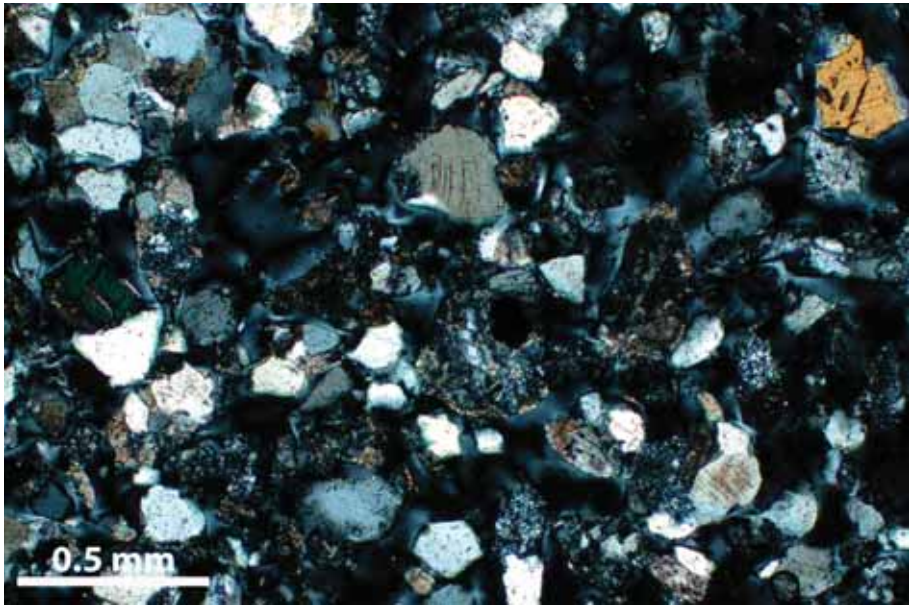
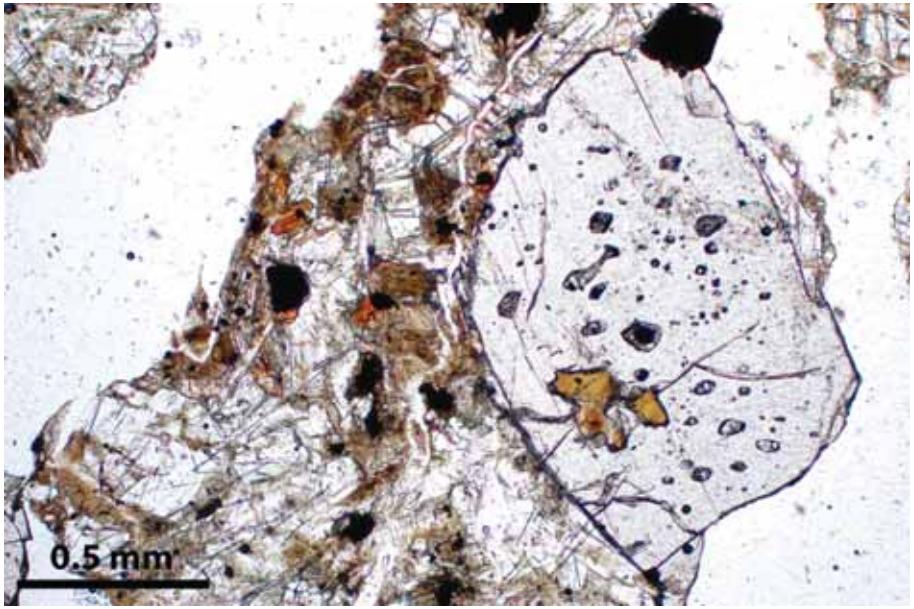


Figure 2. MtnTW-1 As-Built Log

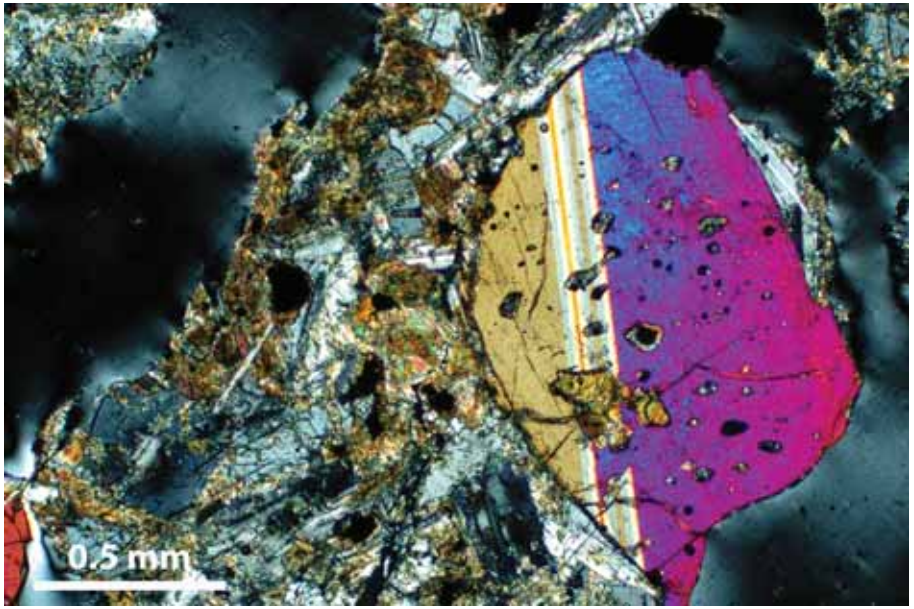
A. MtnTW-1, 750 ft, Muddy Sandstone chips and grains, plain polarized light, 40X



B. MtnTW-1, 750 ft, Same as (A) but with crossed polarized light, 40X



C. MtnTW-1, 630 ft, Gabbro sill chip, plain polarized light, 40X



D. MtnTW-1, 630 ft, Same as (C) but with crossed polarized light, 40X

Figure 3. MtnTW-1 Sample Photos

4. TEST WELL MTNTW-2

This test well is located along the hinge of the Middle Fork Anticline, a geologic structure that trends approximately N30°E where drilled, and targets the Kootenai formation basal sandstone (**Figure 4**, **Attachment C**). The hinge area of anticline folds may be prone to tension fractures in strong rocks, such as sandstone, that can increase permeability.

4.1 Borehole Samples and Water Production

The borehole was drilled into the basal sandstone of the Thermopolis shale to a depth of about 40 ft, where it then entered the Kootenai formation. The upper Kootenai rocks consisted of mostly siltstone with claystone and limestone beds. A sandstone interval with limited water production occurred from 300- to 360-ft. Predominantly siltstone, but also including claystone and limestone beds, was then encountered to the top of the basal sandstone at 540 ft below ground. The basal sandstone extended to a depth of about 595 ft, where the borehole entered the Morrison formation. Drilling was terminated at 620 ft.

The basal sandstone consists of hard, silica cemented sand grains of ~100% quartz mineralogy, but also appears to include sand grains of chert (**Figure 5**). These rocks have little to no porosity and transmit water primarily through fractures.

Air-lift discharge during drilling was about 9 gpm at 300 ft, gradually increasing to 80 gpm by a depth of 520 ft. There was light sulfide odor at the 80 gpm rate. This discharge also contained at times substantial color, mostly bright orange. Air-lift discharge increased to 150+ gpm below 520 ft, the sulfide odor was absent, and the water was clear.

After drilling on 9/27/19, the well was flowing artesian with an open discharge of about 30 gpm and shut-in pressure of 15- to 20-psig. By 10/2/19 the discharge had stopped and the static level was at 9 ft below ground. When wireline logging the well on 11/14/19, static water level was 92 ft below ground. At the time of pump testing on 12/3/19, static water level was at 110 ft below ground. These observations indicate subsurface discharge is occurring in the well, which is constructed with an open borehole from 100 ft below ground to total depth.

4.2 Wireline Logging

Wireline logging of the well (**Attachment C**) included logs that reflect rock type (lithology) and also a spinner flow meter log that measures flow occurring in the borehole. The lithology logs pinpoint the basal sandstone to occur from 543- to 595-ft below ground. The upper 20-ft of this unit is shown to be the cleanest sandstone of the interval.

The spinner flow meter log was run in both the down and up directions. The logging tool entered water at about 92 ft below ground. Based on the logging down plot (blue line), there may be some indication of upward flow between 100- and 300-ft, but this could also be related to logging speed adjustment. The first major indication of upward flow occurs at 355 ft in sandstone. This depth corresponds to a zone of outflow from the borehole. This outflow is the cause of subsiding artesian flow and continued deepening of the static water level. From 355 ft, a constant flow is indicated to about 460 ft, where the rate of upward flow starts to wane—this occurs as the tool is lowered past zones that are contributing inflow to the well. By the top of the basal sandstone at 540 ft, upward flow has declined by about 1/3. Through the basal sandstone, the upward flow declines to 0.

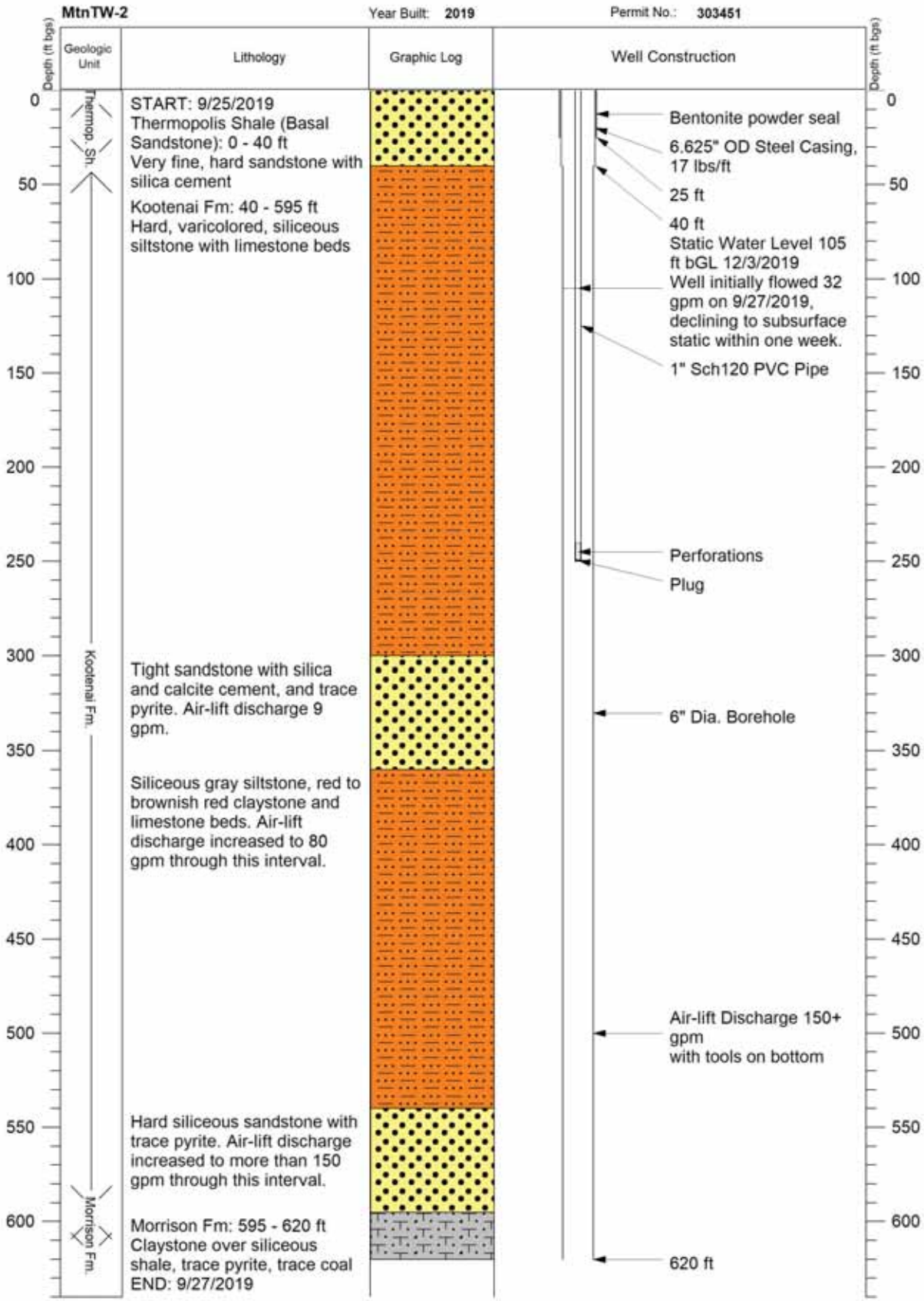
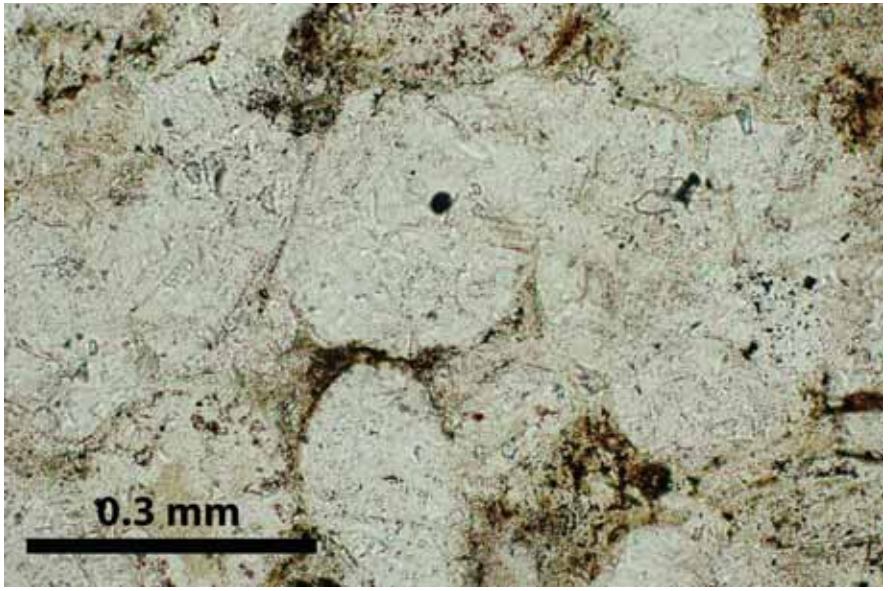
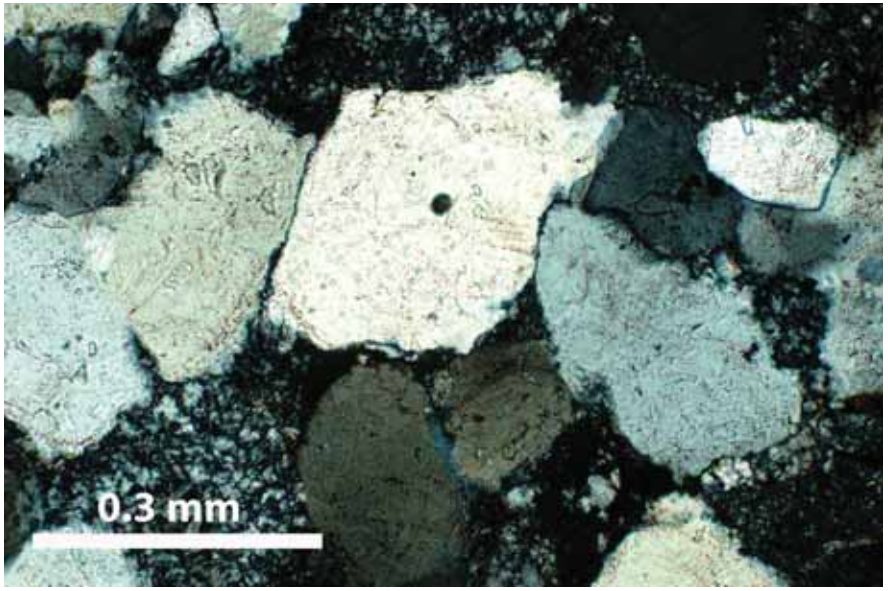


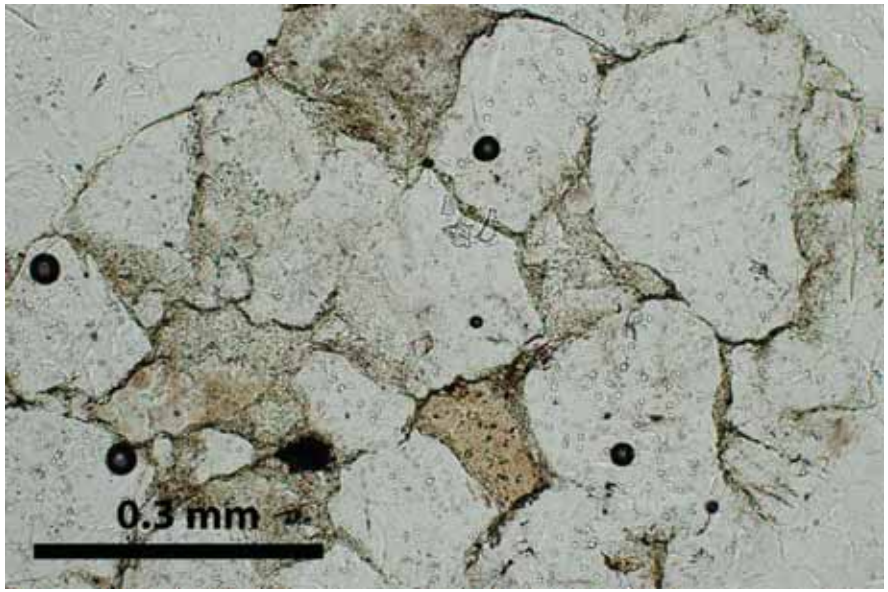
Figure 4. MtnTW-2 As-Built Log



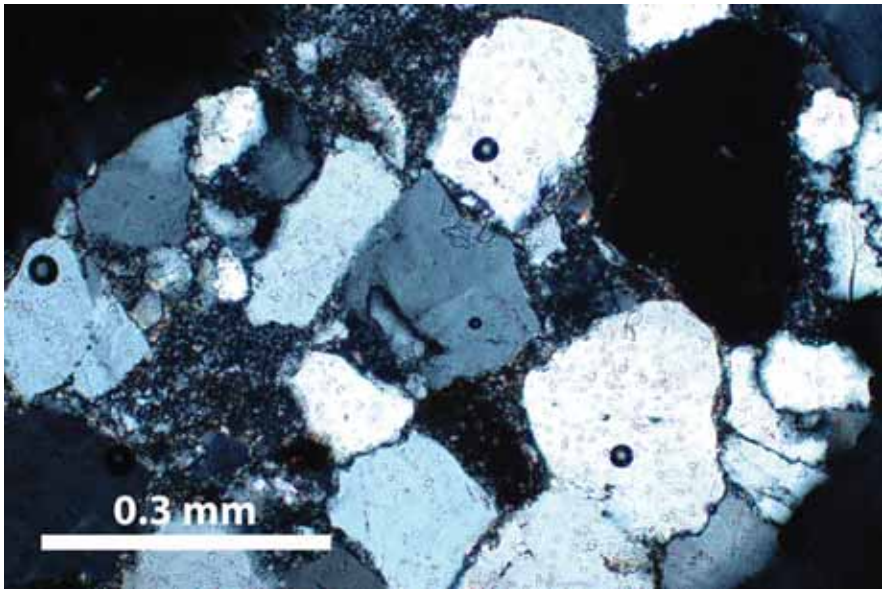
A. MtnTW-2, 550 ft, Kootenai basal sandstone chip, plain polarized light, 100X



B. MtnTW-2, 550 ft, Same as (A) but with crossed polarized light, 100X



C. MtnTW-2, 570 ft, Kootenai basal sandstone chip, 100X



D. MtnTW-2, 570 ft, Same as (C) but with crossed polarized light, 100X

Figure 5. MtnTW-2 Sample Photos

In completing a well at this location, the spinner flow meter data are indicating that some flow will be lost if the well is cased to the top of the basal sandstone. One option for completion may be to construct the well with a screen from about 460- to 540-ft, and then open hole through the basal sandstone. The screen may be needed to keep the borehole open through the claystone beds occurring in the interval.

4.3 Pumping Test

A 4-1/2 inch diameter PVC liner casing was set to approximately 250 ft below ground for pump testing. A 4-inch diameter pump rated to about 85 gpm was set to the bottom of the liner, with an instrument tube for water level monitoring. Wester Groundwater Services furnished and operated computer logging instruments for pumping water level and discharge rate for the test. Data were collected at 1-minute intervals (**Figure 6**).

A step rate pumping test was run on 12/3/19 consisting of three steps, ranging from 54- to 80-gpm with a maximum drawdown of 41.5 ft. The well recovered to a residual drawdown of 3.7 ft after about 9.3 hours after pumping was stopped. This remaining drawdown was likely corresponding to a new quasi-static water level in the well.

On the next day, a 23-hour constant rate test was run at an average rate of 79 gpm. The constant rate test was run at the maximum rate of the pump that was considered sustainable for the duration of testing. The test was terminated based on substantial boundary effects impacting the test and the likelihood the well site would not be recommended for completion.

Hydraulic analysis was completed for the constant rate test. The bounded aquifer condition is best illustrated by the log-log plot derivative (**Figure 7A**). The derivative, which is the slope of the drawdown data curve, is indicating at least two boundaries are present. The derivative is increasing unbounded, which is particularly undesirable for a water supply well. The rate of increase is reduced due to waning discharge from the well (this occurs as the pump must lift the water from greater depth). Had the discharge been held perfectly constant for the test, the derivative curve would be steeper than is shown.

Aquifer transmissivity is estimated at 1,035 ft^2/d using data in the period from 20- to 40-minutes after pumping began (**Figure 7B)**. This is the only segment of the data that is reflecting clean aquifer response. At earlier time, the data are impacted by well storage. At later time, the boundaries are impacting the well response. The straight line fit to the data illustrates the trend that would be followed by an unbounded aquifer—the preferred response for a water supply well. As shown, test data deviate substantially from the unbounded aquifer line.

A model was fit to the test data to estimate water production potential of the well (**Figure 8**). Two scenarios were modeled, both of which consisted of a well located between two equally offset parallel boundaries, as noted in the plot captions. Numerical fitting was used to match the models to the test data, which resulted in good fits for later time data. Both models reduced the transmissivity from the previously estimated value, and both models estimated storativity. The model with a 10,000 ft offset resulted in estimated parameters that generally are more reasonable for the aquifer being tested.

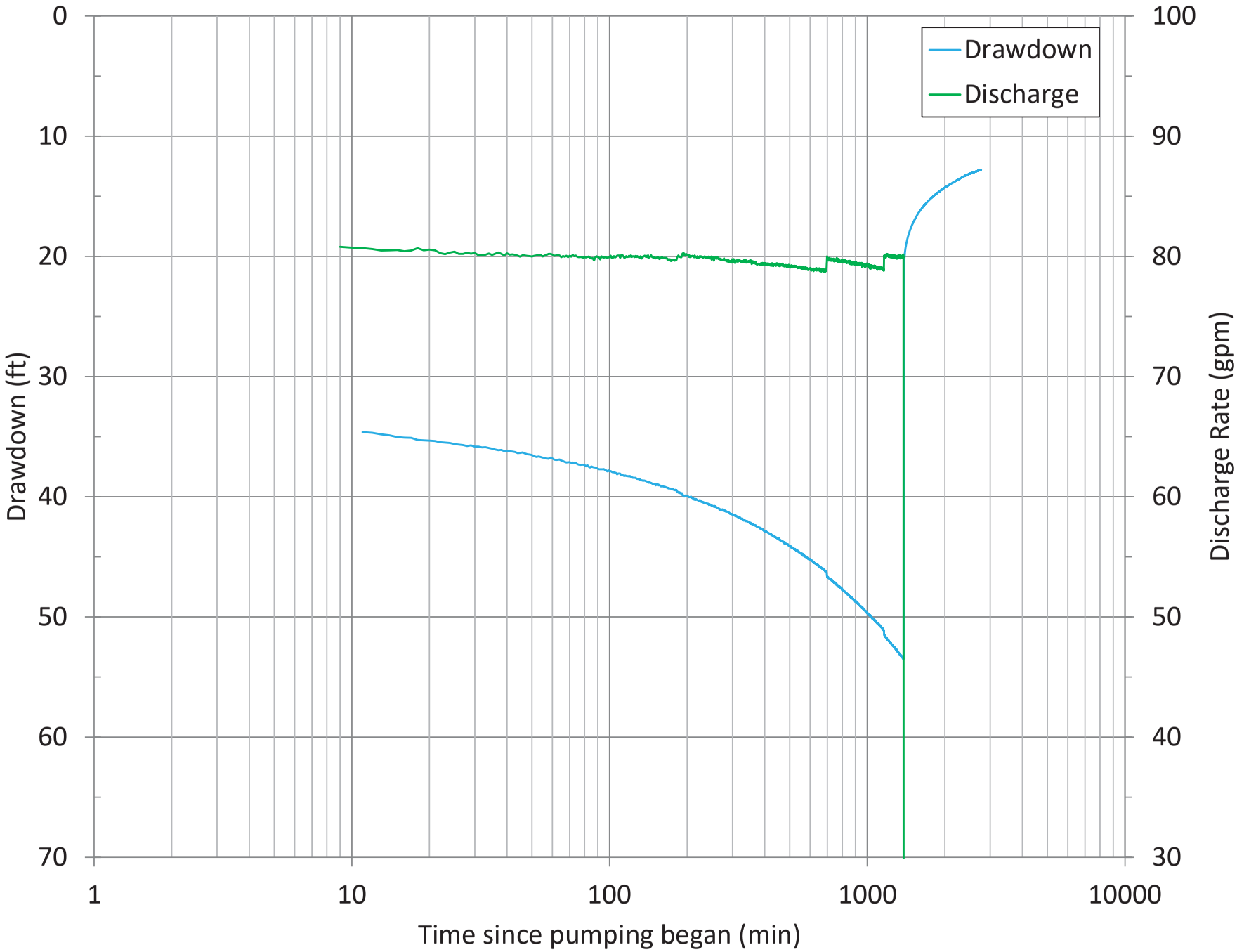
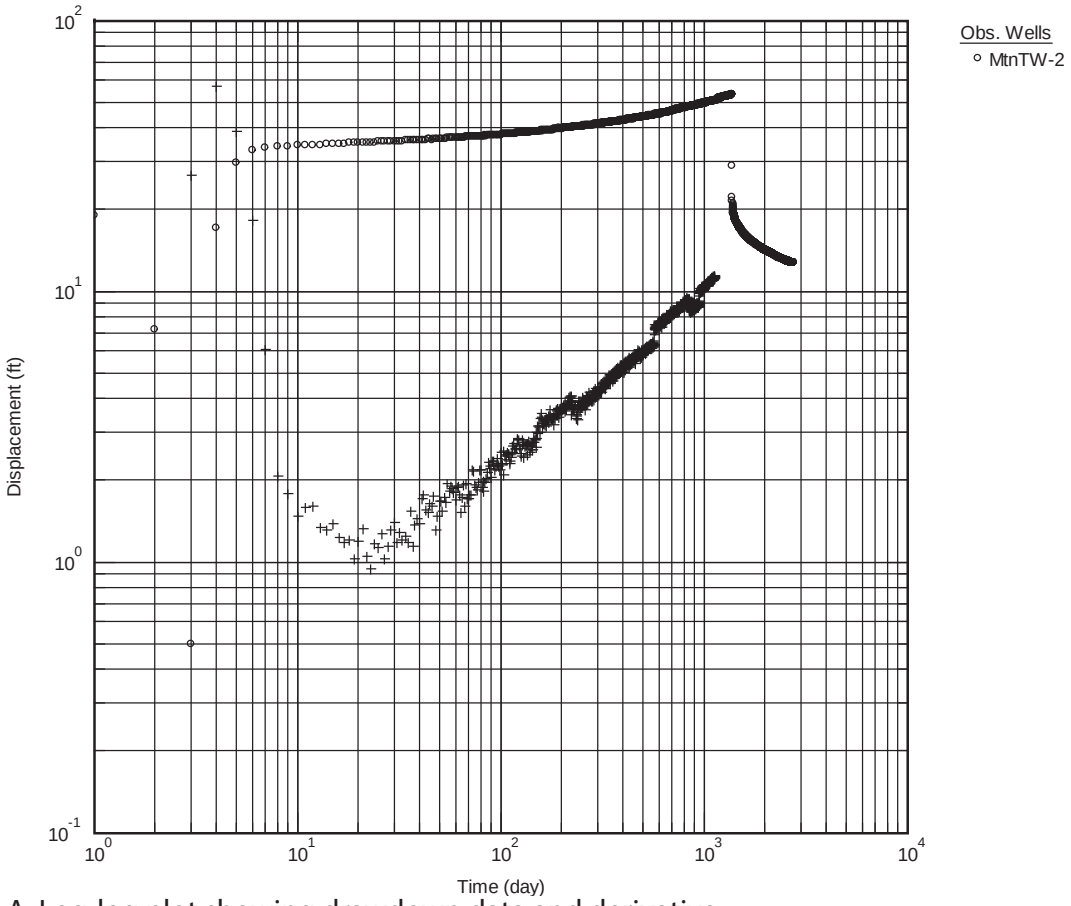
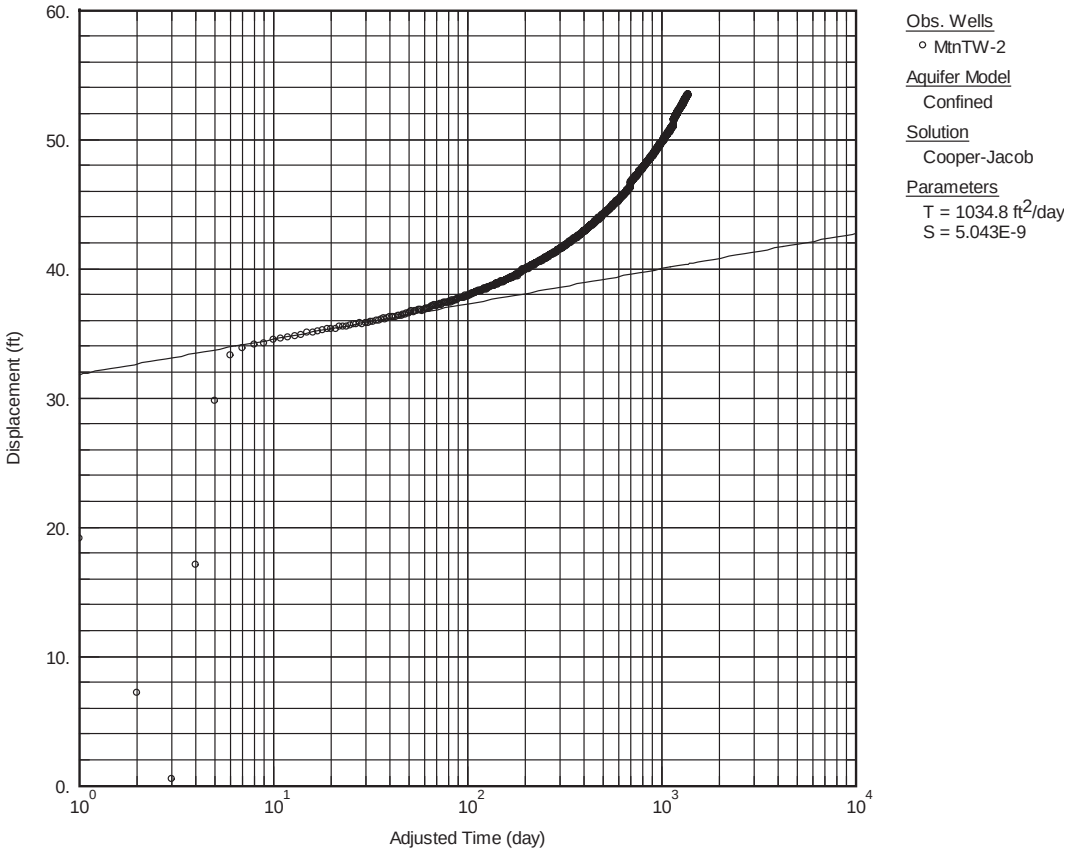


Figure 6. MtnTW-2 Pumping Test Hydrograph

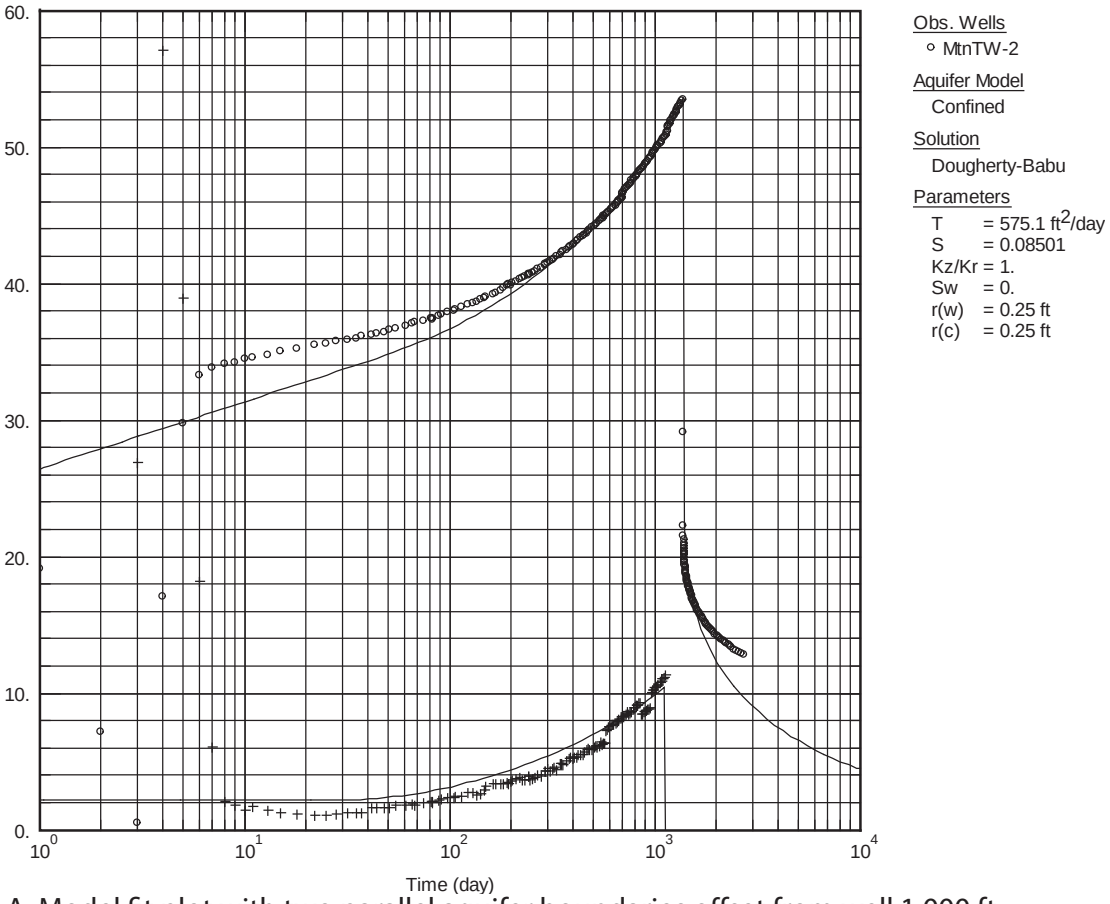


A. Log-log plot showing drawdown data and derivative.

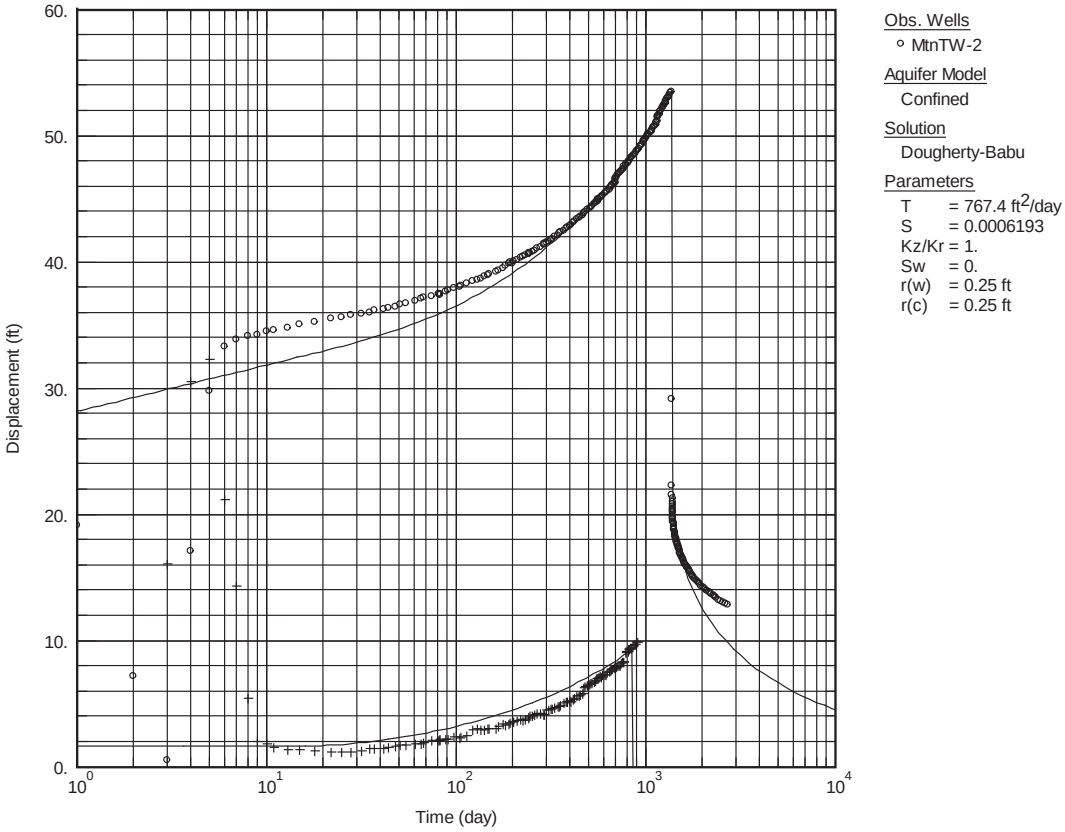


B. Semi-log plot showing straight line fit to drawdown data.

Figure 7. MtnTW-2 Pumping Test Analysis Plots



A. Model fit plot with two parallel aquifer boundaries offset from well 1,000 ft.



B. Model fit plot with two parallel aquifer boundaries offset from well 10,000 ft.

Figure 8. MtnTW-2 Model Fit Plots

Both model fits overestimate the recovery, but this could in part be explained by the continued discharge into the subsurface that is occurring in the MtnTW-2 borehole.[1] Both models underestimate slightly the derivative slope near to the end of the pumping phase. This underestimation will result in the models tending to overestimate water production potential of the well.

Estimation of water production using the models considered the construction of the well that would install casing to a depth of 460 ft below ground. When cased and sealed, the well would likely return to a flowing artesian under non-pumping conditions. Available drawdown in the well was assumed as 360 ft. Both model fits result in the same estimates. Annual volume is estimated at 45 acre-feet per year, and maximum pump rate is estimated at 85 gpm. The annual volume is based on 5-years of pumping to achieve maximum drawdown. The maximum rate is based on 180-days to achieve the maximum drawdown.

4.4 Water Quality

On 10/1/19 the District collected a sample from the artesian discharge for analysis of selected water quality parameters (**Attachment D**). The well water was slightly alkaline and moderately mineralized. Arsenic and hydrogen sulfide were non-detectable. There was significant iron and manganese present in the sample. Iron was measured at 0.46 mg/L, whereas the secondary standard is 0.3 mg/L. Manganese was measured at 0.057 mg/L, whereas the secondary standard is 0.05 mg/L. Other users of Kootenai formation groundwater in the Big Sky area (e.g., Spanish Peaks) treat the water for iron and manganese. The levels observed are marginally elevated but would likely result in fixture staining when the water was exposed to oxygen for prolonged periods. There is some possibility the iron and manganese concentration may change if a production well were constructed and shallower zones contributing groundwater were sealed. However, pyrite was observed in the Kootenai basal sandstone which is a source of iron in groundwater.

5. CASCADE PRESSURE ZONE WATER DEMAND

The Cascade pressure zone presently includes 185 parcels of which 171 were identified as single-family residences and 10 that were condominiums or townhouses, or that could be developed as condominiums or townhouses.[2] There were three parcels that were commercial or otherwise not considered for residences. Based on existing development, it was estimated that within parcels presently occupied by condominiums or townhouses, there were 3.2 structures/acre, excluding garages. This development density was assumed for all condominium/townhouse parcels, whether they are presently developed or not.

Each home, whether on a single-family parcel or within a condominium/townhouse parcel was designated to require a water demand for 2.55 SFEs, based on four bedrooms, four bathrooms, and one jacuzzi tub. The Mountain Village water system has a unit water use rate of approximately 200 gpd/SFE and a peaking factor of 2.0.[3] A summary of the water demand based on these data is provided in **Table 1**.

Source capacity to serve the Cascade pressure zone for the development identified through parcel analysis is 329 gpm. This source capacity must be achieved with the largest well out of service. If existing and new wells could produce at the average rate for Mountain Village wells of 125 gpm there would be a requirement of 454 gpm, or four wells. This source capacity would not be realized until further development occurs, although it also may underestimate demand at full buildout. A more accurate analysis could be completed

1 Modeling was completed to evaluate if the subsurface discharge could be the cause of the bounded aquifer response (not shown). This analysis concluded that boundaries must be present to achieve the observed aquifer response—it cannot be replicated simply be adding subsurface discharge, which is estimated to be small, on the order of 10 gpm.

2 Based on cadastral shapefile obtained from the State Library.

3 Source Capacity Plan Update, 2015.

by considering existing development, actual SFEs, and then projecting demand based on growth rates for the area.

Table 1. Cascade Pressure Zone Water Demand

Type	Dwellings	SFEs	ADD (gpd)	ADD (gpm)	MDD (gpm)
Condos/Townhouses	293	747.15	149,430	104	208
Single Family	171	436.05	87,210	61	121
TOTAL	464	1183.2	236,640	164	329
SFE – single family equivalent; ADD – average day demand; MDD – maximum day demand.					

6. PRELIMINARY TEST WELL DRILLING PLAN

Identifying sites for tests wells is based on geological conditions that enable drilling to an aquifer target. The least cost approach to explore locations with unknown potential is to drill boreholes of no more than approximately 800 ft depth and use the air-rotary drilling method, as was done for the MtnTW-1 and MtnTW-2 test wells. The aquifer targets available in Mountain Village and which can be accessible by air-rotary drilling include:

- Alluvium deposits around Lake Lavinsky: Alluvium deposits consist of loose sand and gravel and form the aquifer of Mountain Village Wells #1, #2, and #3. The extent of the alluvium is limited to the area south and west of Lake Lavinsky;

- Intrusive rocks south of Lone Mountain Trail (MT 64) within the Mowry, Muddy Sandstone, and Thermopolis formations: Mountain Village Wells #4 and #7 produce groundwater from intrusive rocks in the Mowry formation. There is a strong hydraulic connection between these two wells. For this reason, additional wells targeting the intrusive sills need to be substantially offset from other wells in the same aquifer.

- The basal sandstone of the Kootenai formation: Test wells targeting this aquifer generally are limited to locations where the Thermopolis – Kootenai contact is near surface, or no more than about 200 ft below ground, and where rock orientations are generally flat or gently dipping.

Land ownership and access to drill for and develop permanent wells is also a critical element of test well planning. The present plan considers properties owned by Big Sky Resort/Boyne USA. It is also a design standard that well sites provide for a 100-ft radius control zone centered on the well.

Locations selected based on the above criteria are shown on **Figure 9** and listed in **Table 2**. These locations are shown to be on property owned by Big Sky Resort, LLC. The numbers of the sites are not indicating the order of drilling or priority. Sites #3 and #8 have potential access issues related to saturated ground conditions and could require shifting to the sides of the targeted area. Each of these sites must be visited and evaluated for suitability prior to bidding. A final listing of sites can then be developed with updated drilling depths and budgeting.

Figure 9. Preliminary Test Well Locations

Table 2. Test Well Sites Summary

Site No.	Target Aquifer	Budget Drill Depth (ft)
1	Intrusive	800
2	Alluvium	70
3	Alluvium	70
4	Intrusive	800
5	Kootenai	800
6	Kootenai	800
7	Intrusive	800
8	Intrusive	800

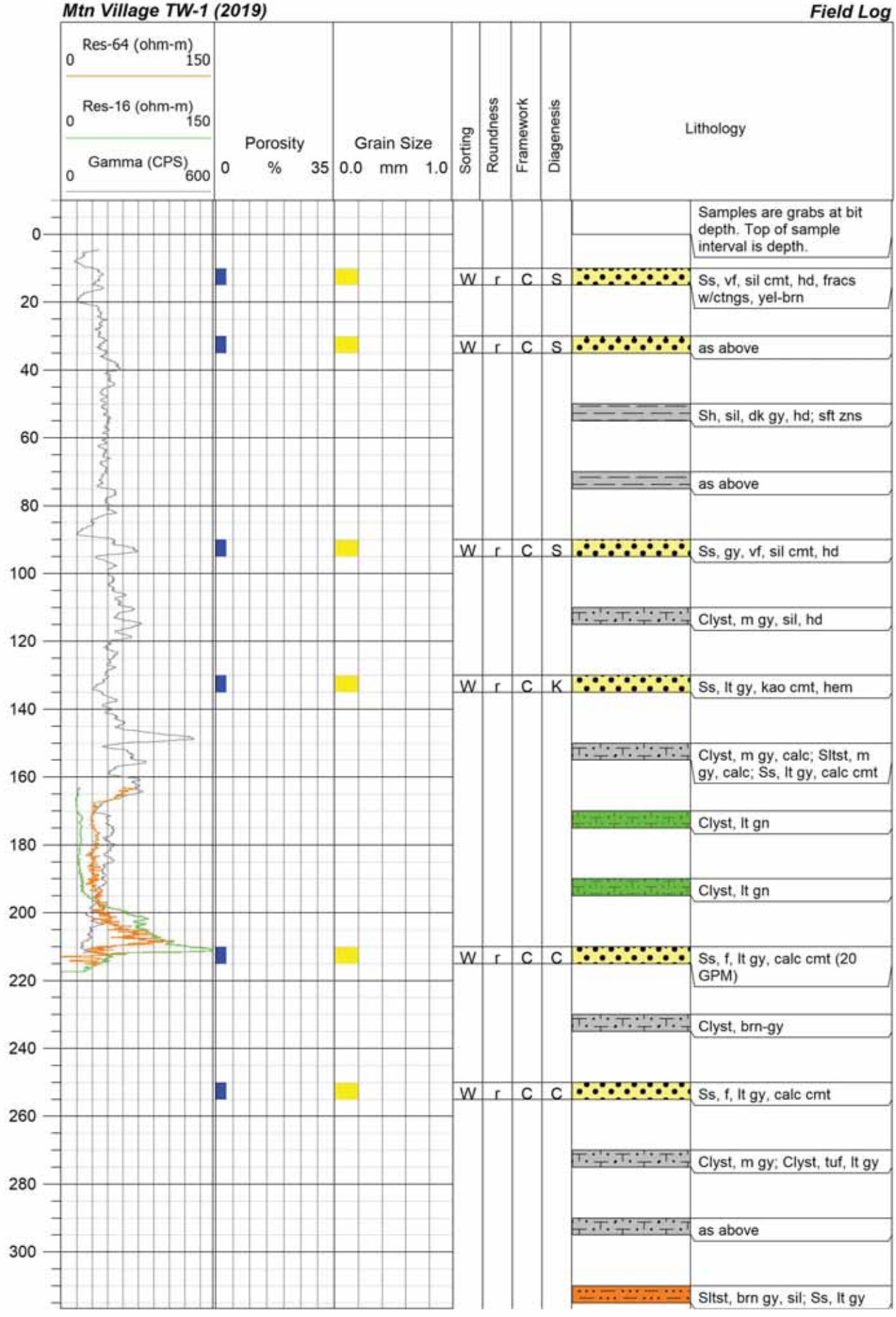
Cost estimates for 800 ft and 70 ft test wells are provided in **Attachment E**. Test wells up to 800 ft have a budget estimate of $27,500. Alluvial test wells to 70 ft have a budget estimate of $4,900. For the eight wells identified total cost for drilling construction is estimated at $174,800. Engineering services are roughly estimated at $43,700. Pumping tests, where completed, are estimated at $15,000 each. If two pumping tests are completed, the total project budget estimate is $248,500.

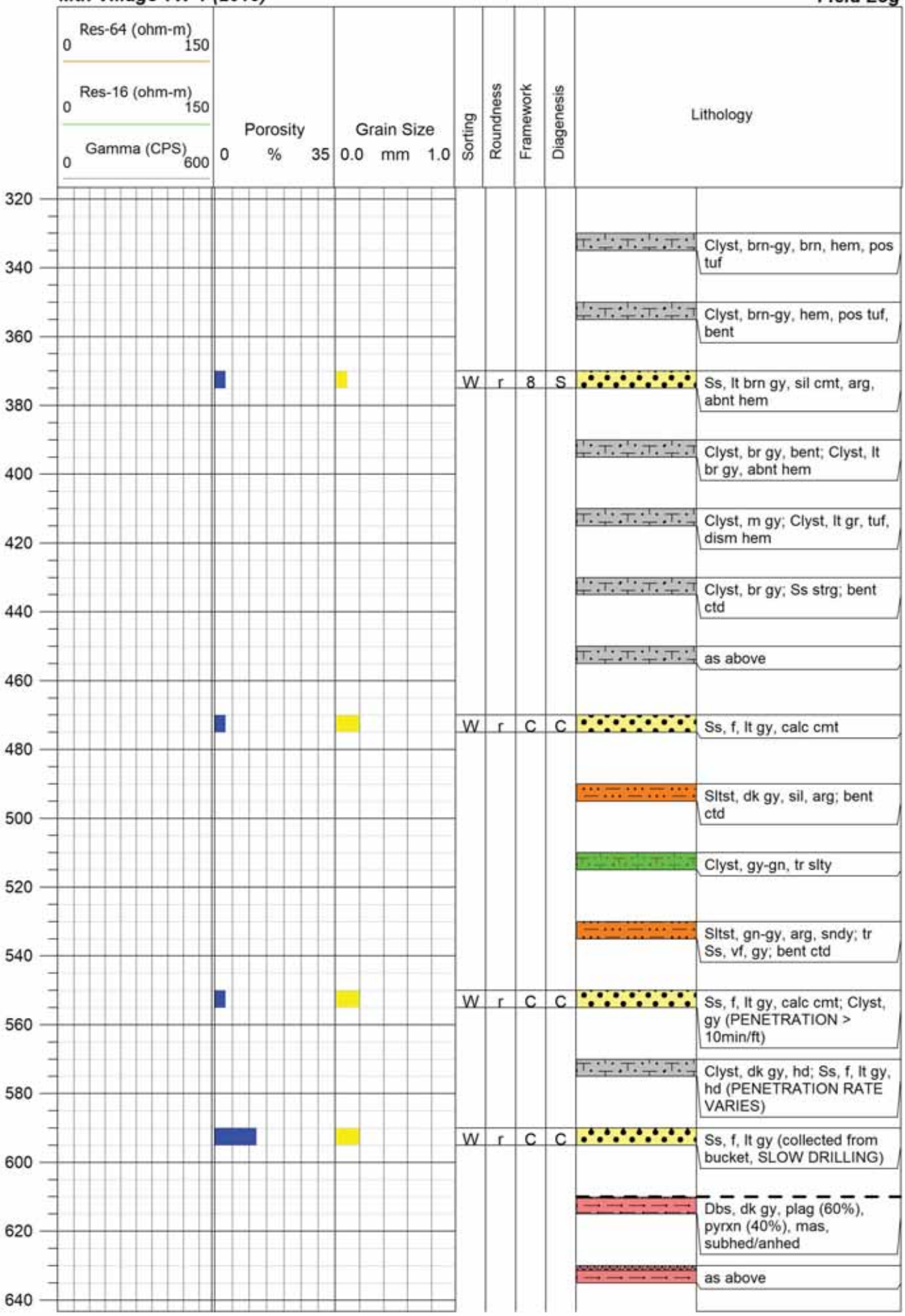
Attachment A
Test Well Driller Bid Tabulation

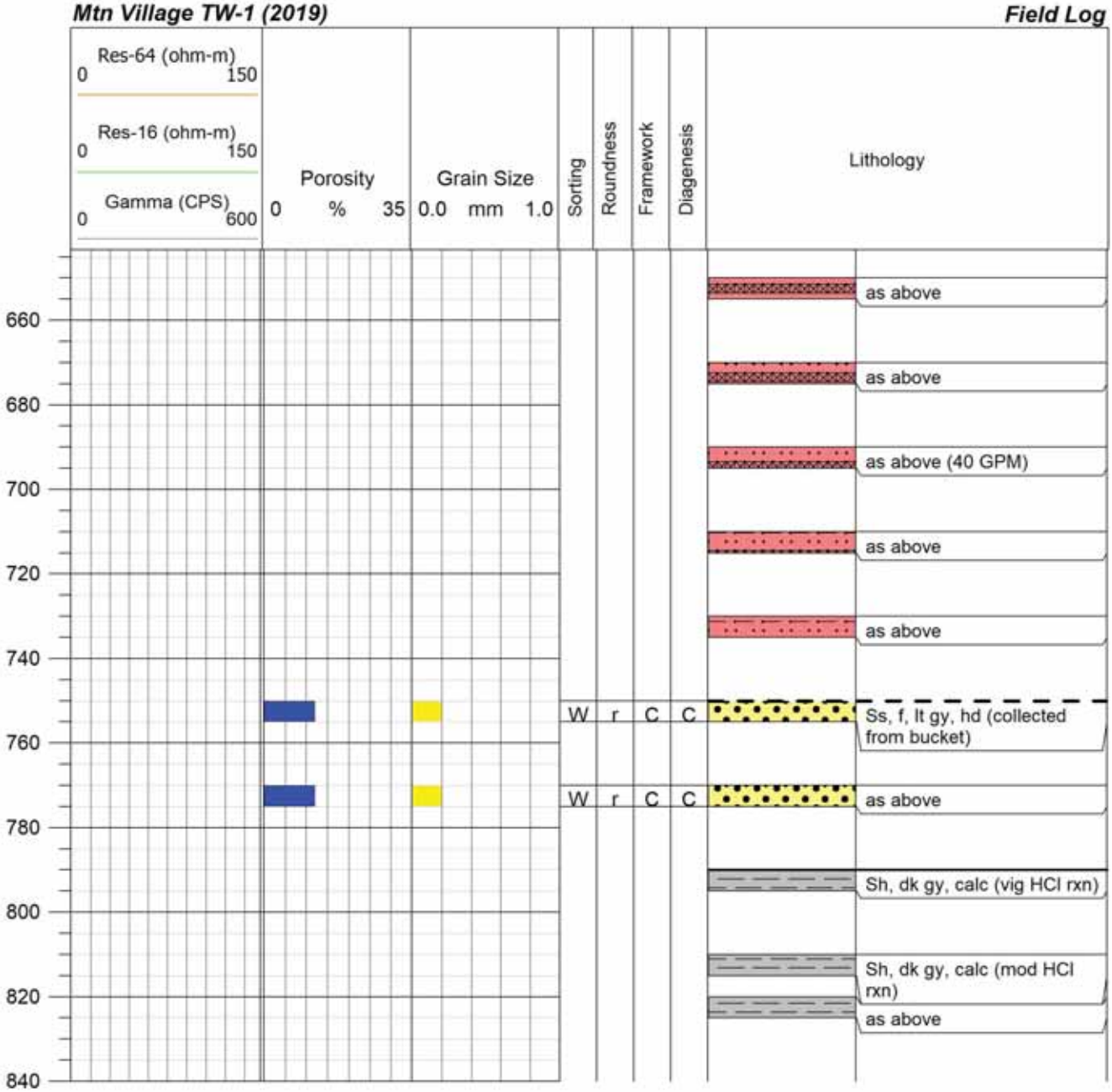
BIG SKY WSD MTN TEST WELLS BID TABULATION

				ENGINEER		POTTS DRILLING		DIAMOND M		VAN DYKEN		O'KEEFE DRILLING	
ITEM NO.	DESCRIPTION	QTY	UNITS	RATE	TOTAL	RATE	TOTAL	RATE	TOTAL	RATE	TOTAL	RATE	TOTAL
B-1	Mobilization	1	LS	$ 3,300	$ 3,300	$ 900.00	$ 900.00	$ 7,270	$ 7,270	$ 750	$ 750	$ 20,000	$ 20,000
B-2	6" Drilling with Casing	120	LF	$ 40	$ 4,800	$ 43.00	$ 5,160.00	$ 40	$ 4,800	$ 38	$ 4,560	$ 90	$ 10,800
B-3	6" Drilling Open Hole	1780	HR	$ 30	$ 53,400	$ 22.50	$ 40,050.00	$ 30	$ 53,400	$ 33	$ 58,740	$ 45	$ 80,100
B-4	Development	24	EA	$ 275	$ 6,600	$ 212.50	$ 5,100.00	$ 125	$ 3,000	$ 250	$ 6,000	$ 400	$ 9,600
B-5	Water Sampling	3	EA	$ 2,500	$ 7,500	$ 1,490.00	$ 4,470.00	$ 1,200	$ 3,600	$ 2,000	$ 6,000	$ 2,100	$ 6,300
			TOTAL		$ 75,600		$ 55,680.00		$ 72,070		$ 76,050		$ 126,800

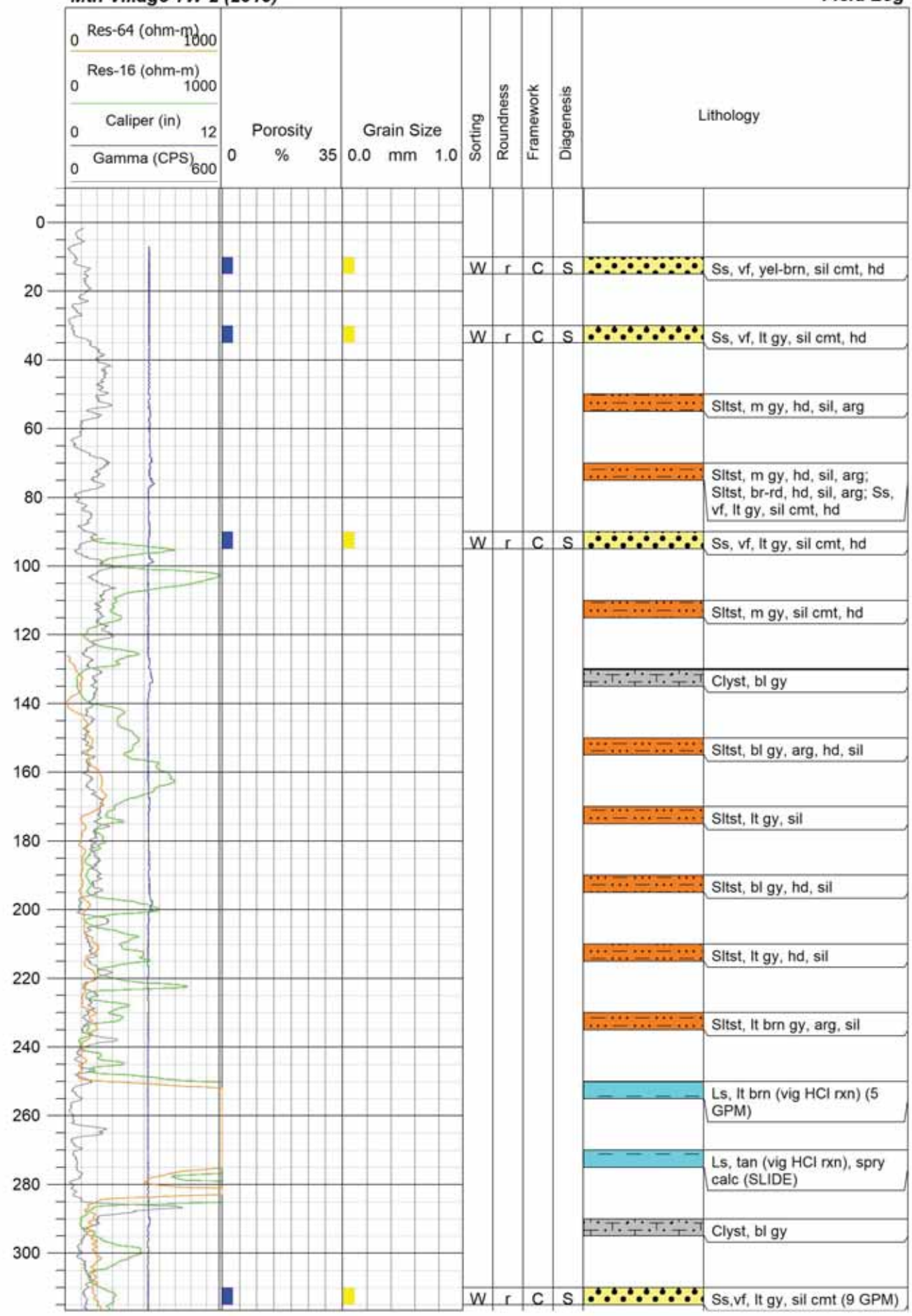
Attachment B
MtnTW-1 Logs

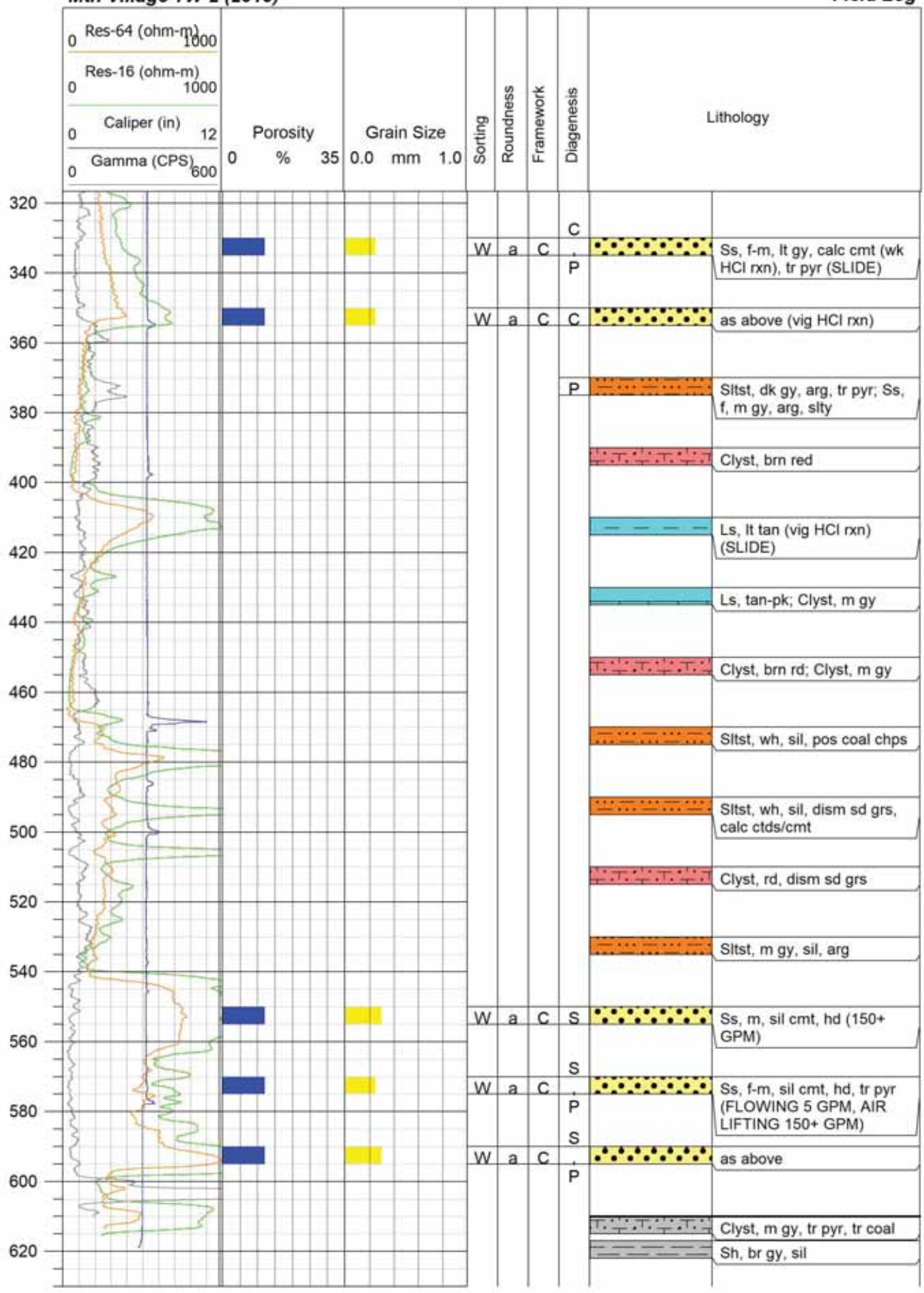

Mtn Village TW-1 (2019)
Field Log
Res-64 (ohm-m)
0
150
Res-16 (ohm-m)
0
150
Gamma (CPS)
0
600
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
Samples are grabs at bit depth. Top of sample interval is depth.
W r C S
Ss, vf, sil cmt, hd, fracs w/ctngs, yel-brn
W r C S
as above
Sh, sil, dk gy, hd; sft zns
as above
W r C S
Ss, gy, vf, sil cmt, hd
Clyst, m gy, sil, hd
W r C K
Ss, lt gy, kao cmt, hem
Clyst, m gy, calc; Sltst, m gy, calc; Ss, lt gy, calc cmt
Clyst, lt gn
Clyst, lt gn
W r C C
Ss, f, lt gy, calc cmt (20 GPM)
Clyst, brn-gy
W r C C
Ss, f, lt gy, calc cmt
Clyst, m gy; Clyst, tuf, lt gy
as above
Sltst, brn gy, sil; Ss, lt gy

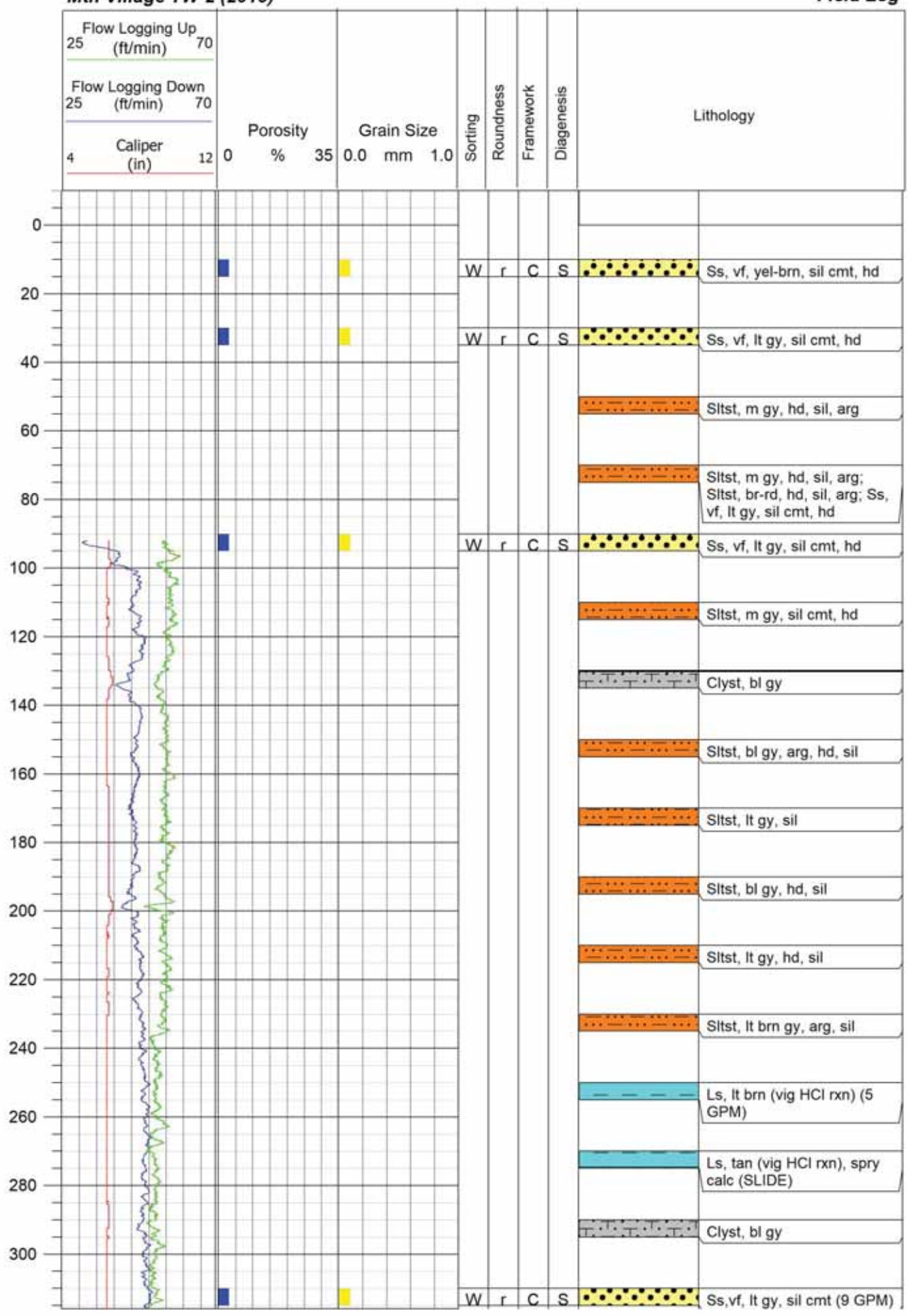

Mtn Village TW-1 (2019)
Field Log
Res-64 (ohm-m)
0
150
Res-16 (ohm-m)
0
150
Gamma (CPS)
0
600
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
Clyst, brn-gy, brn, hem, pos tuf
Clyst, brn-gy, hem, pos tuf, bent
W r 8 S
Ss, lt brn gy, sil cmt, arg, abnt hem
Clyst, br gy, bent; Clyst, lt br gy, abnt hem
Clyst, m gy; Clyst, lt gr, tuf, dism hem
Clyst, br gy; Ss strg; bent ctd
as above
W r C C
Ss, f, lt gy, calc cmt
Sltst, dk gy, sil, arg; bent ctd
Clyst, gy-gn, tr slty
Sltst, gn-gy, arg, sndy; tr Ss, vf, gy; bent ctd
W r C C
Ss, f, lt gy, calc cmt; Clyst, gy (PENETRATION > 10min/ft)
Clyst, dk gy, hd; Ss, f, lt gy, hd (PENETRATION RATE VARIES)
W r C C
Ss, f, lt gy (collected from bucket, SLOW DRILLING)
Dbs, dk gy, plag (60%), pyrxn (40%), mas, subhed/anhed
as above

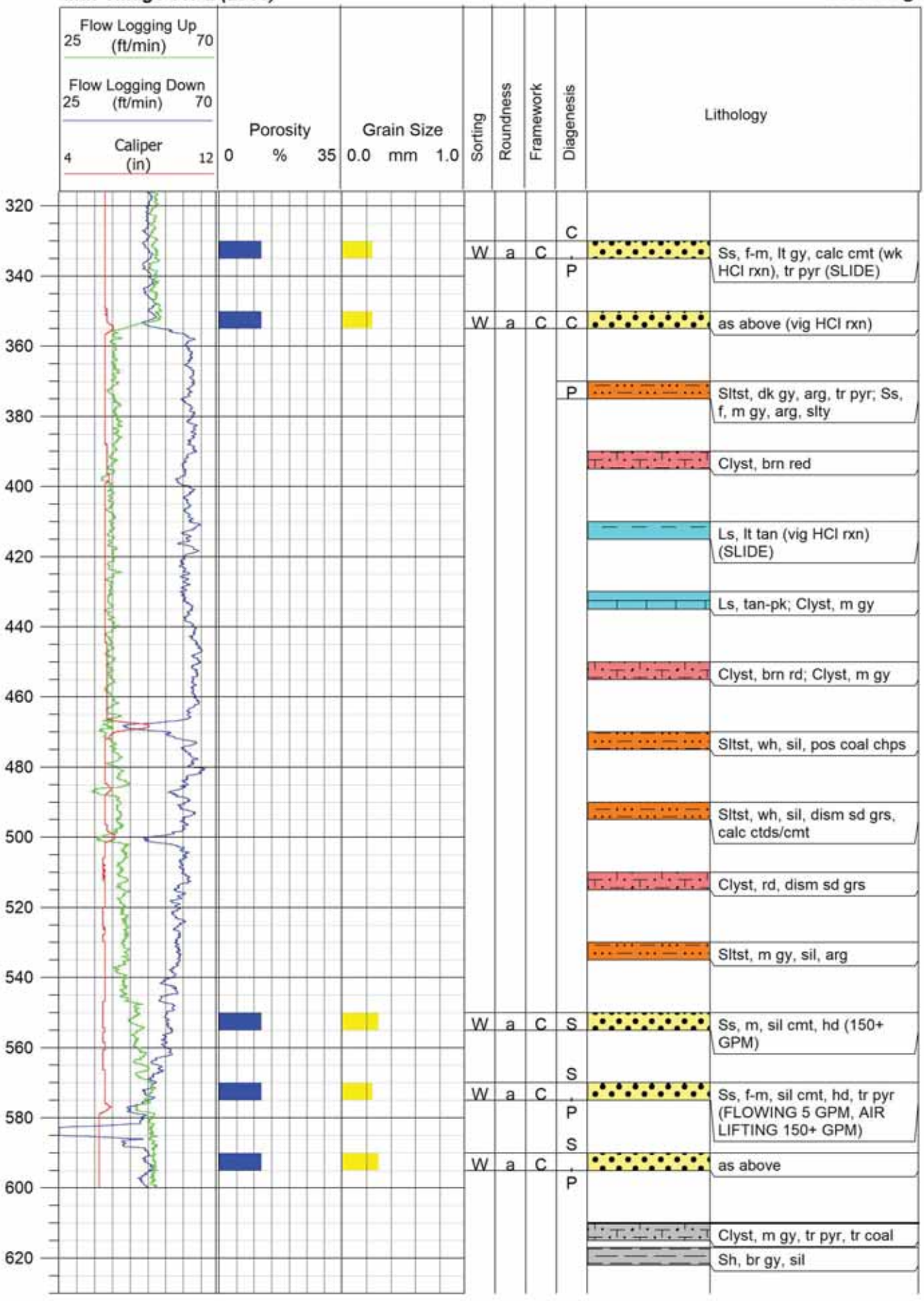

Mtn Village TW-1 (2019)
Field Log
Res-64 (ohm-m)
0
150
Res-16 (ohm-m)
0
150
Gamma (CPS)
0
600
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
660
680
700
720
740
760
780
800
820
840
as above
as above
as above (40 GPM)
as above
as above
W r C C
Ss, f, lt gy, hd (collected from bucket)
W r C C
as above
Sh, dk gy, calc (vig HCl rxn)
Sh, dk gy, calc (mod HCl rxn)
as above

Attachment C
MtnTW-2 Logs


Mtn Village TW-2 (2019)
Field Log
Res-64 (ohm-m)
0
1000
Res-16 (ohm-m)
0
1000
Caliper (in)
0
12
Gamma (CPS)
0
600
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
W r C S
Ss, vf, yel-brn, sil cmt, hd
W r C S
Ss, vf, lt gy, sil cmt, hd
Sltst, m gy, hd, sil, arg
Sltst, m gy, hd, sil, arg; Sltst, br-rd, hd, sil, arg; Ss, vf, lt gy, sil cmt, hd
W r C S
Ss, vf, lt gy, sil cmt, hd
Sltst, m gy, sil cmt, hd
Clyst, bl gy
Sltst, bl gy, arg, hd, sil
Sltst, lt gy, sil
Sltst, bl gy, hd, sil
Sltst, lt gy, hd, sil
Sltst, lt brn gy, arg, sil
Ls, lt brn (vig HCl rxn) (5 GPM)
Ls, tan (vig HCl rxn), spry calc (SLIDE)
Clyst, bl gy
W r C S
Ss,vf, lt gy, sil cmt (9 GPM)


Mtn Village TW-2 (2019)
Field Log
Res-64 (ohm-m)
0
1000
Res-16 (ohm-m)
0
1000
Caliper (in)
0
12
Gamma (CPS)
0
600
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
W a C C , P
Ss, f-m, lt gy, calc cmt (wk HCl rxn), tr pyr (SLIDE)
W a C C
as above (vig HCl rxn)
P
Sltst, dk gy, arg, tr pyr; Ss, f, m gy, arg, slty
Clyst, brn red
Ls, lt tan (vig HCl rxn) (SLIDE)
Ls, tan-pk; Clyst, m gy
Clyst, brn rd; Clyst, m gy
Sltst, wh, sil, pos coal chps
Sltst, wh, sil, dism sd grs, calc ctds/cmt
Clyst, rd, dism sd grs
Sltst, m gy, sil, arg
W a C S
Ss, m, sil cmt, hd (150+ GPM)
S
W a C , P
Ss, f-m, sil cmt, hd, tr pyr (FLOWING 5 GPM, AIR LIFTING 150+ GPM)
S
W a C , P
as above
Clyst, m gy, tr pyr, tr coal
Sh, br gy, sil


Mtn Village TW-2 (2019)
Field Log
Flow Logging Up
25 (ft/min) 70
Flow Logging Down
25 (ft/min) 70
Caliper
4 (in) 12
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
W r C S
Ss, vf, yel-brn, sil cmt, hd
W r C S
Ss, vf, lt gy, sil cmt, hd
Sltst, m gy, hd, sil, arg
Sltst, m gy, hd, sil, arg; Sltst, br-rd, hd, sil, arg; Ss, vf, lt gy, sil cmt, hd
W r C S
Ss, vf, lt gy, sil cmt, hd
Sltst, m gy, sil cmt, hd
Clyst, bl gy
Sltst, bl gy, arg, hd, sil
Sltst, lt gy, sil
Sltst, bl gy, hd, sil
Sltst, lt gy, hd, sil
Sltst, lt brn gy, arg, sil
Ls, lt brn (vig HCl rxn) (5 GPM)
Ls, tan (vig HCl rxn), spry calc (SLIDE)
Clyst, bl gy
W r C S
Ss,vf, lt gy, sil cmt (9 GPM)


Mtn Village TW-2 (2019)
Field Log
Flow Logging Up
25 (ft/min) 70
Flow Logging Down
25 (ft/min) 70
Caliper
4 (in) 12
Porosity
0 % 35
Grain Size
0.0 mm 1.0
Sorting
Roundness
Framework
Diagenesis
Lithology
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
W a C C, P
Ss, f-m, lt gy, calc cmt (wk HCl rxn), tr pyr (SLIDE)
W a C C
as above (vig HCl rxn)
P
Sltst, dk gy, arg, tr pyr; Ss, f, m gy, arg, slty
Clyst, brn red
Ls, lt tan (vig HCl rxn) (SLIDE)
Ls, tan-pk; Clyst, m gy
Clyst, brn rd; Clyst, m gy
Sltst, wh, sil, pos coal chps
Sltst, wh, sil, dism sd grs, calc ctds/cmt
Clyst, rd, dism sd grs
Sltst, m gy, sil, arg
W a C S
Ss, m, sil cmt, hd (150+ GPM)
W a C S, P
Ss, f-m, sil cmt, hd, tr pyr (FLOWING 5 GPM, AIR LIFTING 150+ GPM)
W a C S, P
as above
Clyst, m gy, tr pyr, tr coal
Sh, br gy, sil

Attachment D
MtnTW-2 Water Quality

ANALYTICAL SUMMARY REPORT

October 11, 2019

Big Sky Co Water and Sewer Dist 363
PO Box 160670
Big Sky, MT 59716-0670

Work Order: B19100283

Project Name: Test Well #2

Energy Laboratories Inc Billings MT received the following 1 sample for Big Sky Co Water and Sewer Dist 363 on 10/2/2019 for analysis.

Lab ID	Client Sample ID	Collect Date	Receive Date	Matrix	Test
B19100283-001	WSD Test Well #2	10/01/19 10:52	10/02/19	Aqueous	Metals by ICP/ICPMS, Total Alkalinity Conductivity Hardness Chloride Sulfate/Anions by Ion Chromatography pH Metals Digestion by E200.2 Preparation for TDS A2540 C Solids, Total Dissolved Sulfide, Methylene Blue Colorimetric

The analyses presented in this report were performed by Energy Laboratories, Inc., 1120 S 27th St., Billings, MT 59101, unless otherwise noted. Any exceptions or problems with the analyses are noted in the Laboratory Analytical Report, the QA/QC Summary Report, or the Case Narrative. Any issues encountered during sample receipt are documented in the Work Order Receipt Checklist.

The results as reported relate only to the item(s) submitted for testing. This report shall be used or copied only in its entirety. Energy Laboratories, Inc. is not responsible for the consequences arising from the use of a partial report.

If you have any questions regarding these test results, please contact your Project Manager.

Report Approved By:

LABORATORY ANALYTICAL REPORT

Prepared by Billings, MT Branch

Client: Big Sky Co Water and Sewer Dist 363
Project: Test Well #2
Lab ID: B19100283-001
Client Sample ID: WSD Test Well #2

Report Date: 10/11/19
Collection Date: 10/01/19 10:52
DateReceived: 10/02/19
Matrix: Aqueous

Analyses	Result	Units	Qualifiers	RL	MCL/ QCL	Method	Analysis Date / By
PHYSICAL PROPERTIES							
pH	7.8	s.u.	H	0.1		A4500-H B	10/03/19 12:06 / pjw
pH Measurement Temp	18	C				A4500-H B	10/03/19 12:06 / pjw
Conductivity @ 25 C	433	umhos/cm		5		A2510 B	10/03/19 12:06 / pjw
Solids, Total Dissolved TDS @ 180 C	252	mg/L		10		A2540 C	10/03/19 15:54 / drm
INORGANICS							
Alkalinity, Total as CaCO3	176	mg/L		4		A2320 B	10/03/19 11:50 / zas
Bicarbonate as HCO3	214	mg/L		4		A2320 B	10/03/19 11:50 / zas
Carbonate as CO3	ND	mg/L		4		A2320 B	10/03/19 11:50 / zas
Chloride	ND	mg/L		1		E300.0	10/08/19 04:54 / mrc
Sulfate	61	mg/L		1		E300.0	10/08/19 04:54 / mrc
Sulfide	ND	mg/L		0.04		A4500-S D	10/04/19 15:46 / zas
Hardness as CaCO3	222	mg/L		1		A2340 B	10/05/19 03:47 / klc
METALS, TOTAL							
Arsenic	ND	mg/L		0.001		E200.8	10/09/19 01:06 / car
Calcium	54	mg/L		1		E200.7	10/05/19 03:47 / mas
Iron	0.46	mg/L		0.02		E200.7	10/05/19 03:47 / mas
Magnesium	21	mg/L		1		E200.7	10/05/19 03:47 / mas
Manganese	0.057	mg/L		0.001		E200.7	10/05/19 03:47 / mas
Potassium	4	mg/L		1		E200.7	10/05/19 03:47 / mas
Sodium	3	mg/L		1		E200.7	10/05/19 03:47 / mas

Report Definitions:
RL - Analyte reporting limit.
QCL - Quality control limit.
H - Analysis performed past recommended holding time.
MCL - Maximum contaminant level.
ND - Not detected at the reporting limit.

Attachment E
Cost Estimates

DRILLING COST ESTIMATES

8-5/8" Casing to 1600', 7-7/8" Open Hole to 1700'					
Item No.	Description	Qty	Units	Rate	Total
1	Mobilization/Demobilization	1	LS	$ 90,000	$ 90,000
2	12-1/4 inch Mud-Rotary Drilling	1700	LF	$ 125	$ 212,500
3	8-5/8 inch Casing Installed	1600	LF	$ 90	$ 144,000
4	7-7/8 inch Open Hole Air-Rotary Drilling	100	LF	$ 60	$ 6,000
5	Development	24	HR	$ 400	$ 9,600
6	Temporary Pumping System	1	EA	$ 20,000	$ 20,000
7	Pumping Test Hourly Work	76	HR	$ 250	$ 19,000
8	Drilling Mud Disposal	2	EA	$ 5,000	$ 10,000
9	Open Hole Wireline Logging	1	EA	$ 10,000	$ 10,000
					$ 521,100
	Engineering			10%	$ 52,110
	Contingency			10%	$ 57,321
	TOTAL				$ 630,531
6-5/8" Casing to 100', 5-7/8" Open Hole to 800'					
ITEM NO.	DESCRIPTION	QTY	UNITS	RATE	TOTAL
1	Mobilization	1	LS	$ 500	$ 500
2	6" Drilling with Casing	100	LF	$ 45	$ 4,500
3	6" Drilling Open Hole	700	LF	$ 30	$ 21,000
4	Development	6	HR	$ 250	$ 1,500
			TOTAL		$ 27,500
6-5/8" Casing to 70'					
ITEM NO.	DESCRIPTION	QTY	UNITS	RATE	TOTAL
1	Mobilization	1	LS	$ 250	$ 250
2	6" Drilling with Casing	70	LF	$ 45	$ 3,150
4	Development	6	HR	$ 250	$ 1,500
			TOTAL		$ 4,900

ATTACHMENT C – TEST WELLS TW#3, TW#4, TW#5, TW#6, TW#7, AND TW#11

MEMORANDUM

To: Ron Edwards, Jim Muscat
Big Sky County Water and Sewer District No. 363

Fr: Mark Cunnane

Re: 2020 Mountain Village Test Wells

WESTERN GROUNDWATER SERVICES
6595 Bear Claw Lane • Bozeman, MT 59715
(406) 585-5947

1. INTRODUCTION

Big Sky County Water and Sewer District No. 363 (District) owns and operates the public water system for Mountain Village and other parts of Big Sky, Montana. This memorandum is providing results from test well drilling in Mountain Village during 2020 for the purpose of increasing water supply capacity. There were six test wells drilled for the project in 2020. There are three remaining wells scheduled for drilling during 2021.

1.1 Summary

- Test Wells #3, #4, #5, #6, #7, and #11 were drilled during fall 2020. Test Wells #8 and #10 are both accessible sites and can be drilled spring 2020 under the existing drilling contract. Test Well #9 requires additional site access, but also can be drilled under the existing drilling contract.

- Test Wells #3 and #4 were targeting alluvium in proximity to existing supply wells Mountain Village Nos. 1, 2, and 3. The test wells did not intercept a viable aquifer. Both wells penetrated till and then shale bedrock. Test Well #3 was abandoned to facilitate site use by the owner. Test Well #4 was capped.

- Test Wells #5, #6, and #11 were targeting water bearing zones in intrusive rocks (Mountain Village Nos. 4 and 7 both produce from intrusive rock). These wells did not encounter a viable aquifer. Intrusive rock thickness ranged from 160- to 310-feet and consisted of a medium grained, gabbro sill. Total depths of these wells ranged from 738- to 1,040-feet. Test Well #6 was terminated at 1,040-ft in the Kootenai formation. Test Wells #5 and #11 were both terminated in the top of the Thermopolis formation. Water quality analysis of Test Well #6 air-lift discharge measured 11 µg/L arsenic.

- Test Well #7 targeted the Kootenai formation and was drilled to a depth of 730 ft. This well fully penetrated the Kootenai formation and was pump tested. A four-hour step rate test was run with a maximum rate of 260-gpm. A 72-hour constant rate test was run on the next day at a rate of 215-gpm. Testing data indicate flow limiting boundary effects. Hydraulic modeling indicated a design capacity of 70-gpm and annual volume of 25-acre feet. Test Well #7 groundwater quality was measured to have 10 µg/L arsenic and trace levels of dissolved iron and manganese. The water was also classified as Hard.

2. DRILLING CONTRACTOR SERVICES

A public procurement process was used to select a drilling contractor for the project. Legal ads were run in the Bozeman Daily Chronicle on April 30th and May 7th. Bids were obtained electronically until midnight May 15, 2020. Bridger Drilling, Inc. was the lowest bidder and was awarded the project. Drilling contractor fees for the wells completed in 2020 are provided in **Table 1**. Test Wells #8 and #10 (Bedrock Wells – Artesian

Protection) are scheduled for drilling in 2021. Drilling contractor time runs to 9/15/2021.

Table 1. Bid and 2020 Contractor Fees

Item No.	Description	Qty	Units	Rate	Bid Total	Actual Qty	Actual Total
BEDROCK WELLS – NON-ARTESIAN							
B-1.1	Mobilization	3	LS	$ 1,000	$ 3,000	3	$ 3,000
B-1.2	6" Drilling with Casing	240	LF	$ 36	$ 8,640	580	$ 20,880
B-1.3	6" Drilling Open Hole	2160	LF	$ 26	$ 56,160	2038	$ 52,988
B-1.4	Development	18	HR	$ 275	$ 4,950	1	$ 275
				TOTAL	$ 72,750		$ 77,143
BEDROCK WELLS – ARTESIAN PROTECTION							
B-2.1	Mobilization	4	LS	$ 1,000	$ 4,000	1	$ 1,000
B-2.2	10" Drilling with Casing	320	LF	$ 50	$ 16,000	122	$ 6,100
B-2.3	Set and Cement 6" Casing	320	LF	$ 36	$ 11,360	122	$ 4,331
B-2.4	6" Drilling Open Hole	2880	LF	$ 26	$ 74,880	608	$ 15,808
B-2.5	Development	24	HR	$ 275	$ 6,600	3	$ 825
				TOTAL	$ 112,840		$ 28,064
ALLUVIUM WELLS							
B-3.1	Mobilization	2	LS	$ 1,000	$ 2,000	2	$ 2,000
B-3.2	6" Drilling with Casing	140	LF	$ 36	$ 5,040	157	$ 5,652
B-3.3	Development	12	HR	$ 275	$ 3,300	0	$ -
				TOTAL	$ 10,340		$ 7,652
CHANGE ORDERS							
C1	Contract time extension	0	NA	$ -	$ -		
C2	TW#3 Well Abandonment	80	LF	$ 20	$ 1,600	80	$ 1,600
C3-1	Wellhead Valve	1	EA	$ 1,100	$ 1,100	1	$ 1,100
C3-2	Downhole casing cutting	1	EA	$ 1,500	$ 1,500	1	$ 1,500
				TOTAL	$ 4,200		$ 4,200
				PROJECT TOTAL	$ 200,130		$ 117,059

3. WELL CONSTRUCTION

Test wells discussed below were drilled at the locations shown on **Figure 1**. Field logs for each well and sample photos are provided in **Attachment A**.

Figure 1. Well Location Map

3.1 Test Well TW #3

Test Well #3 targeted the shallow alluvial aquifer in proximity to Lake Lavinsky. It was drilled to 80 feet below ground surface (ft bgs) (**Figure 2**). Unconsolidated, low permeability glacial till was drilled to 76 ft bgs where claystone of the Mowry formation was encountered. No more than 2-gallons per minute (gpm) was air-lifted from the borehole. Most of the drilling required the addition of water to create a cuttings slurry. This test well was abandoned to facilitate use of the site by the owner during winter.

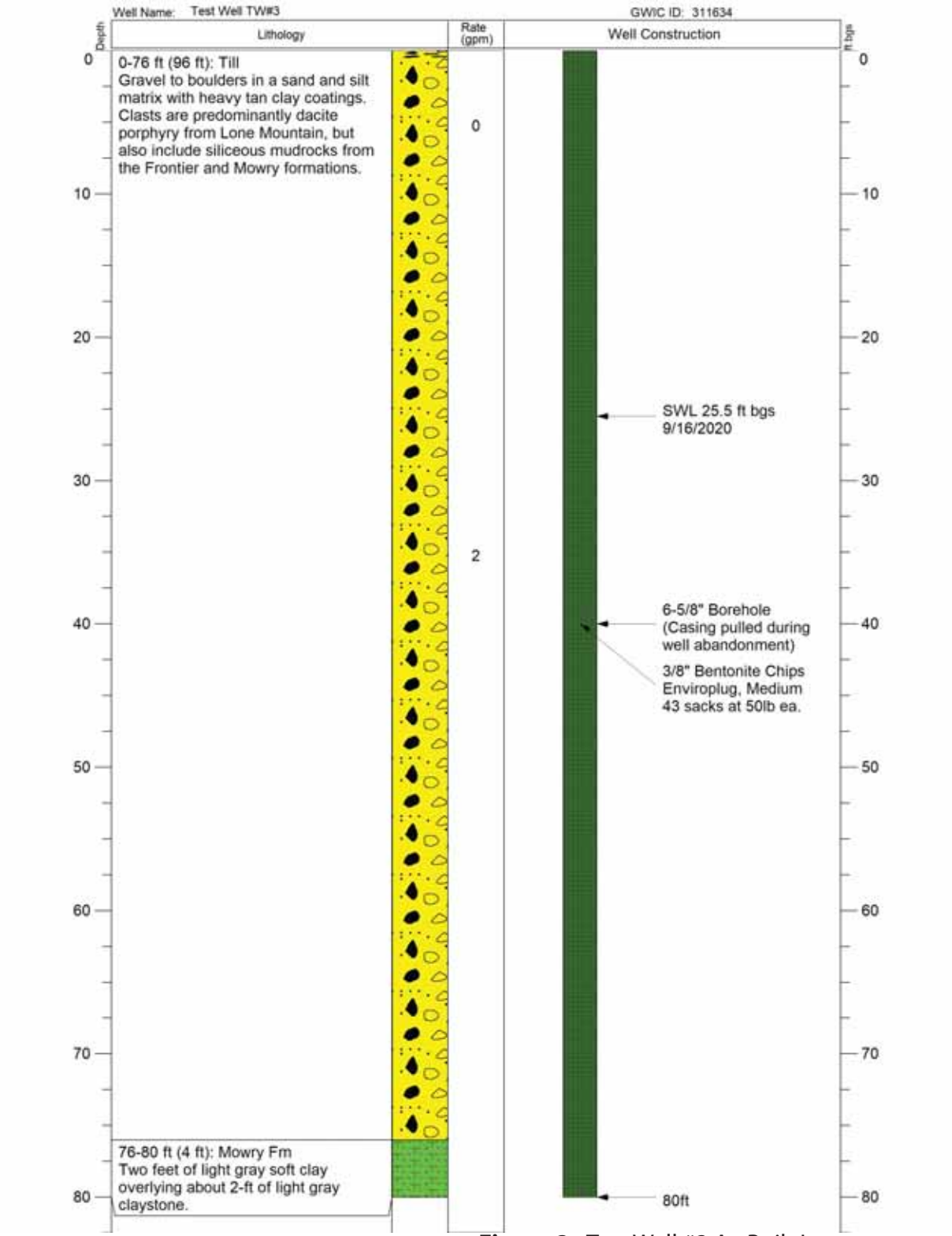


Figure 2. Test Well #3 As-Built Log

3.2 Test Well TW #4

Test Well #4 also targeted the shallow alluvial aquifer. It is located in proximity to an unnamed tributary of the Middle Fork. The borehole penetrated alluvium at shallow depth and then entered glacial till (**Figure 3**). Claystone of the Mowry formation was encountered at about 70 ft bgs. Negligible water production occurred during drilling. The well has not been abandoned and is equipped with a well cap set onto the casing.

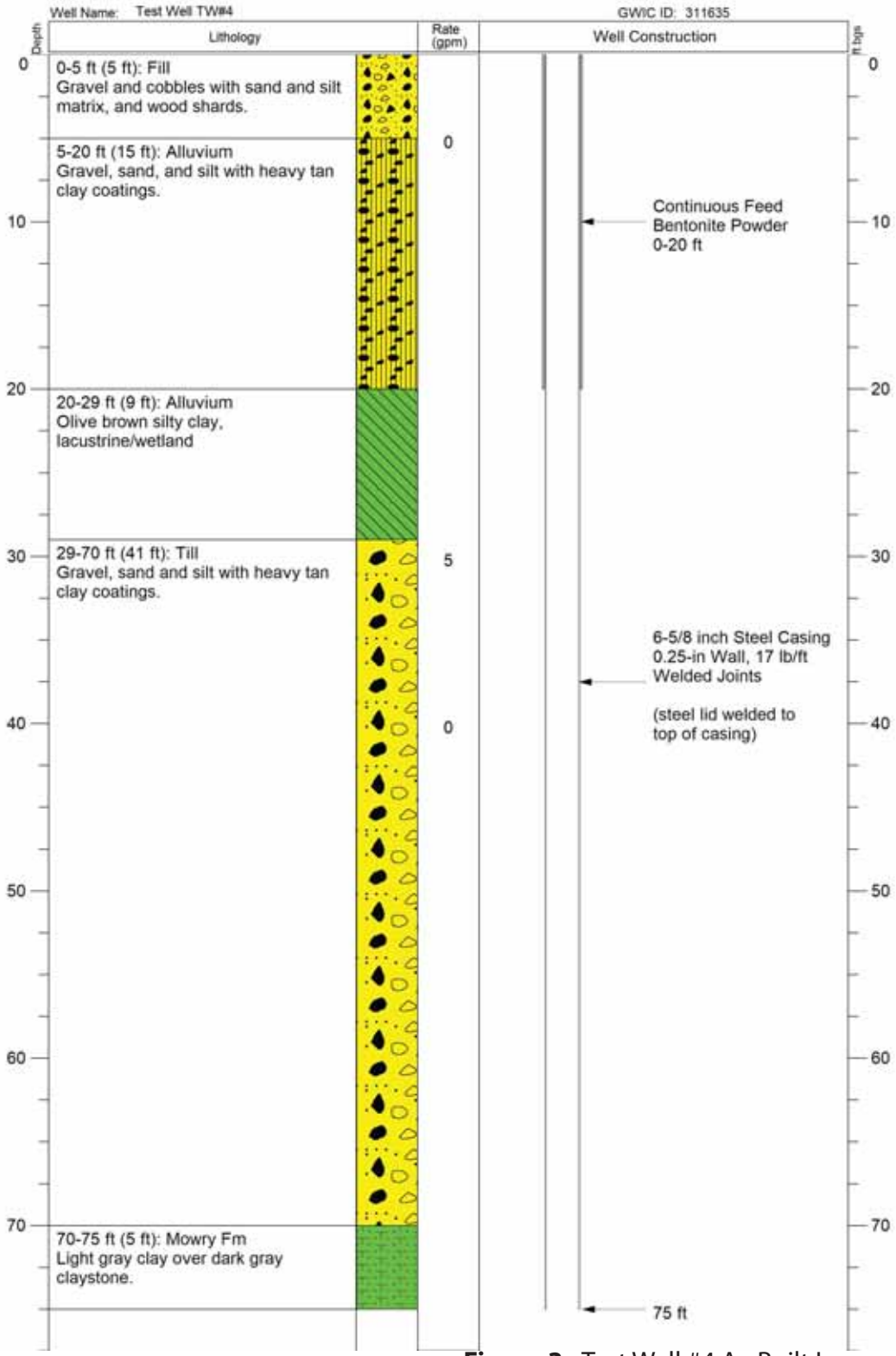


Figure 3. Test Well #4 As-Built Log

3.3 Test Well TW #5

Test Well #5 targeted intrusive rock near to the location of the Mountain Village storage tank. This well was drilled to 738 ft bgs, encountering intrusive rock from 520- to 680-ft bgs, for a total thickness of 160 ft (**Figure 4**). Total air-lift production from the well was about 30-gpm. A viable aquifer was not encountered.

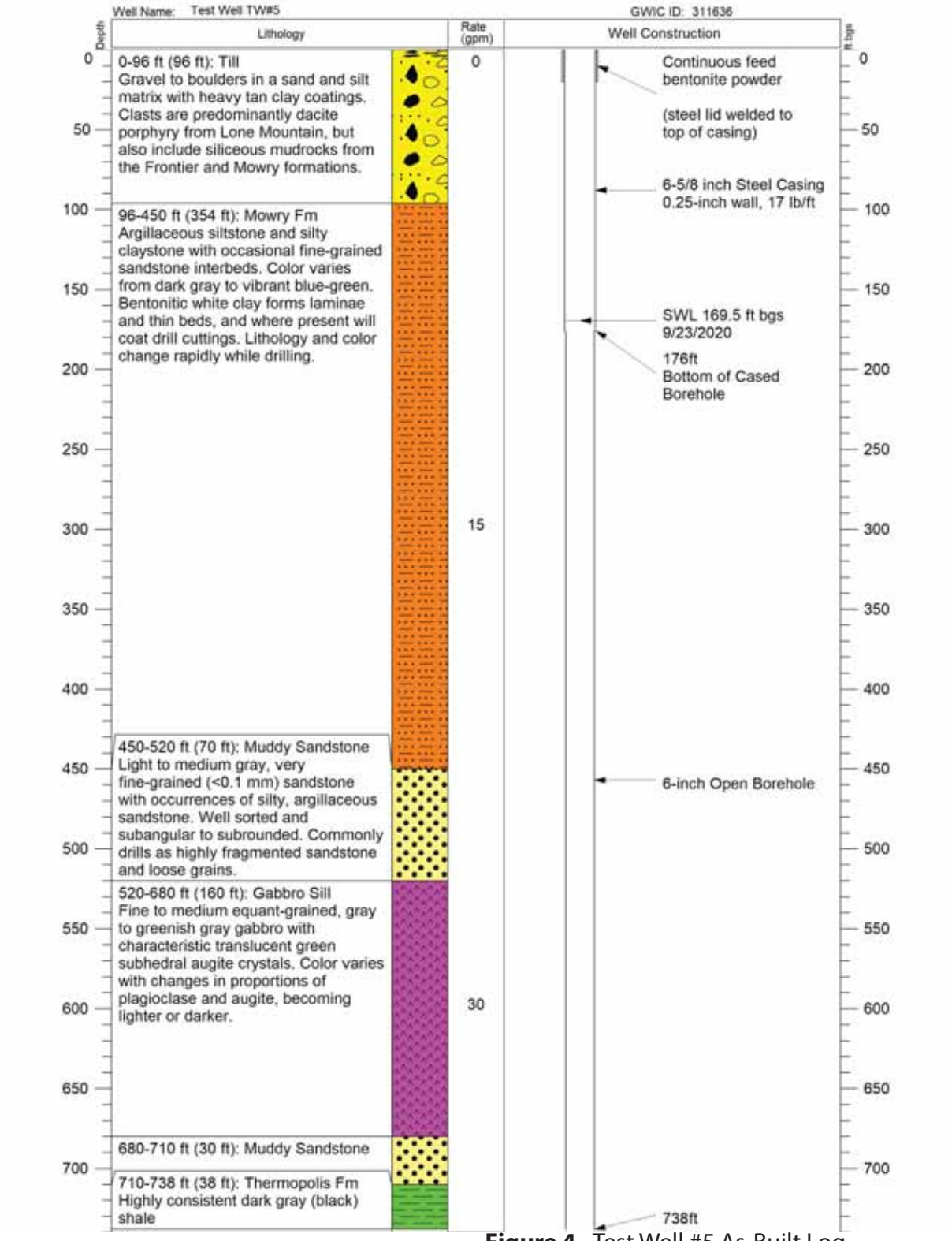


Figure 4. Test Well #5 As-Built Log

Till was penetrated from surface to 96-ft bgs where the borehole entered the Mowry formation. Due to poor quality rock, casing was extended to 176 ft bgs. Intrusive rock consisting of a gabbro sill in the Muddy Sandstone was encountered at 520 ft bgs. This sill appears to be prolific in the Mountain Village area, as it was also encountered in Test Well #1, and can be observed on Highway 64 near to the Gallatin – Madison County line. At 680 ft bgs, the borehole re-entered Muddy Sandstone, and then at 710 ft bgs, the Thermopolis formation.

Although the intrusive rock was non-productive at this location, it is possible to drill to the Kootenai formation, with greater production potential. A Kootenai well is estimated to have a total depth of approximately 1,700 ft bgs. A cost estimate for a Kootenai aquifer well at this site is provided below. Drilling of this well may not be possible by the air-rotary method, as the upper formations could cave before total depth was reached. Mud rotary would be the preferred method for the estimated drilling depth.

3.4 Test Well TW #6

Test Well #6 also targeted intrusive rock. Till was drilled to 165-ft bgs, where a thin section of Muddy Sandstone occurred and then the borehole entered intrusive rock (**Figure 5**). The intrusive at this location also was a gabbro sill and occurred at the same stratigraphic position as in TW #5.

Intrusive rock continued to 455 ft bgs, for a total thickness of 270 ft, where the borehole then re-entered Muddy Sandstone. The intrusive rock did not yield significant water flow into the borehole, with a total air-lift discharge of about 5 gpm. A sudden discharge of up to 30 gpm occurred where the borehole transitioned from intrusive rock back into the Muddy Sandstone, which occurred from 455- to 495-ft bgs.

The Thermopolis formation was drilled from 495- to 915-ft bgs, a total thickness of 380 ft. The basal sandstone of the Thermopolis was poor quality at this location. At 995 ft bgs, the borehole entered the limestone of the Kootenai formation. Drilling continued to a total depth of 1,040 ft bgs, remaining in the limestone. There was a substantial increase in water production to 150 gpm in the limestone.

Field parameters were measured in water sampled from the air-lift discharge (**Table 2**). Air-lift pumping impacts the field data substantially, with the exception of specific conductance.

Table 2. TW #6 Field Parameters (from Air-lift Discharge)

Temp (C)	pH	ORP (Eh, V)	SC (uS/cm)	Turb (NTU)	DO (mg/L)
16.26	8.11	0.376	472	37.7	9.57
ORP – oxidation reduction potential; SC – specific conductance; DO – dissolved oxygen					

Sulfide gas odor occurred from the Kootenai limestone discharge. A water sample collected from the air-lift discharge was analyzed for selected parameters (**Attachment B**). Analysis of this sample measured 11 µg/L arsenic, exceeding the MCL of 10 µg/L. Fluoride was also measured at 2.3 mg/L which exceeds the secondary standard of 2 mg/L. Water hardness was classified as Soft, with sodium at 66 mg/L. These results are unlikely to reflect the Kootenai aquifer, but are being influenced by shallower groundwater entering the well.

A production well at this location is not recommended for the drilled depth. A well fully penetrating the Kootenai aquifer, with a total depth estimated at 1,600 ft bgs, is expected to encounter increased production potential. Mud rotary would be the preferred drilling method. Cost estimation for a Kootenai aquifer well at this site is provided below.

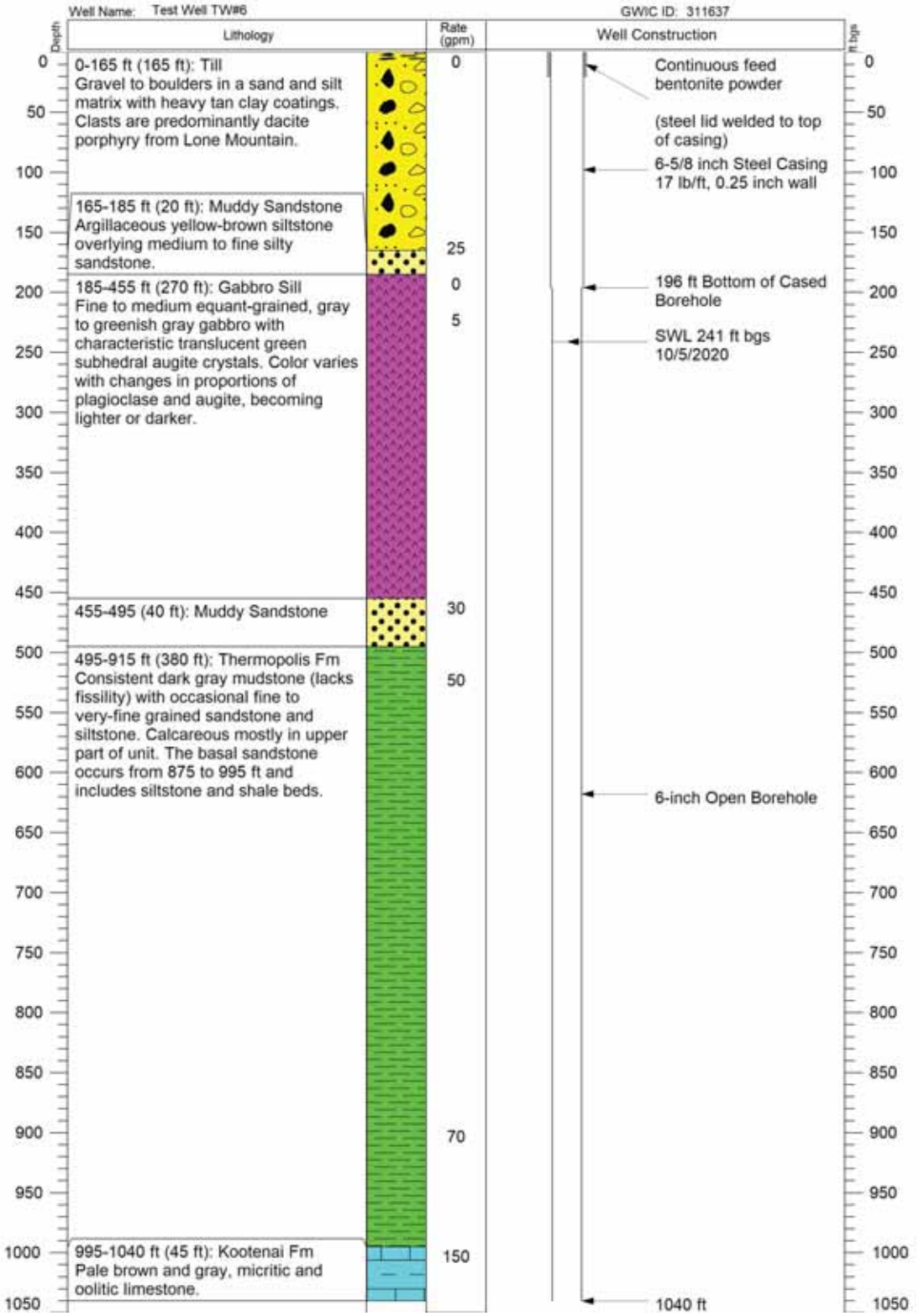


Figure 5. Test Well #6 As-Built Log

3.5 Test Well TW #7

3.5.1 Well Log

Test Well #7 targeted the Kootenai formation. It was drilled into the Middle Fork anticline, which was also drilled by Test Well TW #2 in 2019. TW #7 penetrated till to 96 ft bgs where the borehole entered the basal sandstone of the Thermopolis formation (**Figure 6**). This sandstone was silica cemented and very hard. It

continued to a depth of 185 ft bgs. The Kootenai formation was encountered from 185- to 715-ft bgs, where the borehole penetrated the Morrison formation to a total depth of 730 ft bgs.

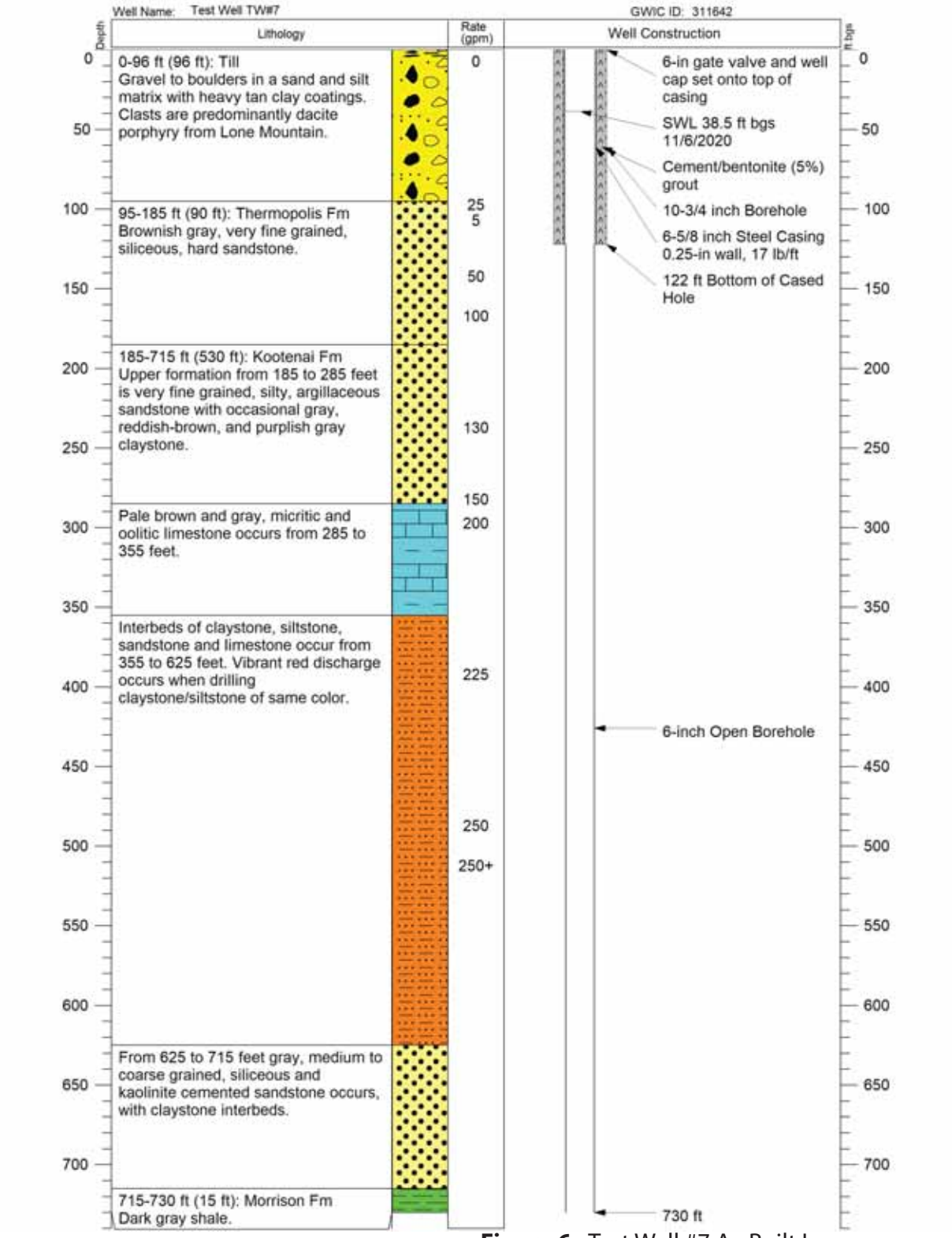


Figure 6. Test Well #7 As-Built Log

A 10-3/4 inch diameter borehole was drilled to 122 ft bgs to seal the well. Six inch casing was set into this borehole and cemented to surface. A 6-inch diameter gate valve was then set onto the casing and drilling occurred through the valve for the remainder of the work. The valve provided the ability to shut-in the well if flowing artesian conditions occurred. The final static water level of the well, however, was 38 ft bgs. The valve and fittings can be used when drilling Test Well #8 in 2021.

The Kootenai formation samples were very similar to Test Well TW #2, with limestone and vari-colored clay- and silt-stones occurring in the upper part of the formation. The basal sandstone was about 90 ft thick and appeared to be mostly kaolin cemented, and included some claystone interbeds. Sample quality was generally poor owing to drilling with a worn out bit.[1]

Contact with the underlying Morrison formation was poorly defined due to poor sample quality. It appears most likely that the borehole entered the Morrison at 715 ft bgs, although some sandstone grains and chips were encountered to the total depth of the well. The thickness of the Kootenai is consistent with the thickness observed at other locations. It appears the thickness was not exaggerated by a steeply dipping rock orientation.

Air-lift discharge from TW #7 was up to 100 gpm within the basal sandstone of the Thermopolis formation at 160 ft bgs. Discharge continued to increase to greater than 250 gpm by a depth of about 525 ft bgs. At this point, the air-lift system was likely at maximum rate and could not produce additional flow.

3.5.2 Pumping Tests

Step-rate and constant-rate pumping tests were completed in TW #7 with a pump setting of about 116 ft bgs (**Figure 7**). Static water level in the well had declined from 38- to 54-ft bgs at the time of testing. The step rate test determined a low head loss coefficient and that the constant rate test could be run at nominally 200 gpm (**Figure 8**).

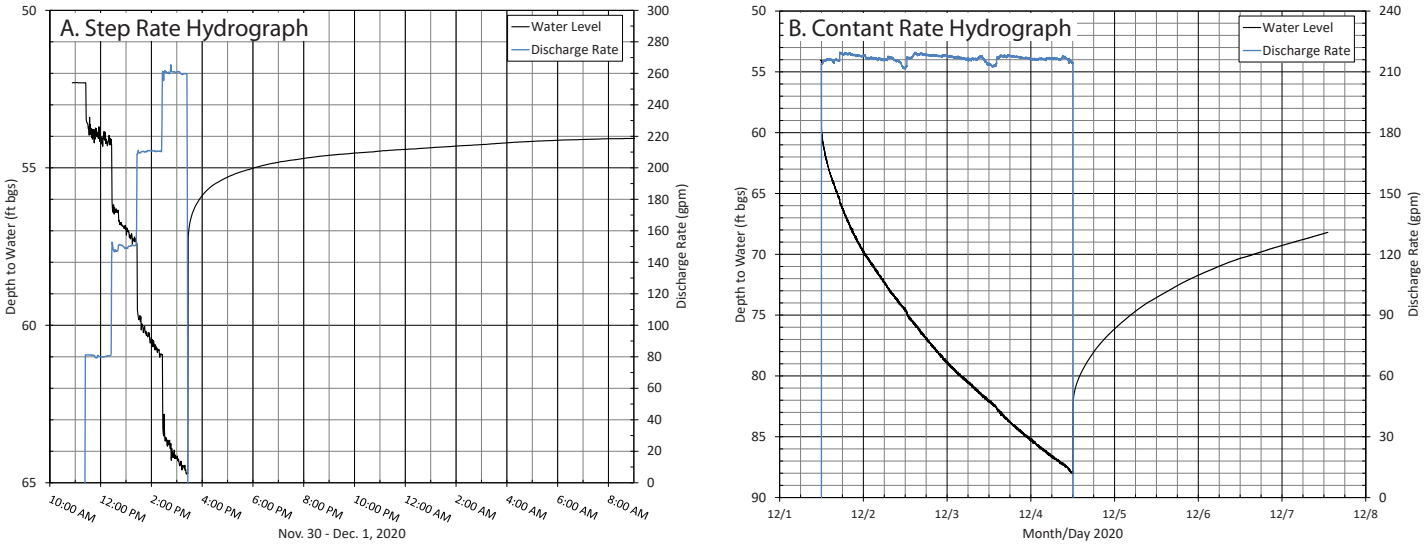


Figure 7. TW #7 Pumping Test Hydrographs

Constant rate testing was run at an average rate of 215 gpm. Analysis plots for this test show the aquifer has a transmissivity of about 4,500 ft^2/d, which is exceptional for bedrock formations and indicates a highly fractured formation (**Figure 9A**). The aquifer is also shown to be severely bounded which is limiting recharge (**Figure 9B**).[2] A reasonable concept of this setting is a compartmentalized aquifer with a recharge rate much lower than the pumping rate of the well. Consequently, after three-days for recovery, the drawdown in the well as about 14.5 ft (**Figure 9C**).

1 A tungsten carbide insert (TCI) tri-cone bit was over-used and lost buttons downhole. The hard steel buttons were not air-lifted out of the hole and impeded drilling progress, resulting in highly pulverized samples.

2 This condition is shown by the steeply increasing derivative of the drawdown data.

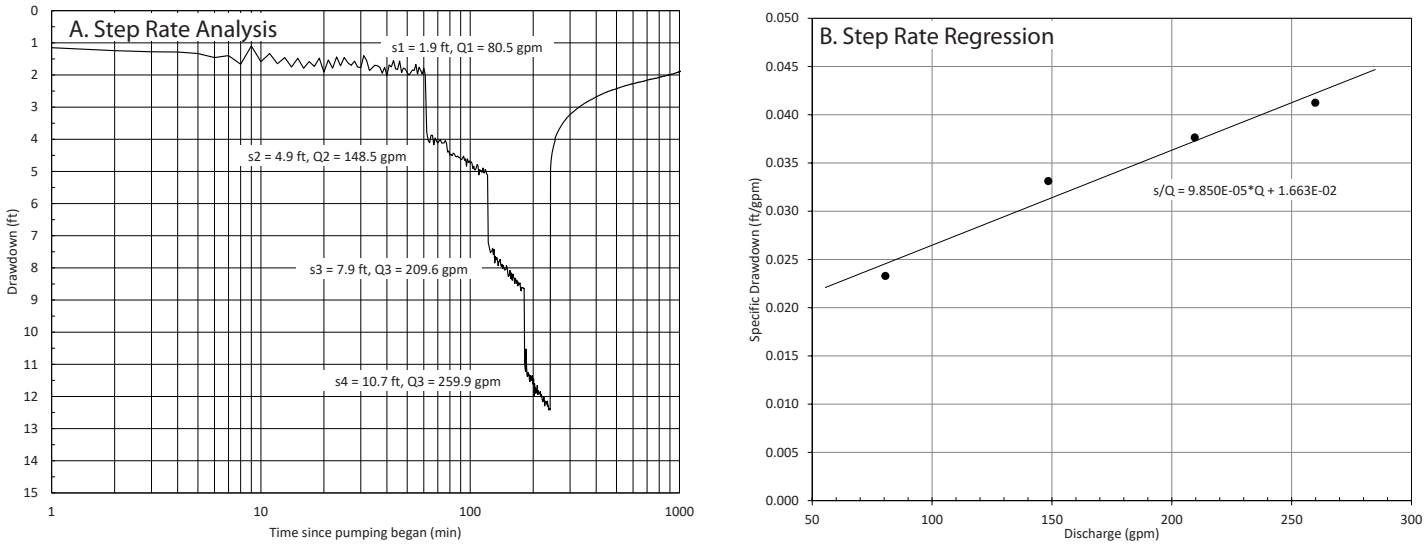


Figure 8. TW #7 Step Rate Analysis Plots

Hydraulic modeling of the constant rate test was completed using data corrected for turbulent head losses (**Figure 9D**).[3] This model is for a confined aquifer with three orthogonal flow limiting boundaries offset from the well 2,500 ft. While the solution is non-unique, it is providing a good visual match to the testing data.[4]

Design rate was determined for a well casing depth of 140 ft bgs and static water level of 50 ft bgs, with a pump setting at the bottom of casing. This construction would require a new well installation. A deeper casing depth could be contemplated, however, based on the test well data, some production could be lost. Design rate based on a 180-day continuous pumping period was determined to be 70 gpm. Based on 5-years of continuous pumping, the annual volume was determined to be 25 acre-feet. The existing test well also could be completed as a production well and used approximately at these same rates and volumes.

DEQ would approve the test well for the tested rate, as the standard allows for design rate to be determined by 1X pumping for 72-hours. Likewise, DNRC would approve the well for the tested rate based on the same criteria. These simpler methods are appropriate for unbounded aquifers and while they can be applied to TW #7 for regulatory purposes, they result in much higher rates than could be sustained.

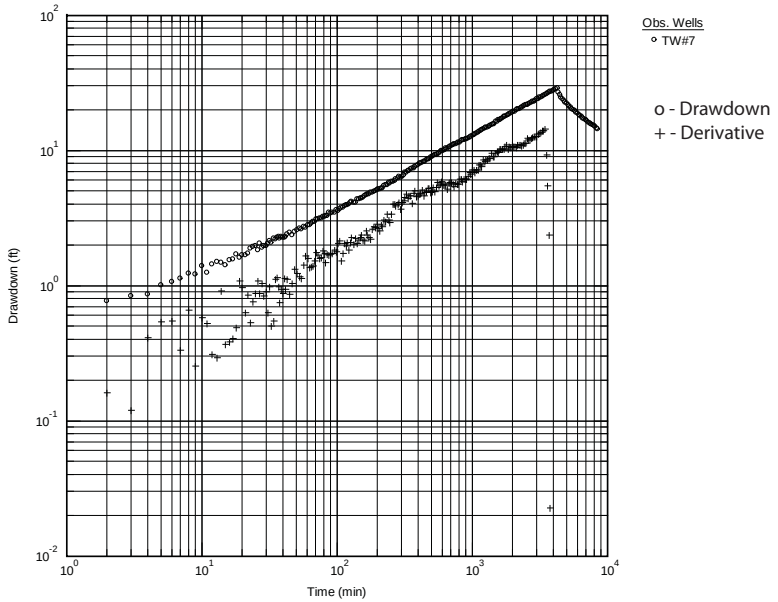
Based on the bounded aquifer response to pumping, the TW #7 site would not be recommended for a production well if more viable locations were known to exist. However, under the present conditions where more viable options are not known, additional testing is recommended to further assess water quality and capacity. Based on the present results from the test well drilling program, the District may need to accept development of several smaller capacity wells.

A seven-day pumping test run at 175 gpm and with monitoring of TW #2 is recommended. This test will enable further assessment of water quality and capacity. Determination of arsenic, iron and manganese concentrations from daily samples would most usefully characterize these parameters. Monitoring in the pumping well and also TW #2 would be useful for additional capacity analysis. If TW #8 were to also fully penetrate the Kootenai, it would provide a third monitoring location. For this reason, testing should be planned after TW #8 is drilled.

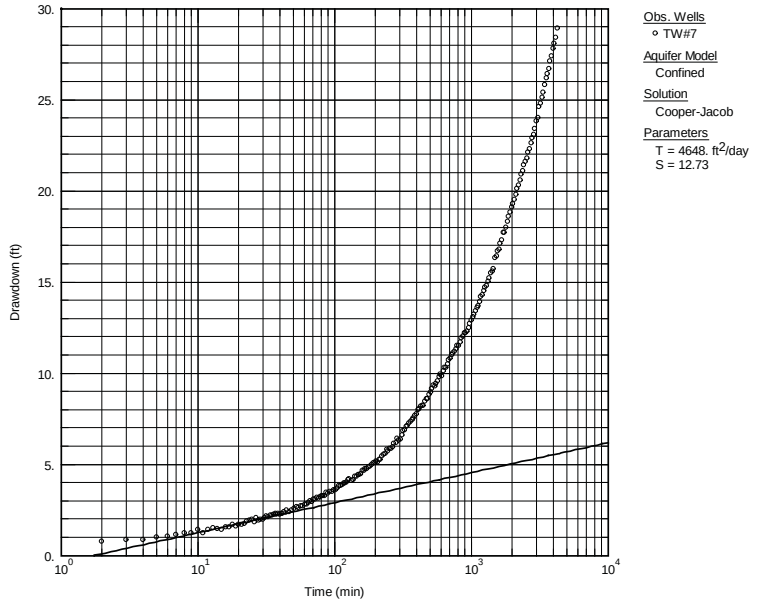
3 Turbulent head loss determined from the step rate test was subtracted from total drawdown.

4 Analysis plots and modeling was completed using the AQTESOLV software by HydroSOLVE, Inc. The model was numerically and manually fit to the test data.

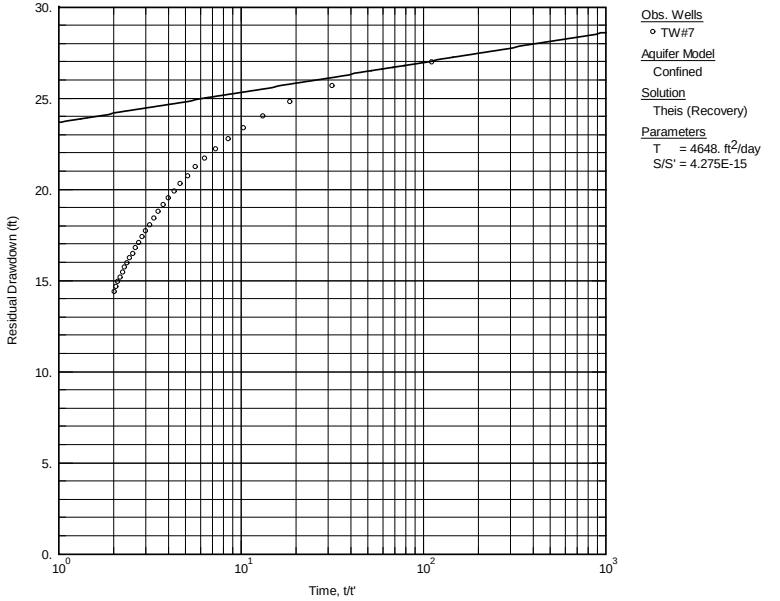
A.



B.



C.



D.

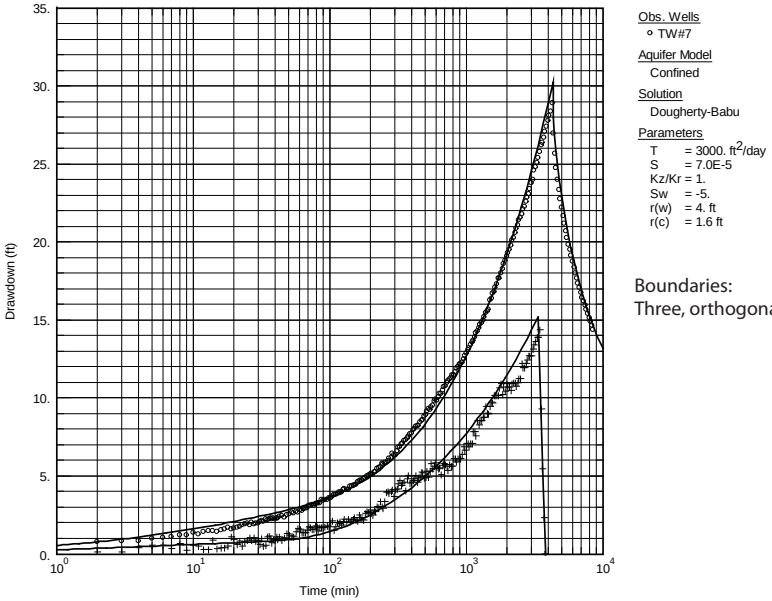


Figure 9. TW #7 Constant Rate Analysis Plots

3.5.3 Water Quality

Field parameters were measured through a flow cell that prevents contact with atmospheric air, but does not prevent degassing of carbon dioxide which creates gas bubbles and apparent turbidity (**Table 3**). The discharge was observed to have excellent clarity and was also odorless. Dissolved oxygen was absent from the water which is also reflected in the low oxidation-reduction potential. pH was slightly acidic and specific conductance was about typical for bedrock aquifers in Mountain Village.

Table 3. TW #7 Field Parameters (during pump testing)

Temp (°F)	pH	ORP (Eh, V)	SC (uS/cm)	Turb (NTU)	DO (mg/L)
44	6.88	0.188	471	694	0.00
ORP – oxidation reduction potential; SC – specific conductance; DO – dissolved oxygen					

The lab report (**Attachment B**) indicates compliance with radionuclides, but arsenic was measured at the MCL of 10 µg/L. There was also trace levels of iron and manganese. The water was also moderately high in calcium and magnesium and is classified as Hard. The lab sample pH of 8.4 is typical of groundwaters that degass abundant CO_2, as was the case for TW #7.

3.6 Test Well TW #11

Test Well TW #11 was drilled in proximity to the Yellowstone Club booster station located south from the Swift Current chairlift loading facility. This location drills into a syncline hinge area and has potential to be located over moderately steeply dipping rock. Borehole geology of TW #11 is very similar to TW #5 located uphill to the west, although TW #5 is closer to the Middle Fork anticline hinge area.

TW #11 penetrated till to the Mowry formation at 96 ft bgs (**Figure 10**). The Mowry formation extends to 475 ft bgs where a thin section of Muddy Sandstone occurs (10 ft) before the borehole enters the gabbro sill, which had a drilled thickness of 310 ft. The gabbro sill is observed at the same stratigraphic location in test wells TW #1, TW #5, TW #6, and TW #11 (and also in outcrop along Highway 64). Below the sill, a slightly thicker Muddy Sandstone was encountered (30 ft) and then the borehole entered the Thermopolis formation at 815 ft bgs, which continued to the total drilled depth of 840 ft bgs. Water production during drilling reached about 60 gpm by the depth of the gabbro sill and then remained constant. A deeper test well at this location could target the Kootenai aquifer with a total estimated depth of approximately 1,900 ft bgs.

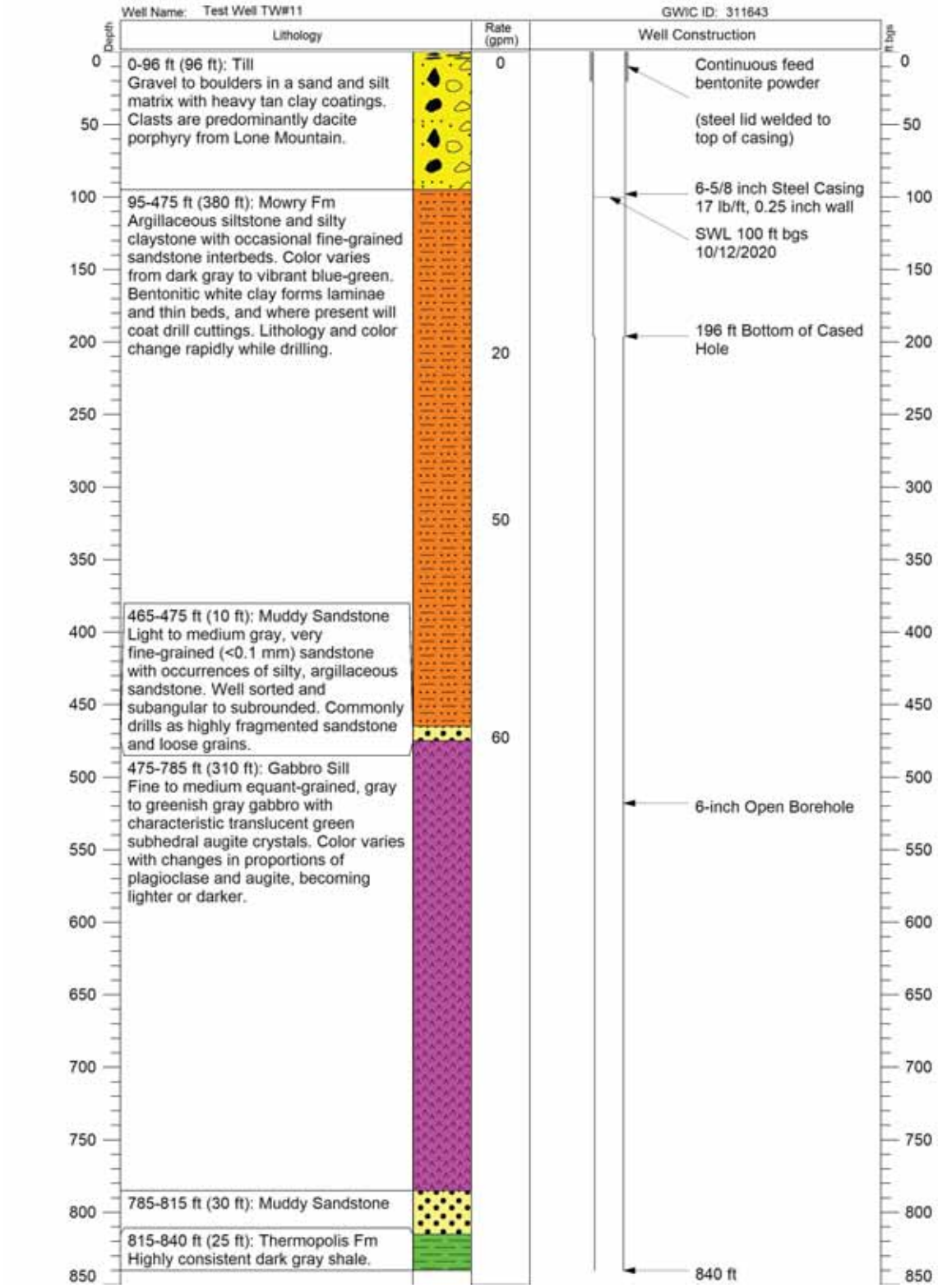


Figure 10. TW #11 As-Built Log

4. DRILLING COST ESTIMATE

A budget estimate for a Kootenai well drilled to 1,800 ft bgs using a combination of air- and mud-rotary drilling is provided in **Table 4**. A design illustration is provided on **Figure 11**. This well construction would set a 12-inch diameter casing through till and soft sedimentary rock to a depth of 200 ft using air-rotary drilling. The borehole at nominal 12-inch diameter would then be drilled by mud-rotary to the Kootenai limestone at an estimated depth of 1400 ft bgs (for budget purposes). An 8-5/8 inch diameter casing would

be set and cemented into this borehole and the 12-inch casing would be pulled. The aquifer formation would be drilled open hole at 7-7/8 inch diameter through the basal sandstone at 1800 ft bgs (either air- or mud-rotary). Air-lift development would follow, and pump testing is also included. There is some chance a liner would be needed if the Kootenai was prone to caving. Installation of the liner is not included.

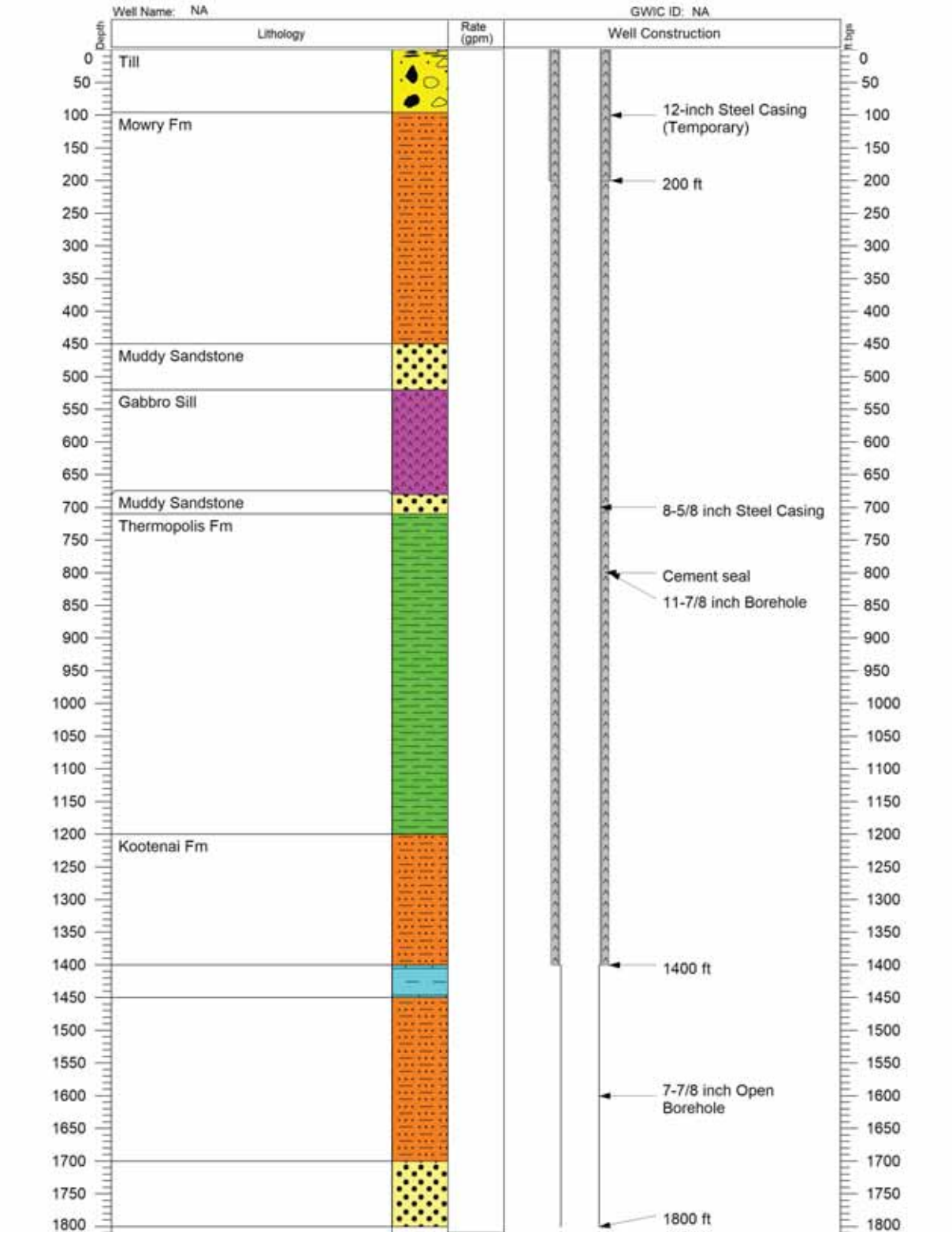


Figure 11. Kootenai Well Design (Preliminary)

Table 4. Kootenai Well Cost Estimate (8-inch casing, 1800 ft)

Description	Qty	Unit	Rate	Total
Mobilization	1	LS	$ 50,000	$ 50,000
12" Drilling with Casing	200	LF	$ 150	$ 30,000
11-7/8" Open Hole Drilling	1200	LF	$ 100	$ 120,000
Wireline logging	1	EA	$ 10,000	$ 10,000
Set and cement 8-5/8 in casing	1400	LF	$ 100	$ 140,000
7-7/8" Open Hole Drilling (Air Rotary)	400	LF	$ 100	$ 40,000
Development	24	HR	$ 600	$ 14,400
Temporary Pumping System	1	LS	$ 25,000	$ 25,000
Pumping Test Hourly	76	HR	$ 225	$ 17,100
TOTAL				$ 446,500

5. RECOMMENDATIONS

- Drill Test Well TW #8. TW #7 and TW #8 were redundant wells targeting the Kootenai aquifer, however, given the compartmentalized aquifer conditions being observed, there is a chance wells could be developed at both sites. The Kootenai at this location may be too deep to fully penetrate, however, the test well will provide geologic control to estimate total depth for a Kootenai well at the site. This site also is favorably located for a water supply well. This test well is included in the present drilling contract.

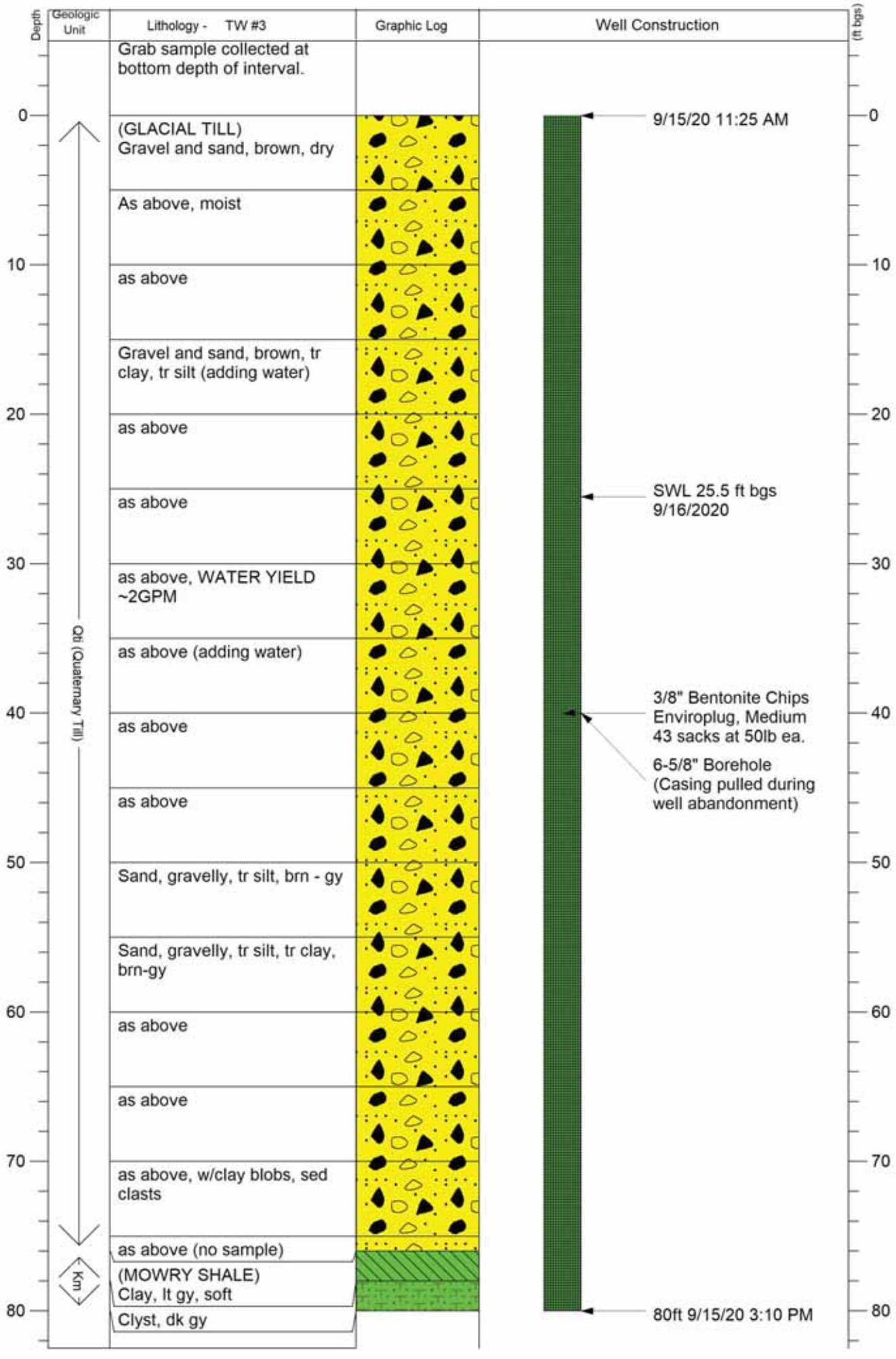
- Drill Test Wells #9 and #10. These locations are both targeting intrusive rock and likely cannot fully penetrate the Kootenai aquifer. TW #9 is located along the Middle Fork channel, which differs from the other intrusive test wells. TW #10 may intercept the same water bearing zone as existing wells MTN-4 and MTN-7. Both test wells are included in the present drilling contract.

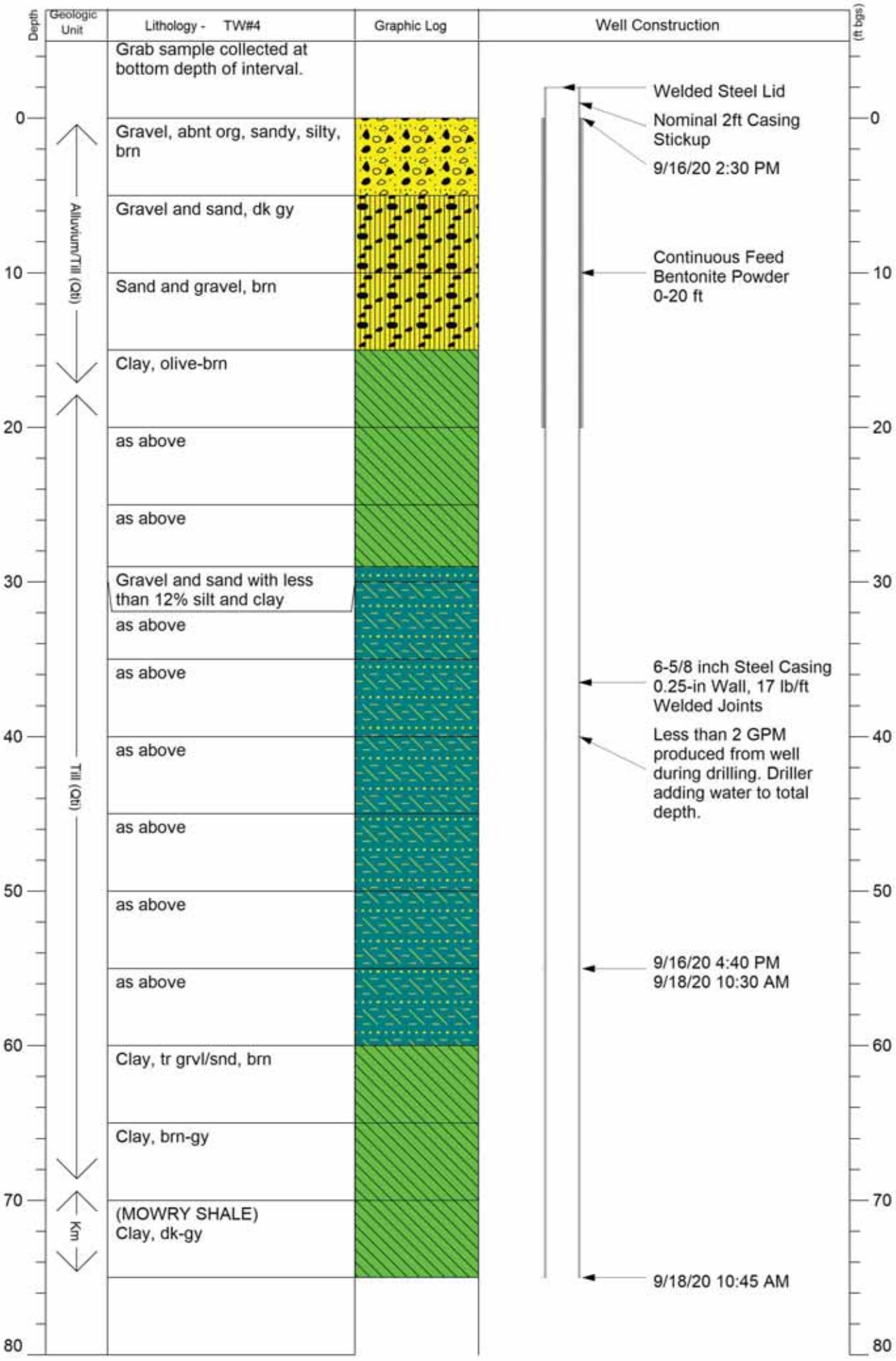
- Conduct a longer pumping test in TW #7. A 7-day (10,000 minute) test is recommended to evaluate both groundwater quality and capacity. This work would be a contractor change order. A testing plan can also be developed to utilize District resources. The District could furnish and refuel the generator, conduct daily data downloads from testing instruments, and collect and ship water quality samples.

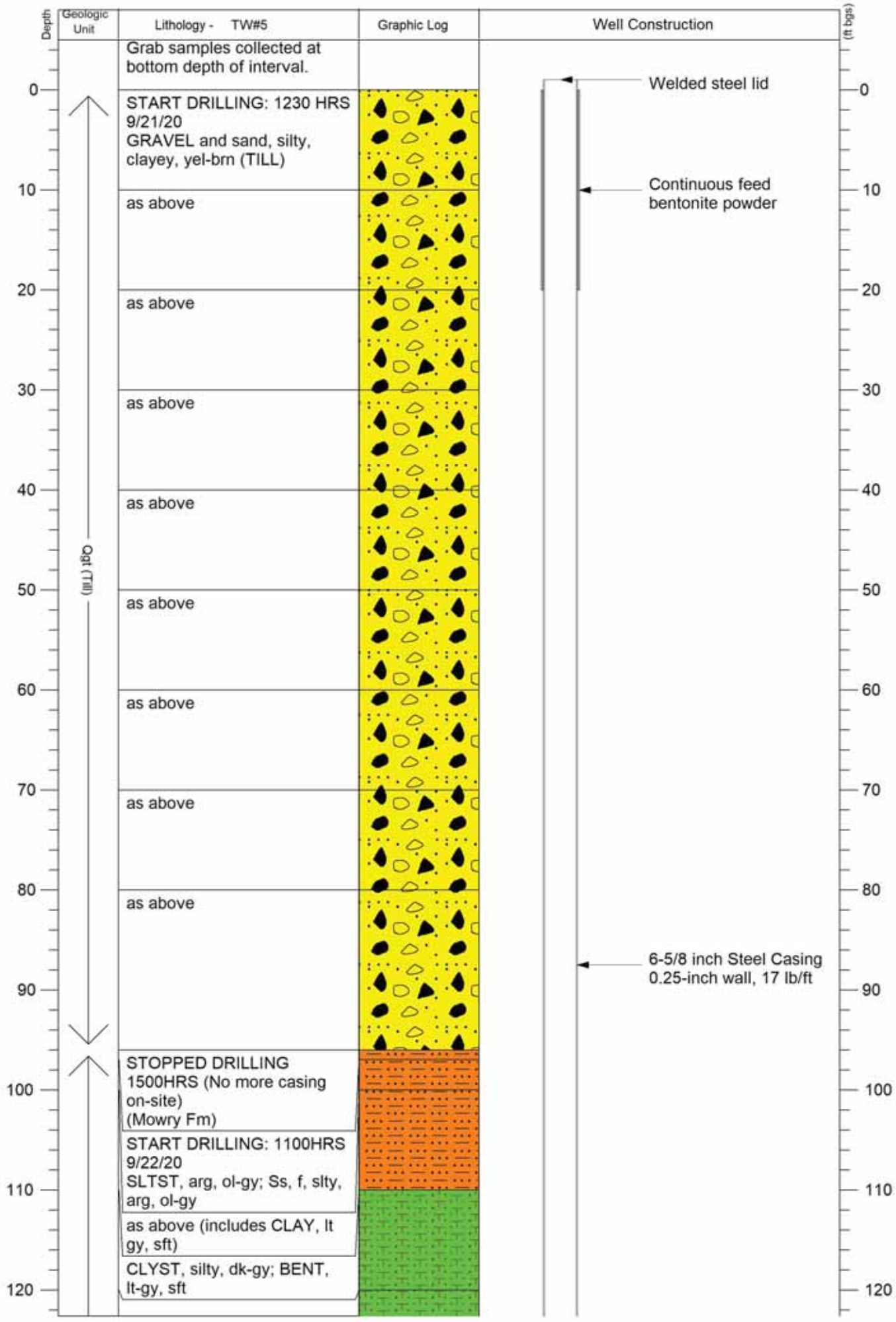
- A groundwater recharge analysis is recommended for the Mountain Village area. This analysis would estimate total groundwater recharge rate and recharge rate to specific formations. These analyses have accuracy of ±25% to ±50%, giving primarily order of magnitude results. The results can be considered with respect to total groundwater production potential. This analysis can be completed at anytime as it is not contingent upon drilling work.

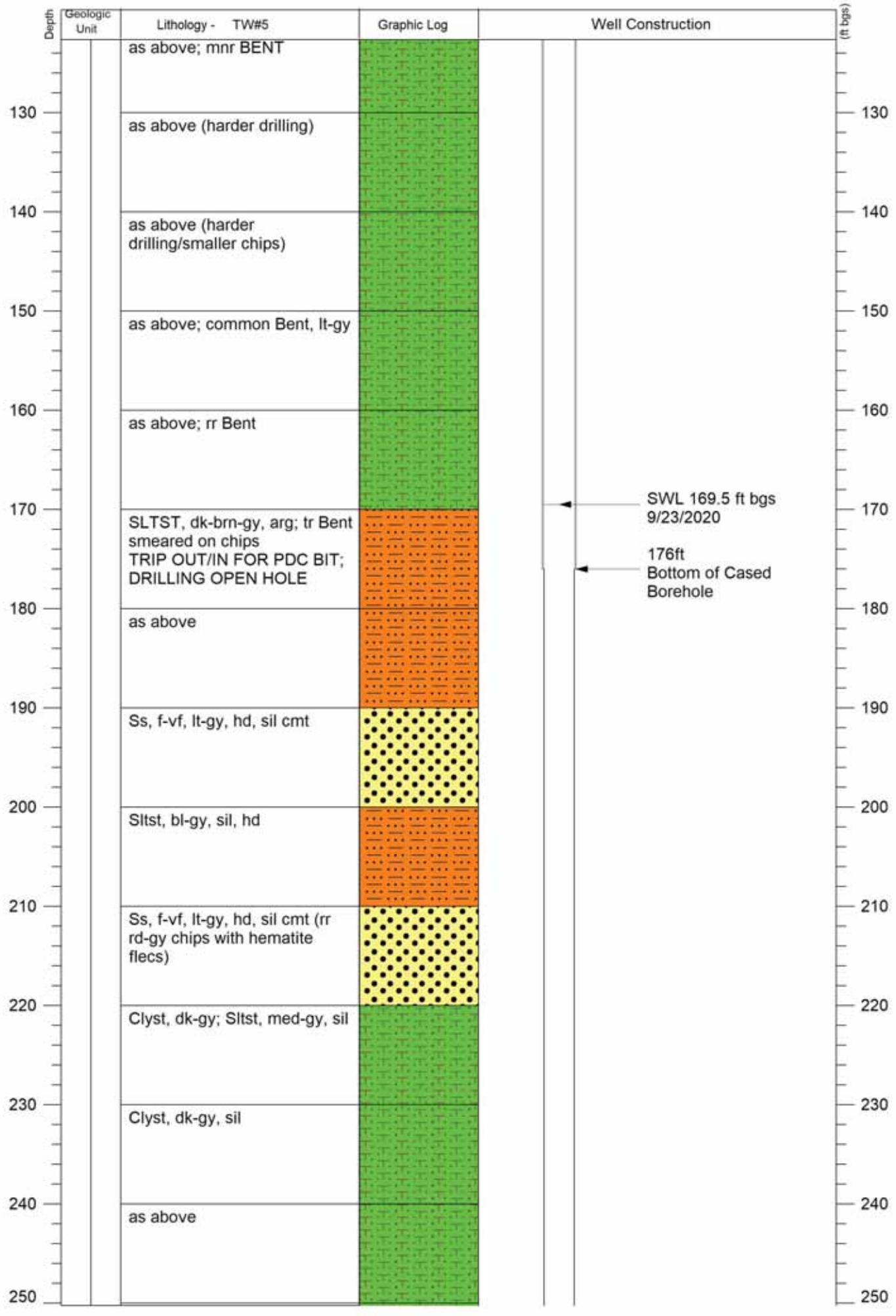
- An aquifer storage and recovery (ASR) feasibility study is recommended. ASR artificially recharges wells that are known to produce from bounded aquifers. The wells are then available for peak demand use. This phase one feasibility study would evaluate existing water supply data to determine injection rate/volume that is available from existing sources (during off-peak periods). The evaluation would also estimate recharge capacity and geochemistry reactions that may occur during injection and storage. The study would also include a review of regulatory requirements including water right permitting. A cost analysis for a phase two pilot test and projected costs for permanent facilities also would be included.

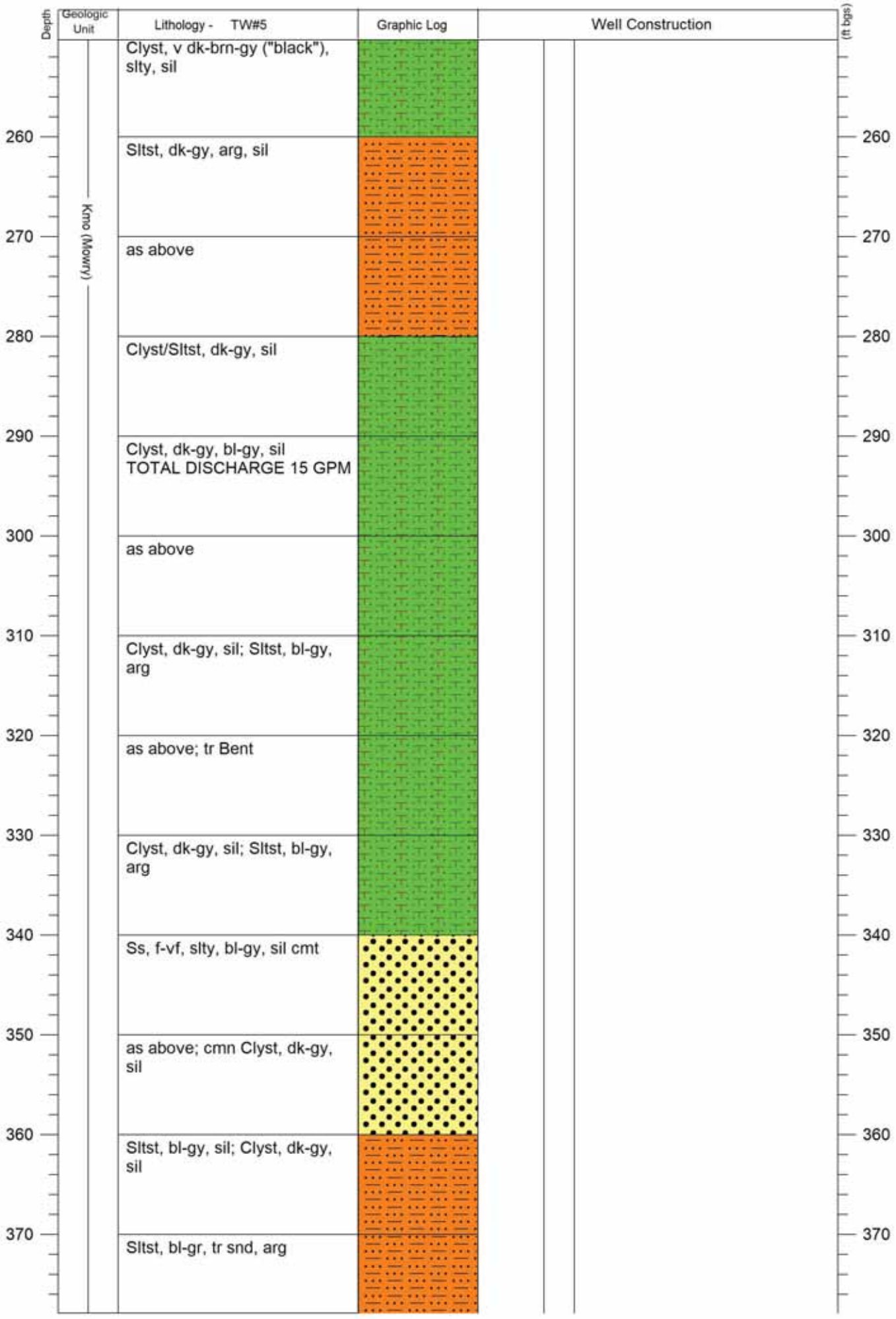
ATTACHMENT A
WELL LOGS AND PHOTOS

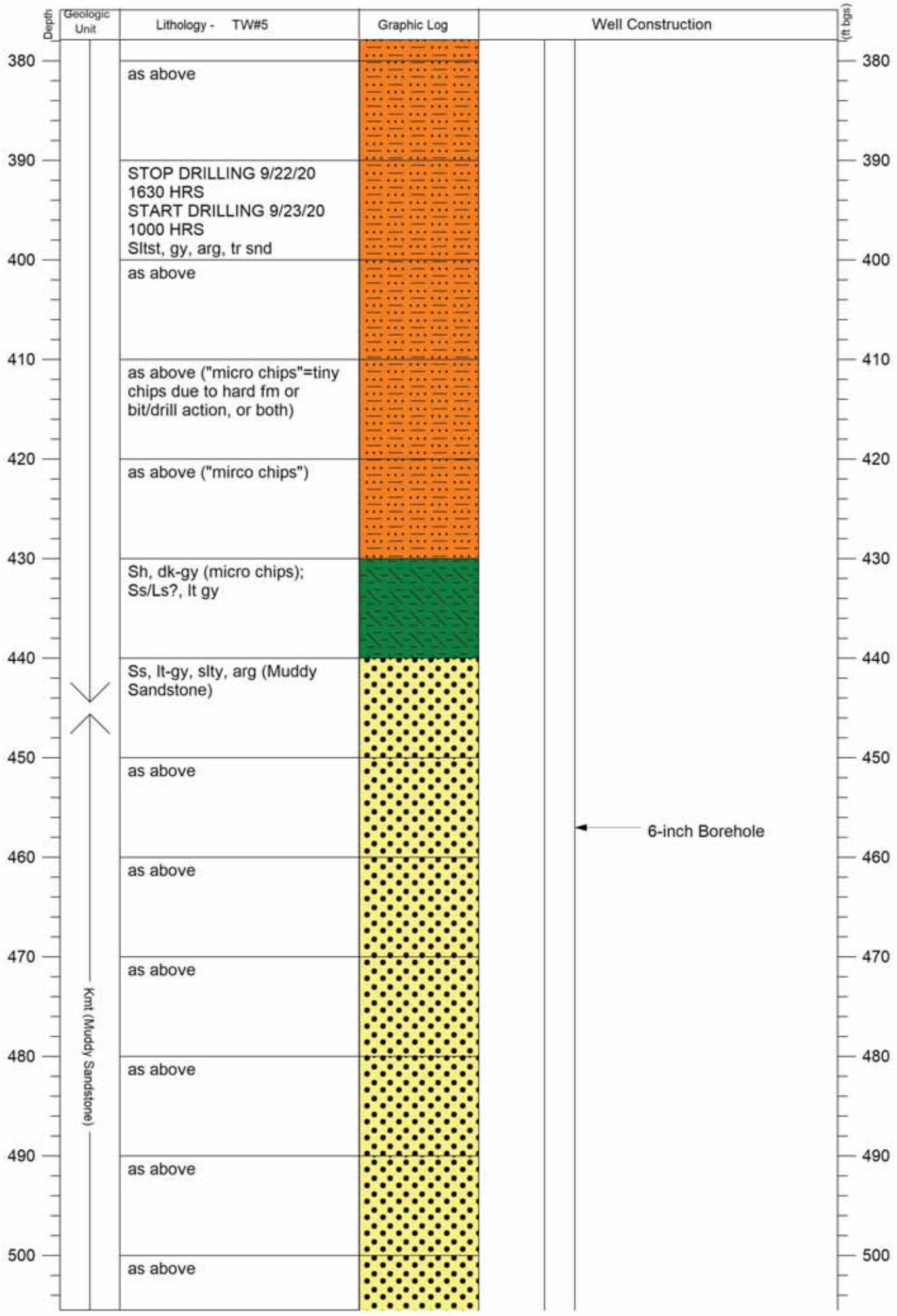

Depth
Geologic Unit
Lithology - TW #3
Graphic Log
Well Construction
(ft bgs)
Grab sample collected at bottom depth of interval.
(GLACIAL TILL)
Gravel and sand, brown, dry
As above, moist
as above
Gravel and sand, brown, tr clay, tr silt (adding water)
as above
as above
as above, WATER YIELD ~2GPM
as above (adding water)
as above
as above
Sand, gravelly, tr silt, brn - gy
Sand, gravelly, tr silt, tr clay, brn-gy
as above
as above
as above, w/clay blobs, sed clasts
as above (no sample)
(MOWRY SHALE)
Clay, lt gy, soft
Clyst, dk gy
Qti (Quaternary Till)
Km
0
10
20
30
40
50
60
70
80
9/15/20 11:25 AM
SWL 25.5 ft bgs
9/16/2020
3/8" Bentonite Chips
Enviroplug, Medium
43 sacks at 50lb ea.
6-5/8" Borehole
(Casing pulled during well abandonment)
80ft 9/15/20 3:10 PM

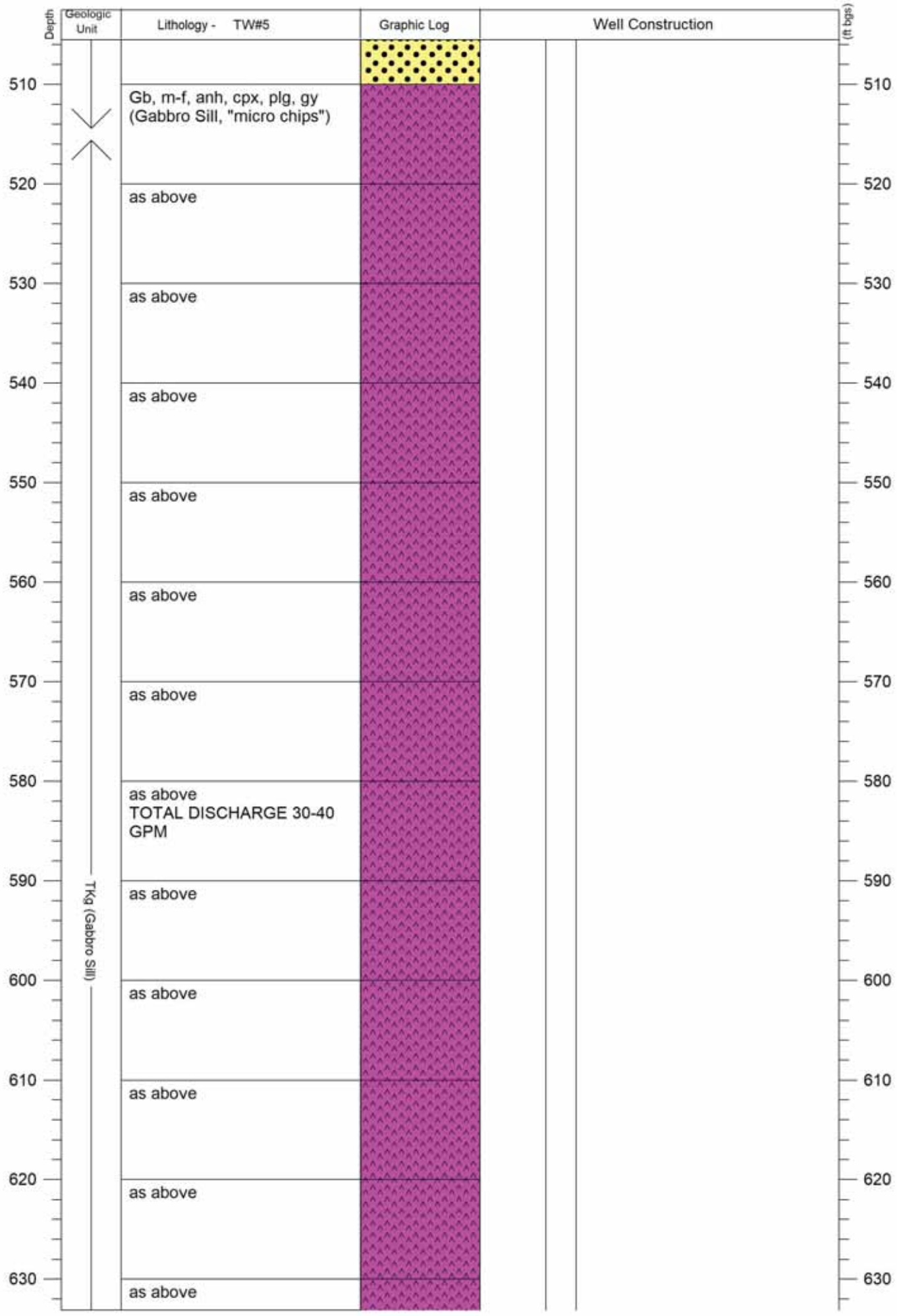

Depth
Geologic Unit
Lithology - TW#4
Graphic Log
Well Construction
(ft bgs)
Grab sample collected at bottom depth of interval.
Gravel, abnt org, sandy, silty, brn
Gravel and sand, dk gy
Sand and gravel, brn
Clay, olive-brn
as above
as above
Gravel and sand with less than 12% silt and clay
as above
as above
as above
as above
as above
as above
Clay, tr grvl/snd, brn
Clay, brn-gy
(MOWRY SHALE)
Clay, dk-gy
Alluvium/Till (Qti)
Till (Qti)
Km
0
10
20
30
40
50
60
70
80
Welded Steel Lid
Nominal 2ft Casing Stickup
9/16/20 2:30 PM
Continuous Feed Bentonite Powder 0-20 ft
6-5/8 inch Steel Casing 0.25-in Wall, 17 lb/ft Welded Joints
Less than 2 GPM produced from well during drilling. Driller adding water to total depth.
9/16/20 4:40 PM
9/18/20 10:30 AM
9/18/20 10:45 AM

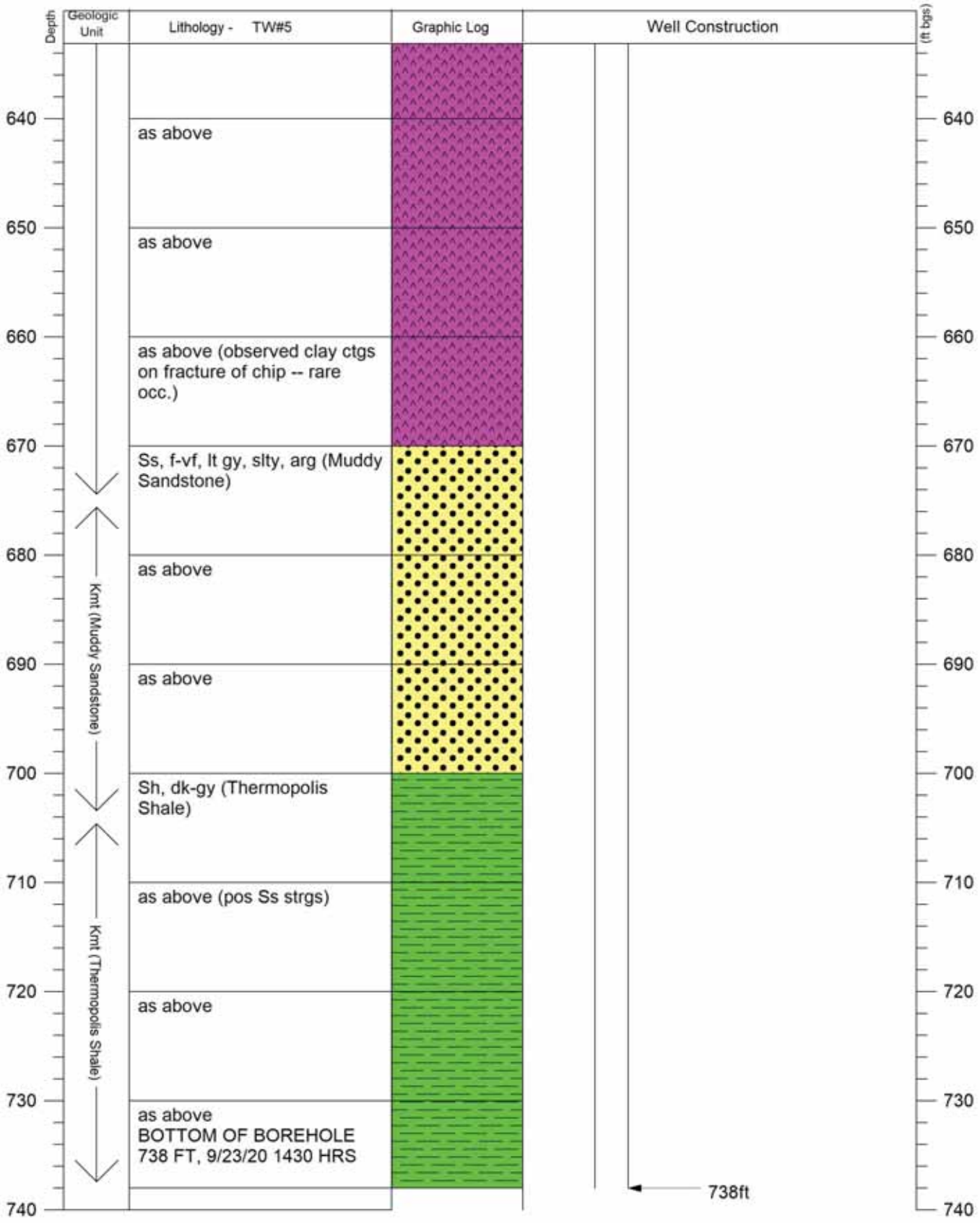

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at bottom depth of interval.
START DRILLING: 1230 HRS 9/21/20
GRAVEL and sand, silty, clayey, yel-brn (TILL)
as above
as above
as above
as above
as above
as above
as above
as above
Qgt (Till)
STOPPED DRILLING 1500HRS (No more casing on-site) (Mowry Fm)
START DRILLING: 1100HRS 9/22/20
SLTST, arg, ol-gy; Ss, f, slty, arg, ol-gy
as above (includes CLAY, lt gy, sft)
CLYST, silty, dk-gy; BENT, lt-gy, sft
Welded steel lid
Continuous feed bentonite powder
6-5/8 inch Steel Casing
0.25-inch wall, 17 lb/ft
0
10
20
30
40
50
60
70
80
90
100
110
120

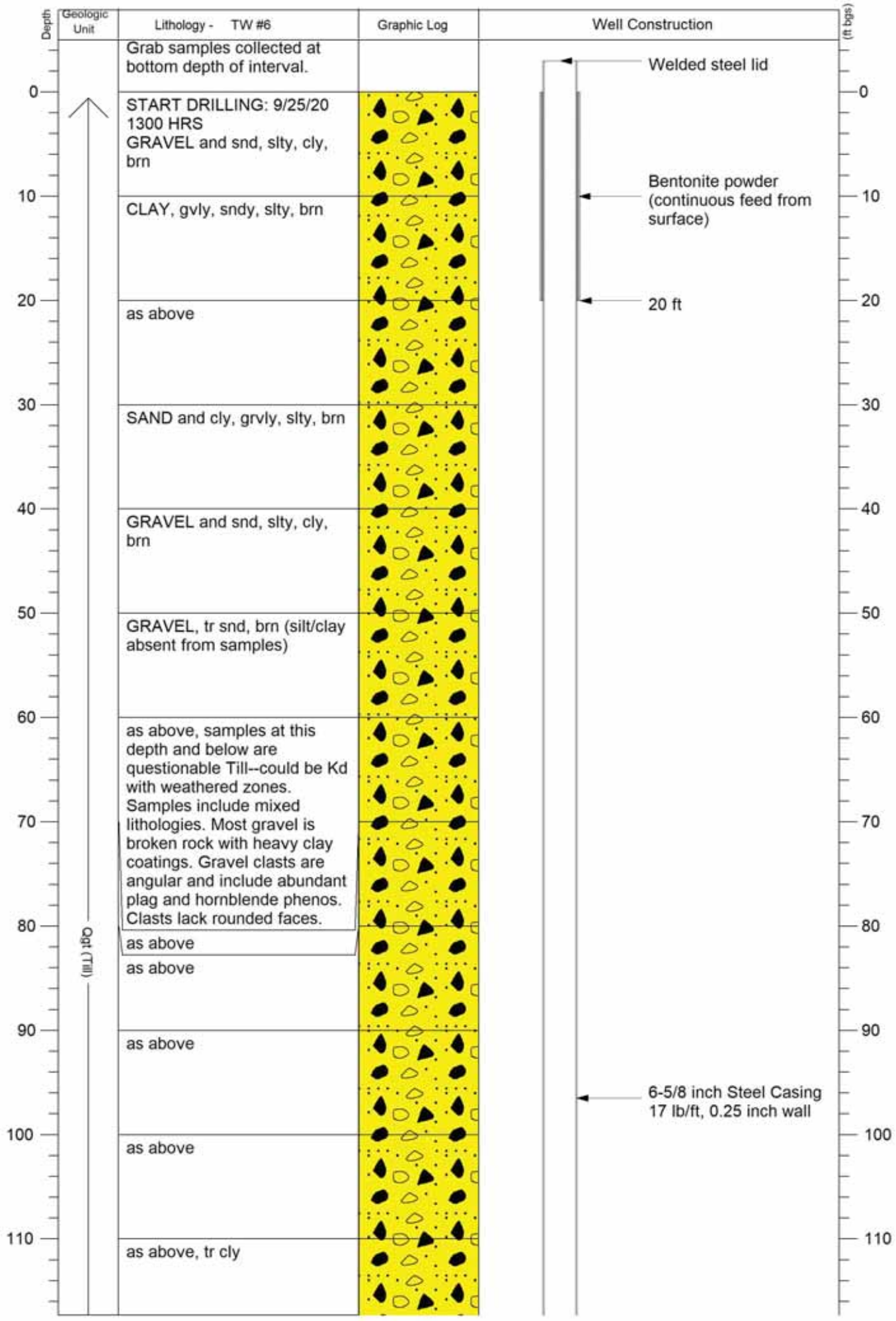

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
as above; mnr BENT
as above (harder drilling)
as above (harder drilling/smaller chips)
as above; common Bent, lt-gy
as above; rr Bent
SLTST, dk-brn-gy, arg; tr Bent smeared on chips
TRIP OUT/IN FOR PDC BIT; DRILLING OPEN HOLE
as above
Ss, f-vf, lt-gy, hd, sil cmt
Sltst, bl-gy, sil, hd
Ss, f-vf, lt-gy, hd, sil cmt (rr rd-gy chips with hematite flecs)
Clyst, dk-gy; Sltst, med-gy, sil
Clyst, dk-gy, sil
as above
SWL 169.5 ft bgs 9/23/2020
176ft Bottom of Cased Borehole
130
140
150
160
170
180
190
200
210
220
230
240
250

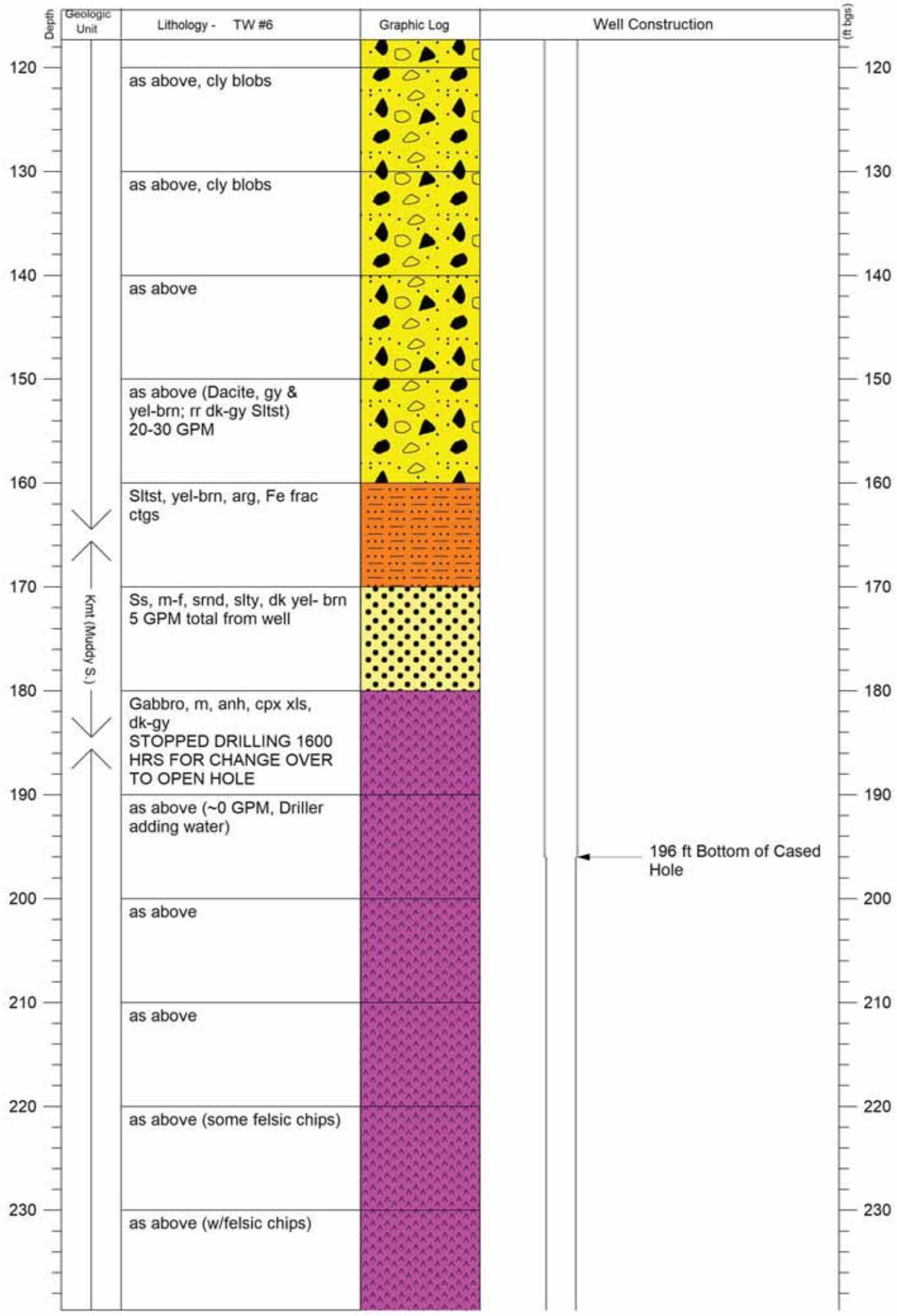

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
Kmo (Mowry)
Clyst, v dk-brn-gy ("black"), slty, sil
Sltst, dk-gy, arg, sil
as above
Clyst/Sltst, dk-gy, sil
Clyst, dk-gy, bl-gy, sil
TOTAL DISCHARGE 15 GPM
as above
Clyst, dk-gy, sil; Sltst, bl-gy, arg
as above; tr Bent
Clyst, dk-gy, sil; Sltst, bl-gy, arg
Ss, f-vf, slty, bl-gy, sil cmt
as above; cmn Clyst, dk-gy, sil
Sltst, bl-gy, sil; Clyst, dk-gy, sil
Sltst, bl-gr, tr snd, arg
260
270
280
290
300
310
320
330
340
350
360
370

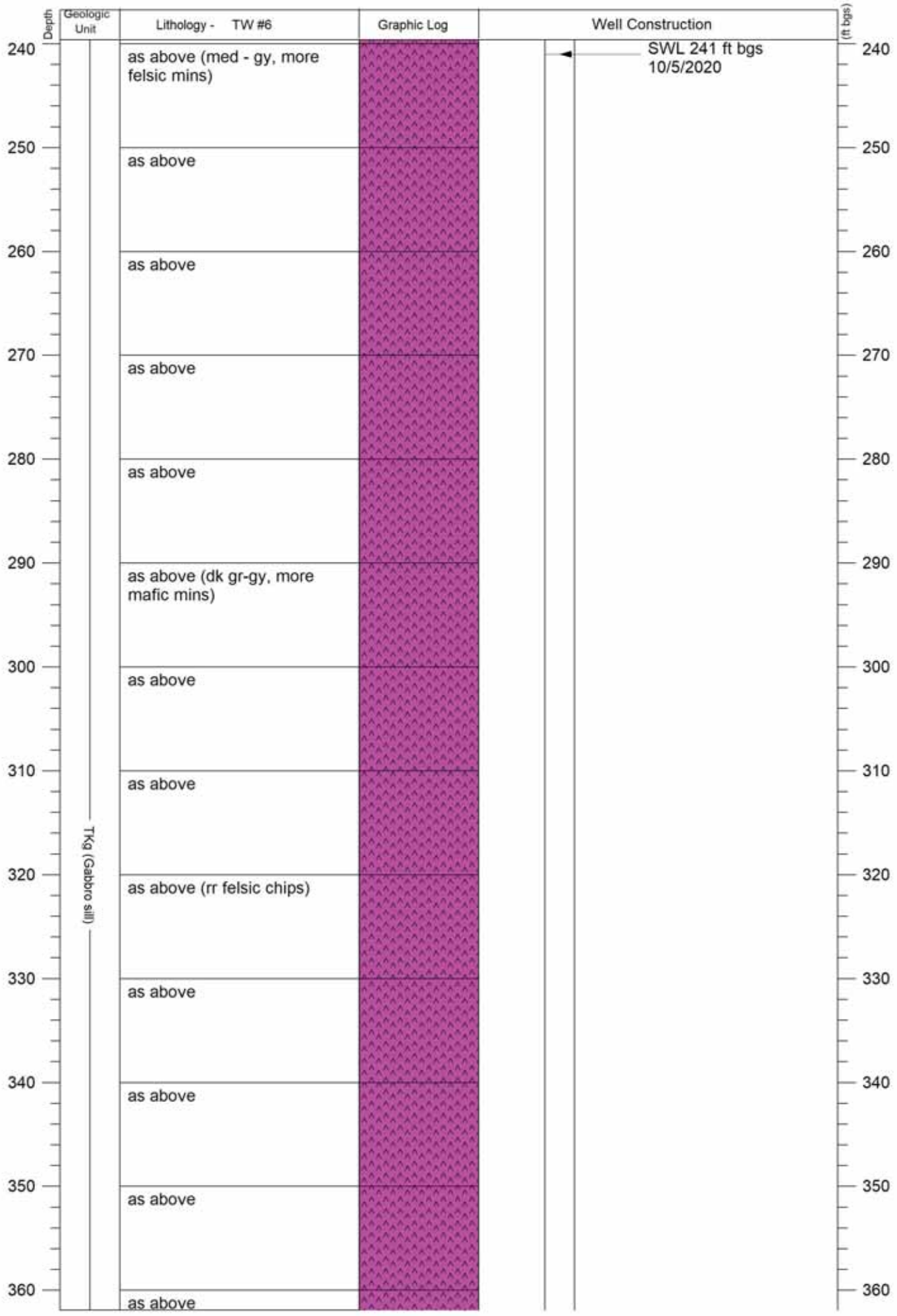

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
380
390
400
410
420
430
440
450
460
470
480
490
500
as above
STOP DRILLING 9/22/20
1630 HRS
START DRILLING 9/23/20
1000 HRS
Sltst, gy, arg, tr snd
as above
as above ("micro chips"=tiny chips due to hard fm or bit/drill action, or both)
as above ("mirco chips")
Sh, dk-gy (micro chips); Ss/Ls?, lt gy
Ss, lt-gy, slty, arg (Muddy Sandstone)
as above
as above
as above
as above
as above
as above
Kmt (Muddy Sandstone)
6-inch Borehole

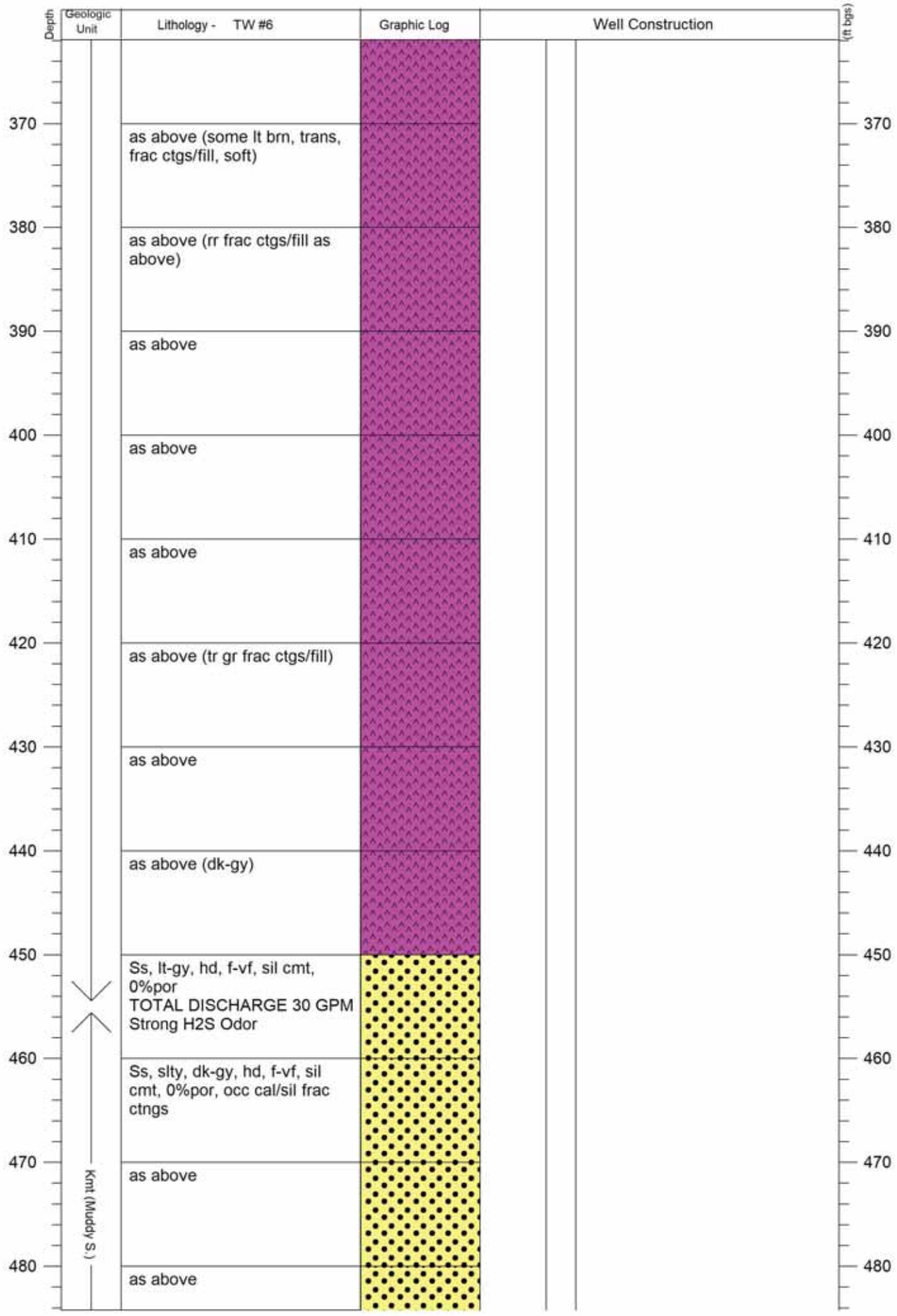

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
510
520
530
540
550
560
570
580
590
600
610
620
630
Gb, m-f, anh, cpx, plg, gy
(Gabbro Sill, "micro chips")
as above
as above
as above
as above
as above
as above
as above
TOTAL DISCHARGE 30-40 GPM
as above
as above
as above
as above
as above
TKg (Gabbro Sill)

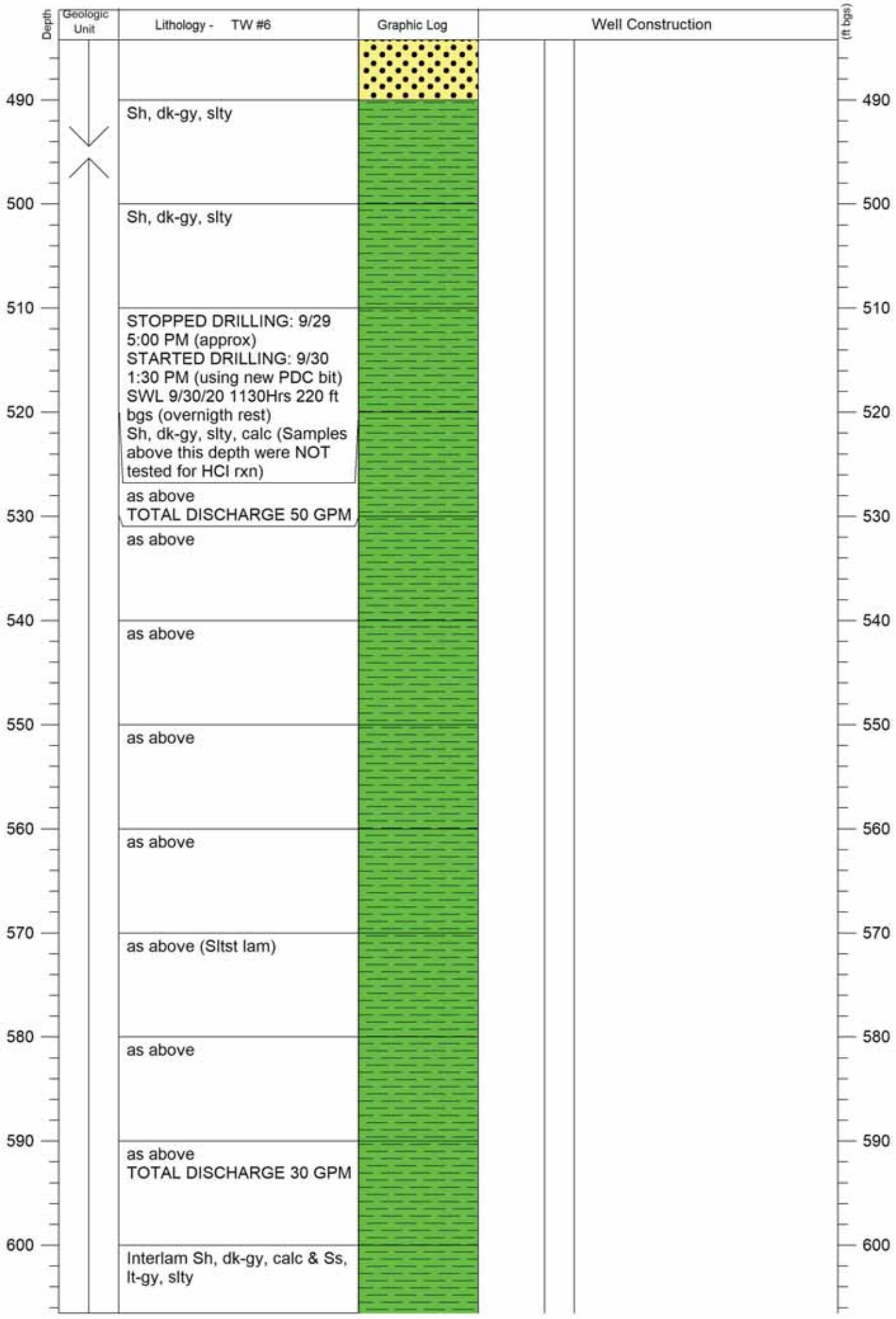

Depth
Geologic Unit
Lithology - TW#5
Graphic Log
Well Construction
(ft bgs)
640
650
660
670
680
690
700
710
720
730
740
as above
as above
as above (observed clay ctgs on fracture of chip -- rare occ.)
Ss, f-vf, lt gy, slty, arg (Muddy Sandstone)
as above
as above
Sh, dk-gy (Thermopolis Shale)
as above (pos Ss strgs)
as above
as above
BOTTOM OF BOREHOLE
738 FT, 9/23/20 1430 HRS
Kmt (Muddy Sandstone)
Kmt (Thermopolis Shale)
738ft

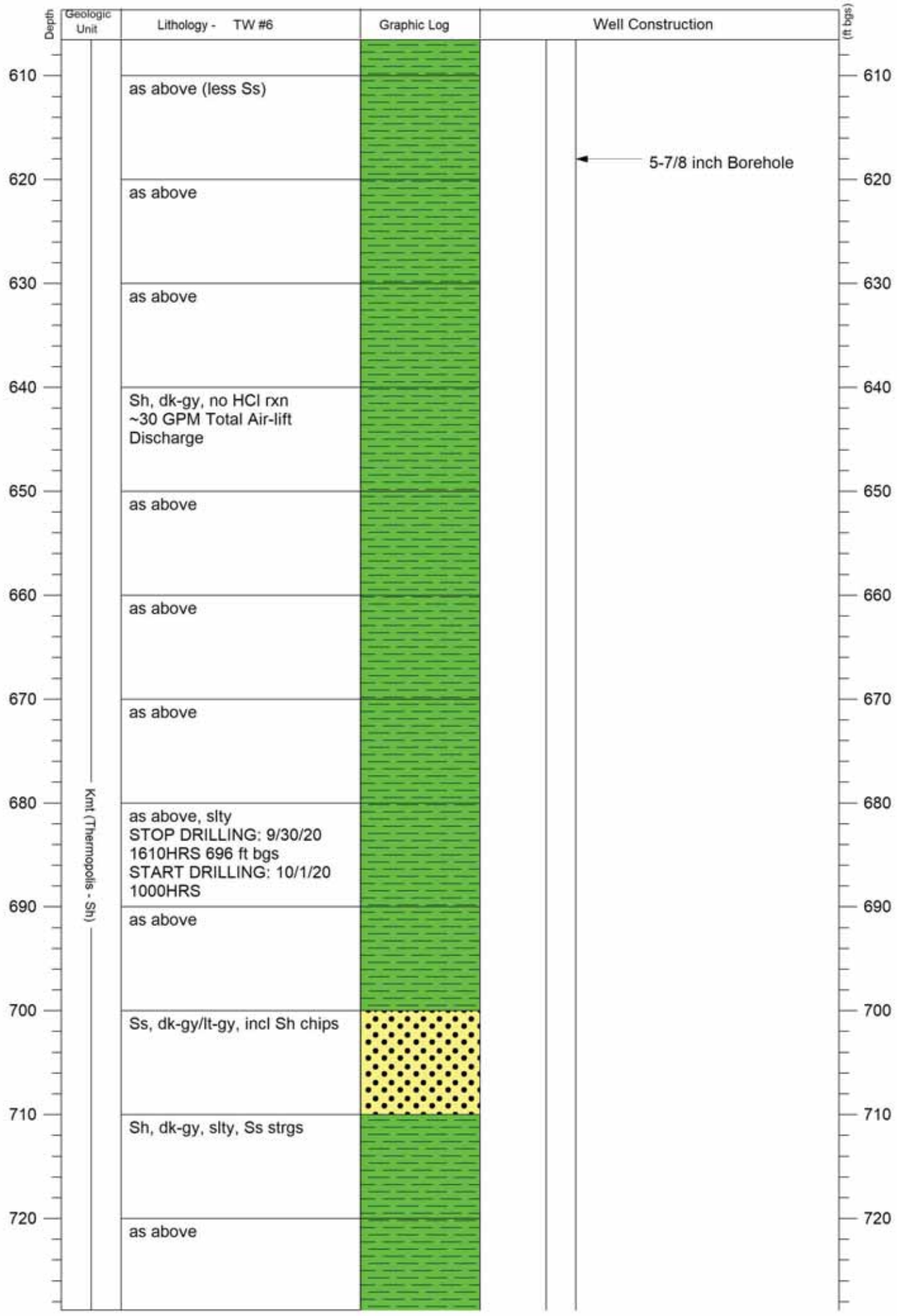

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at bottom depth of interval.
START DRILLING: 9/25/20 1300 HRS
GRAVEL and snd, slty, cly, brn
CLAY, gvly, sndy, slty, brn
as above
SAND and cly, grvly, slty, brn
GRAVEL and snd, slty, cly, brn
GRAVEL, tr snd, brn (silt/clay absent from samples)
as above, samples at this depth and below are questionable Till--could be Kd with weathered zones. Samples include mixed lithologies. Most gravel is broken rock with heavy clay coatings. Gravel clasts are angular and include abundant plag and hornblende phenos. Clasts lack rounded faces.
as above
as above
as above
as above
as above, tr cly
Qgt (Till)
Welded steel lid
Bentonite powder (continuous feed from surface)
20 ft
6-5/8 inch Steel Casing 17 lb/ft, 0.25 inch wall
0
10
20
30
40
50
60
70
80
90
100
110

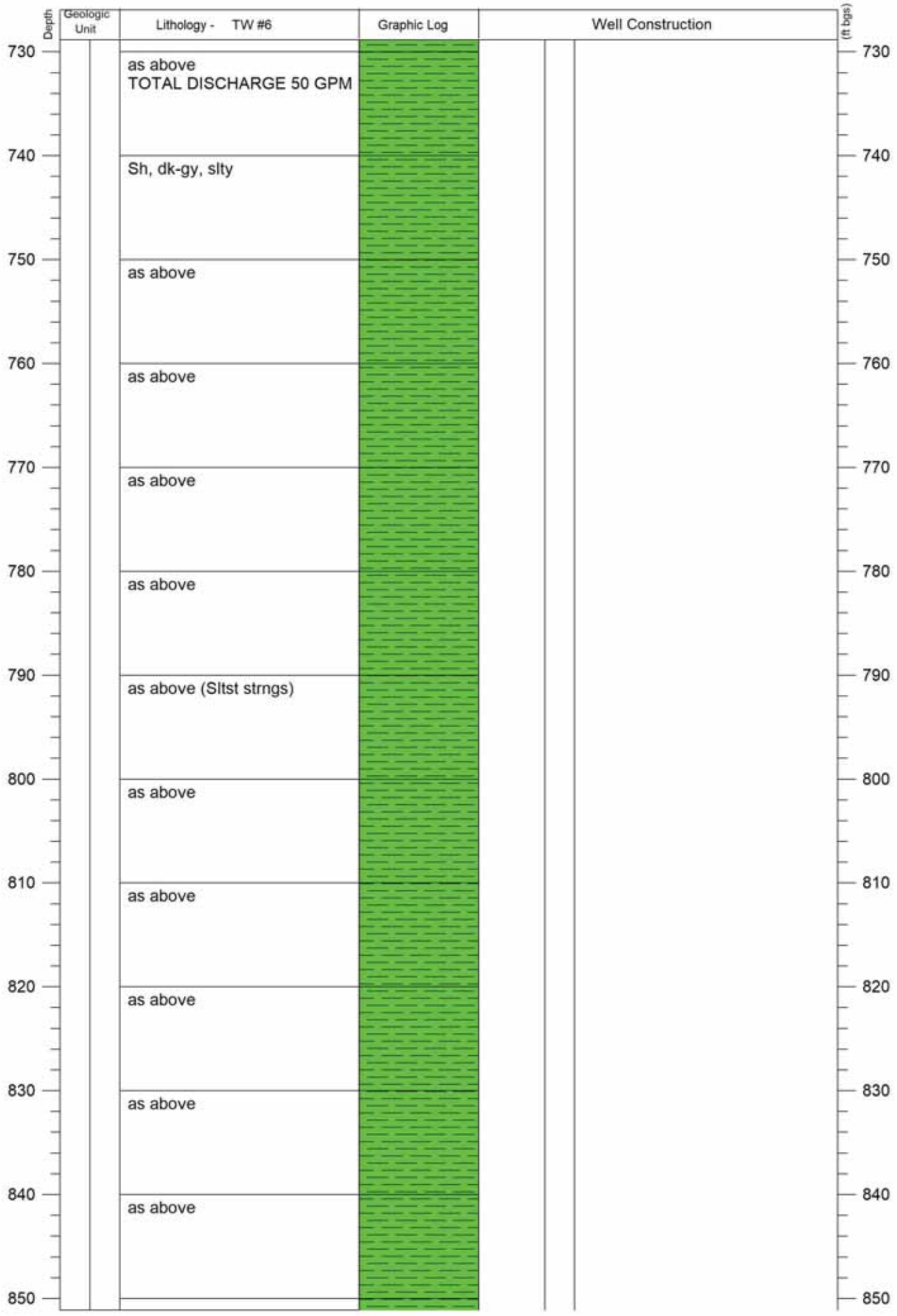

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
120
130
140
150
160
170
180
190
200
210
220
230
as above, cly blobs
as above, cly blobs
as above
as above (Dacite, gy & yel-brn; rr dk-gy Sltst) 20-30 GPM
Sltst, yel-brn, arg, Fe frac ctgs
Ss, m-f, srnd, slty, dk yel- brn 5 GPM total from well
Gabbro, m, anh, cpx xls, dk-gy STOPPED DRILLING 1600 HRS FOR CHANGE OVER TO OPEN HOLE
as above (~0 GPM, Driller adding water)
as above
as above
as above (some felsic chips)
as above (w/felsic chips)
Kmt (Muddy S.)
196 ft Bottom of Cased Hole

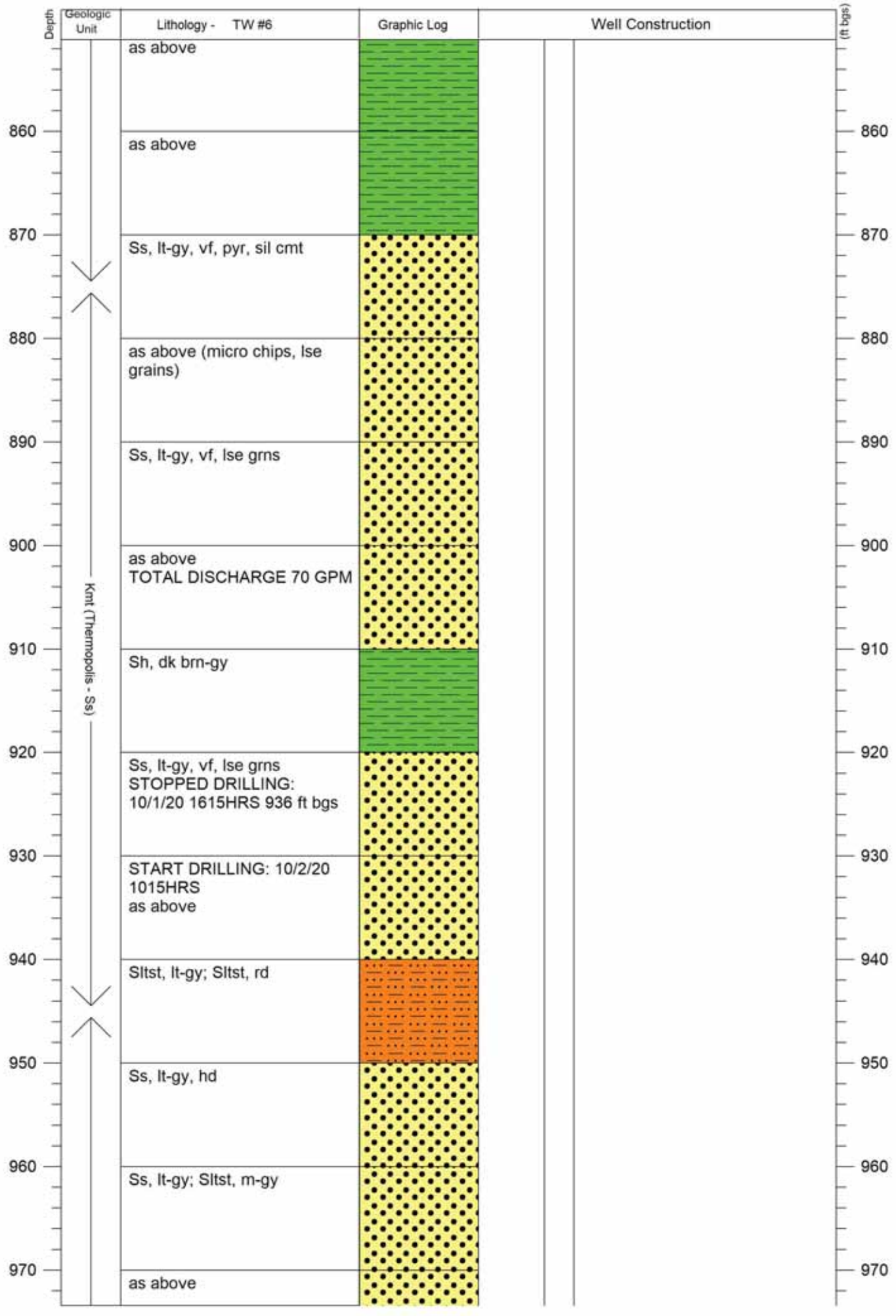

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
240
250
260
270
280
290
300
310
320
330
340
350
360
as above (med - gy, more felsic mins)
as above
as above
as above
as above
as above (dk gr-gy, more mafic mins)
as above
as above
as above (rr felsic chips)
as above
as above
as above
as above
TKg (Gabbro sill)
SWL 241 ft bgs
10/5/2020

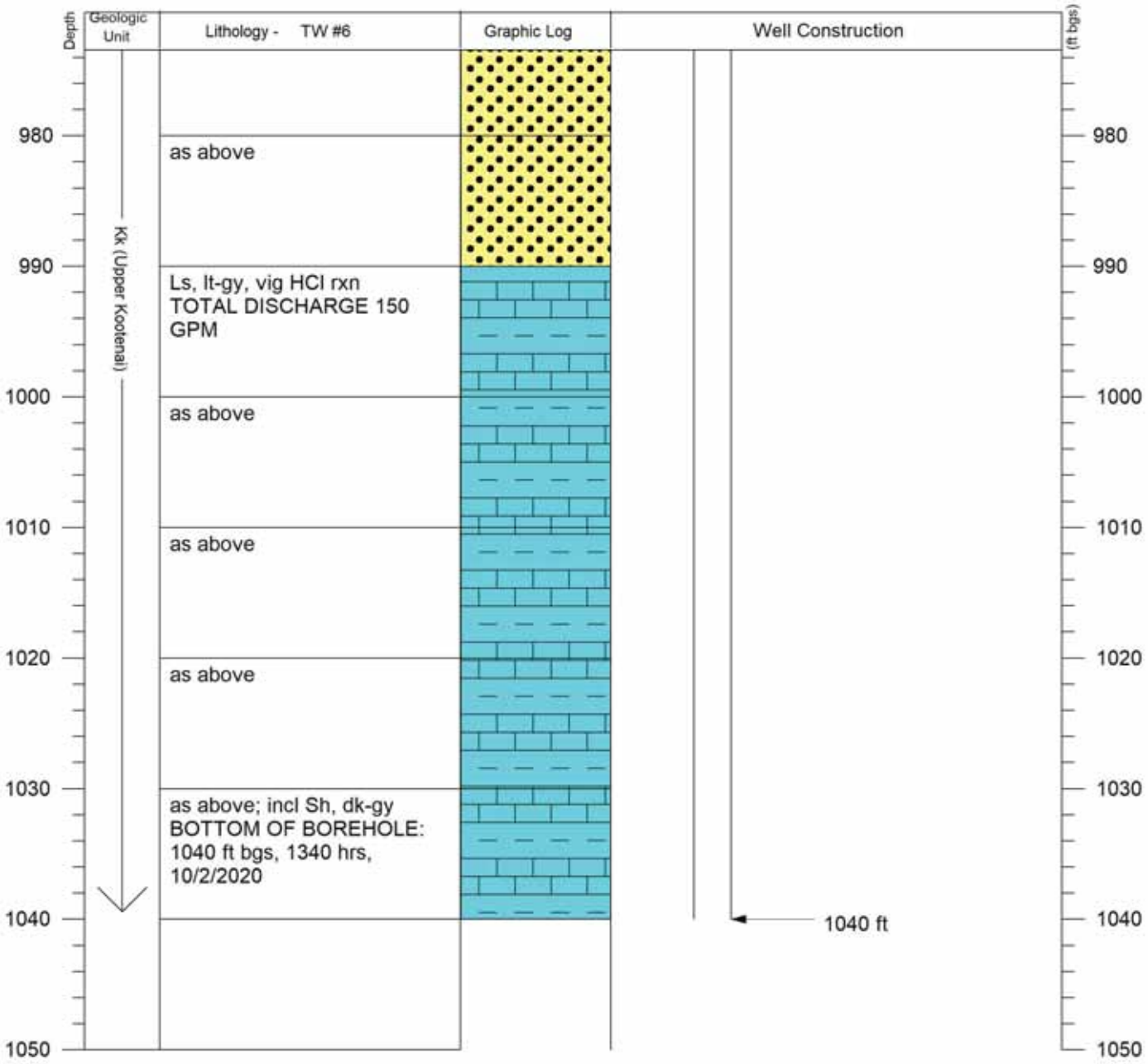

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
370
380
390
400
410
420
430
440
450
460
470
480
as above (some lt brn, trans, frac ctgs/fill, soft)
as above (rr frac ctgs/fill as above)
as above
as above
as above
as above (tr gr frac ctgs/fill)
as above
as above (dk-gy)
Ss, lt-gy, hd, f-vf, sil cmt, 0%por
TOTAL DISCHARGE 30 GPM
Strong H2S Odor
Ss, slty, dk-gy, hd, f-vf, sil cmt, 0%por, occ cal/sil frac ctngs
as above
as above
Kmt (Muddy S.)

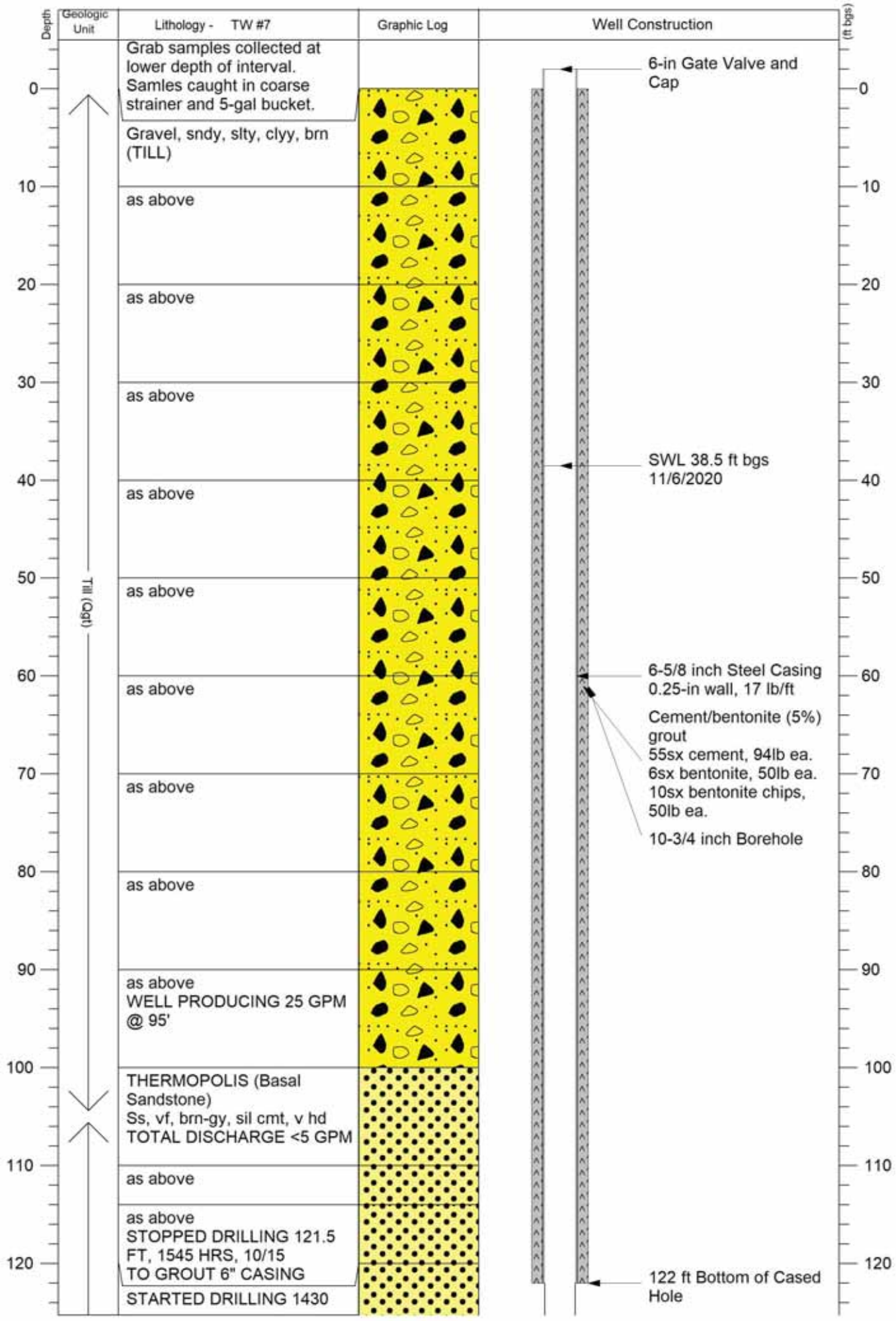

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
490
500
510
520
530
540
550
560
570
580
590
600
Sh, dk-gy, slty
Sh, dk-gy, slty
STOPPED DRILLING: 9/29 5:00 PM (approx)
STARTED DRILLING: 9/30 1:30 PM (using new PDC bit)
SWL 9/30/20 1130Hrs 220 ft bgs (overnigth rest)
Sh, dk-gy, slty, calc (Samples above this depth were NOT tested for HCl rxn)
as above
TOTAL DISCHARGE 50 GPM
as above
as above
as above
as above
as above (Sltst lam)
as above
as above
TOTAL DISCHARGE 30 GPM
Interlam Sh, dk-gy, calc & Ss, lt-gy, slty

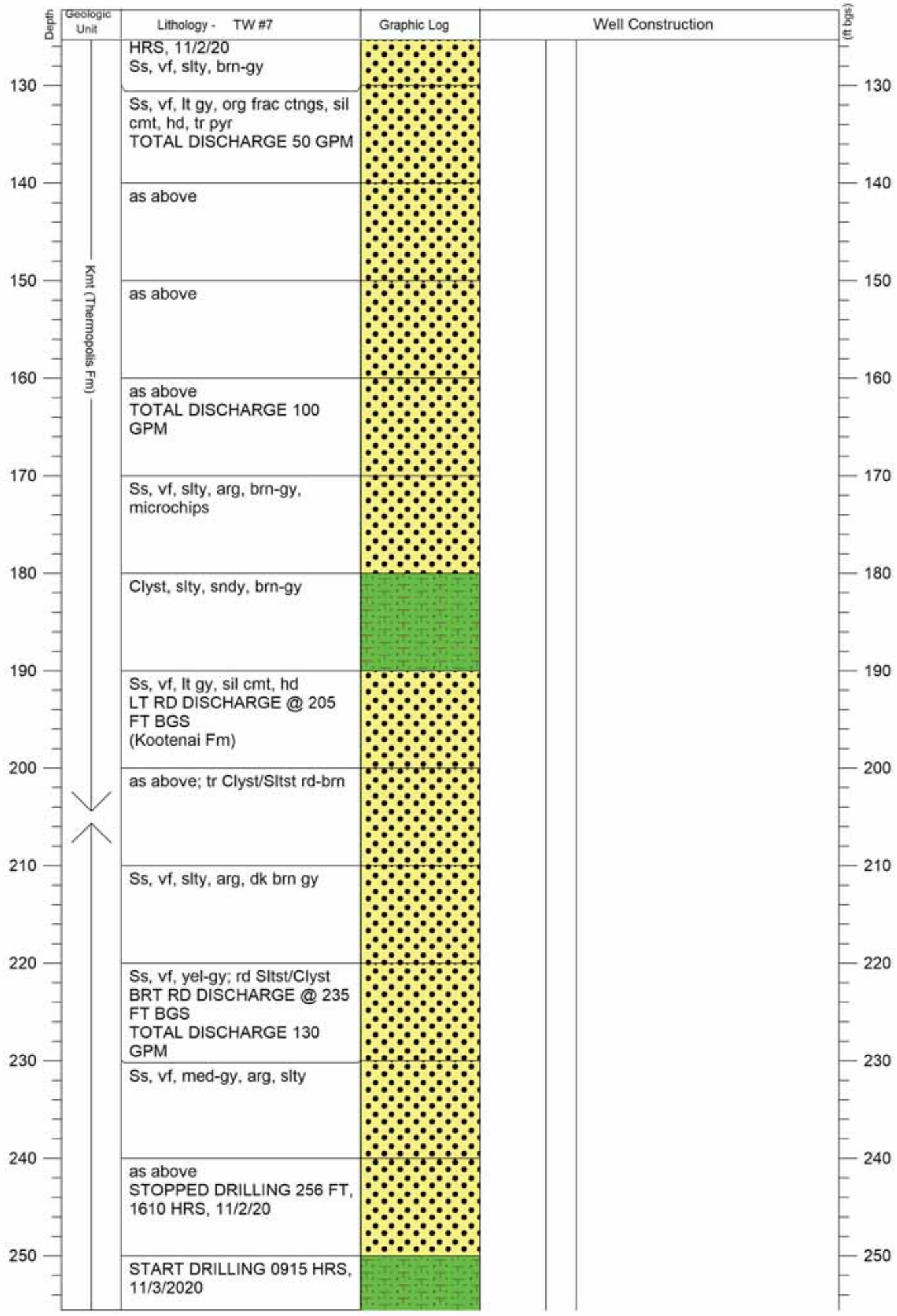

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
610
620
630
640
650
660
670
680
690
700
710
720
as above (less Ss)
as above
as above
Sh, dk-gy, no HCl rxn
~30 GPM Total Air-lift
Discharge
as above
as above
as above
as above, slty
STOP DRILLING: 9/30/20
1610HRS 696 ft bgs
START DRILLING: 10/1/20
1000HRS
as above
Ss, dk-gy/lt-gy, incl Sh chips
Sh, dk-gy, slty, Ss strgs
as above
Kmt (Thermopolis - Sh)
5-7/8 inch Borehole

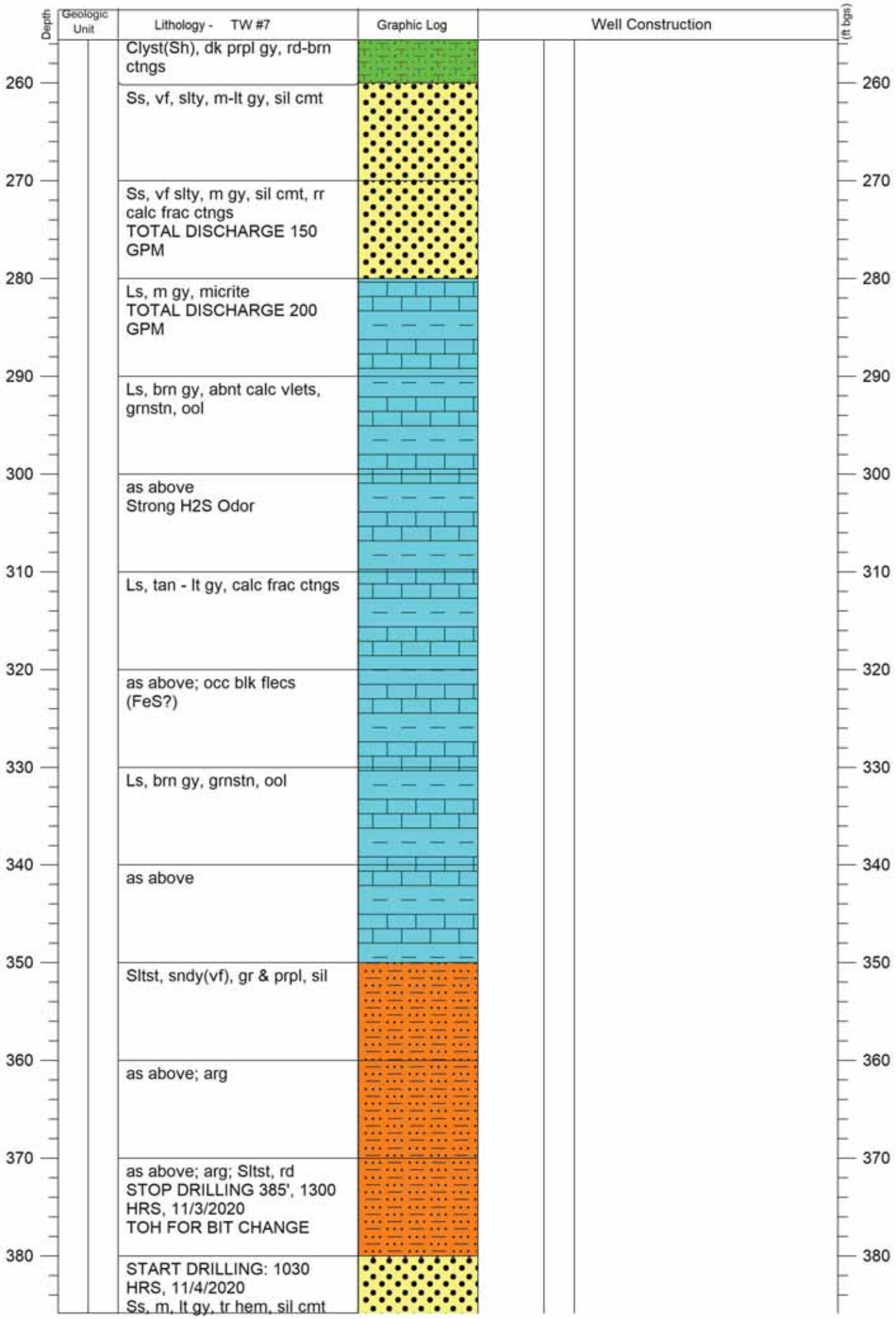

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
730
740
750
760
770
780
790
800
810
820
830
840
850
as above
TOTAL DISCHARGE 50 GPM
Sh, dk-gy, slty
as above
as above
as above
as above
as above (Sltst strngs)
as above
as above
as above
as above
as above

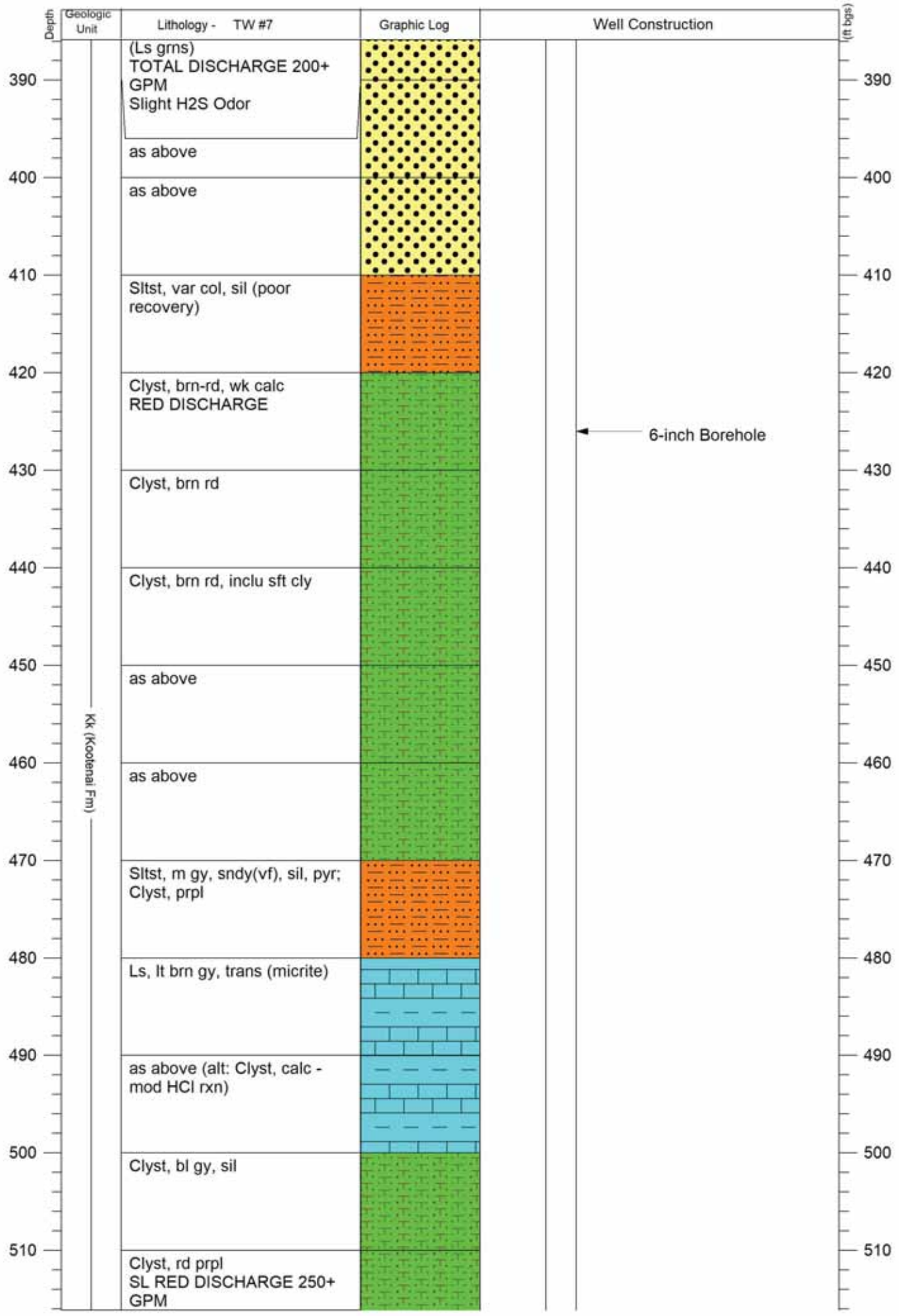

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
as above
as above
Ss, lt-gy, vf, pyr, sil cmt
as above (micro chips, lse grains)
Ss, lt-gy, vf, lse grns
as above
TOTAL DISCHARGE 70 GPM
Sh, dk brn-gy
Ss, lt-gy, vf, lse grns
STOPPED DRILLING:
10/1/20 1615HRS 936 ft bgs
START DRILLING: 10/2/20
1015HRS
as above
Sltst, lt-gy; Sltst, rd
Ss, lt-gy, hd
Ss, lt-gy; Sltst, m-gy
as above
Kmt (Thermopolis - Ss)
860
870
880
890
900
910
920
930
940
950
960
970

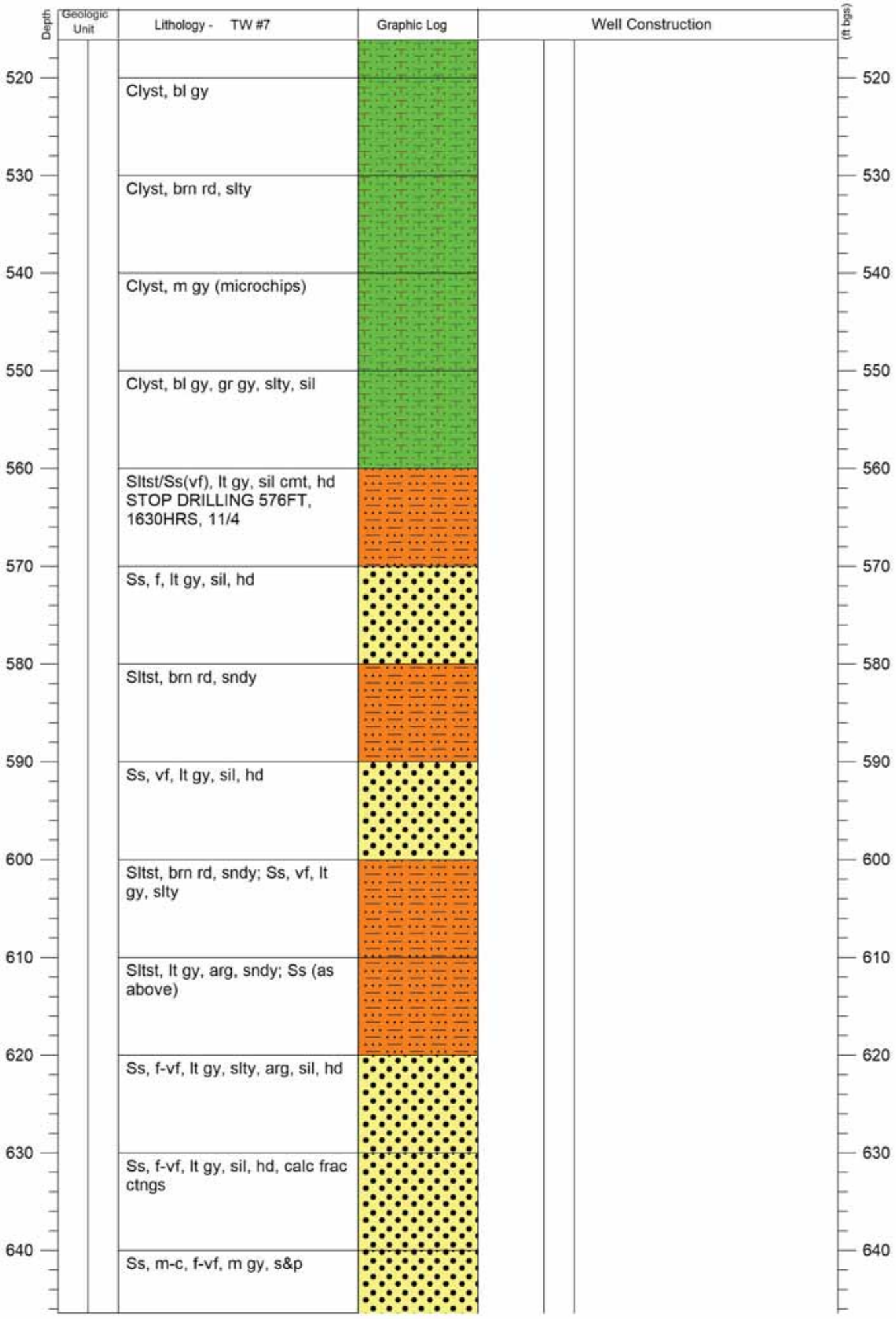

Depth
Geologic Unit
Lithology - TW #6
Graphic Log
Well Construction
(ft bgs)
980
990
1000
1010
1020
1030
1040
1050
Kk (Upper Kootenai)
as above
Ls, lt-gy, vig HCl rxn
TOTAL DISCHARGE 150 GPM
as above
as above
as above
as above; incl Sh, dk-gy
BOTTOM OF BOREHOLE:
1040 ft bgs, 1340 hrs,
10/2/2020
1040 ft

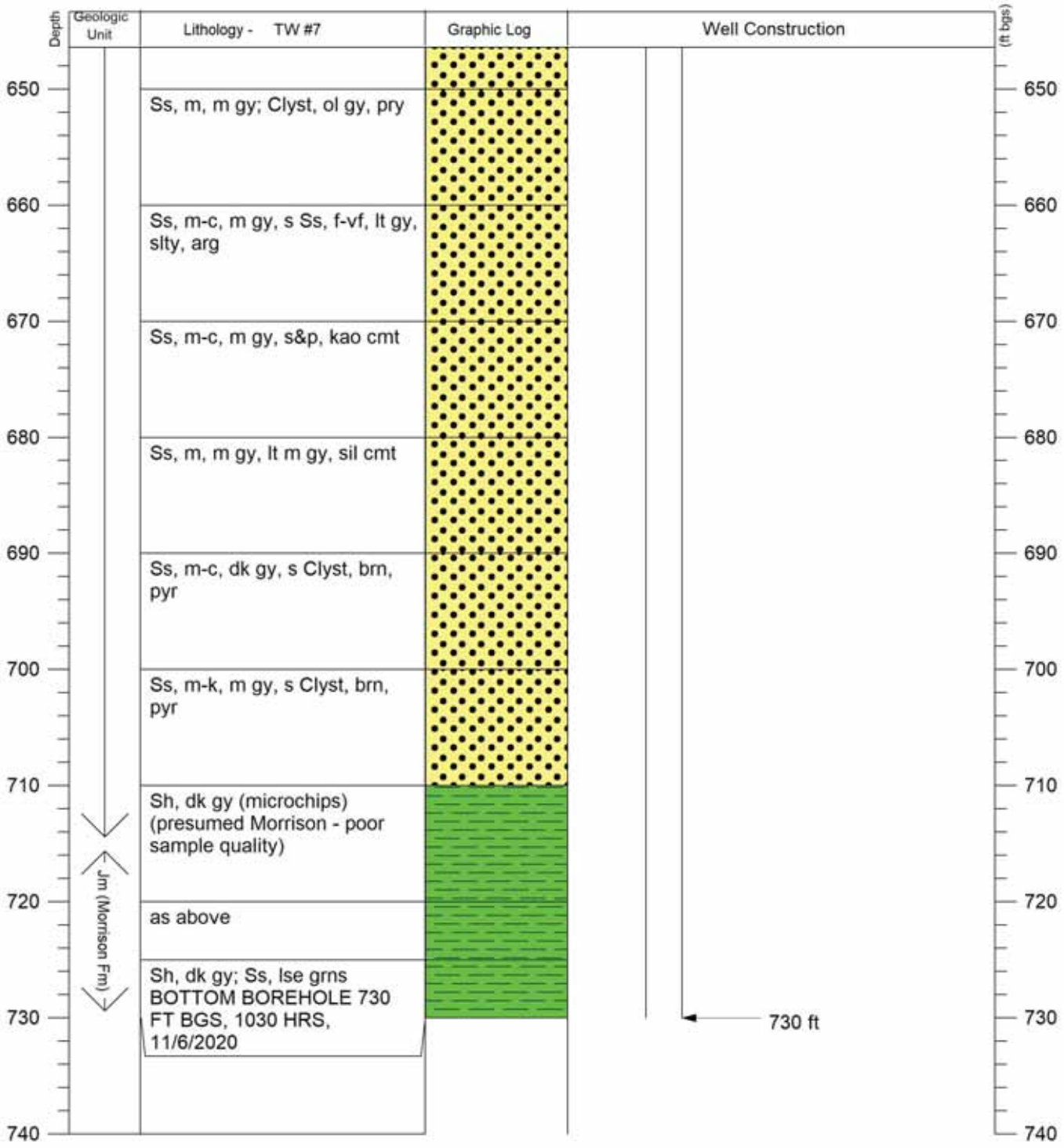

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at lower depth of interval. Samles caught in coarse strainer and 5-gal bucket.
Gravel, sndy, slty, clyy, brn (TILL)
as above
as above
as above
as above
as above
as above
as above
as above
as above
WELL PRODUCING 25 GPM @ 95'
THERMOPOLIS (Basal Sandstone)
Ss, vf, brn-gy, sil cmt, v hd
TOTAL DISCHARGE <5 GPM
as above
as above
STOPPED DRILLING 121.5 FT, 1545 HRS, 10/15
TO GROUT 6" CASING
STARTED DRILLING 1430
Till (Qgt)
0
10
20
30
40
50
60
70
80
90
100
110
120
6-in Gate Valve and Cap
SWL 38.5 ft bgs
11/6/2020
6-5/8 inch Steel Casing
0.25-in wall, 17 lb/ft
Cement/bentonite (5%) grout
55sx cement, 94lb ea.
6sx bentonite, 50lb ea.
10sx bentonite chips, 50lb ea.
10-3/4 inch Borehole
122 ft Bottom of Cased Hole

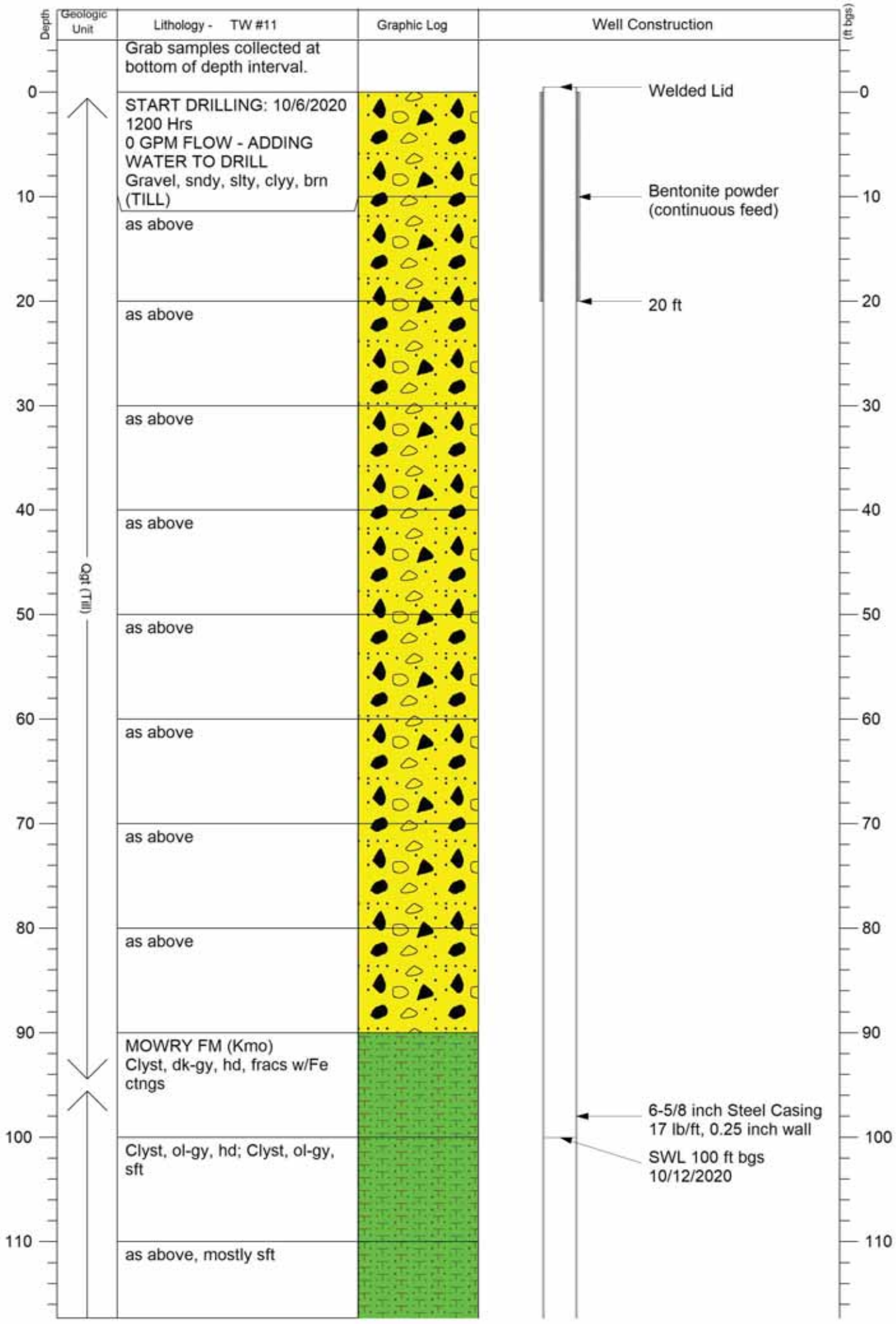

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
Kmt (Thermopolis Fm)
HRS, 11/2/20
Ss, vf, slty, brn-gy
Ss, vf, lt gy, org frac ctngs, sil cmt, hd, tr pyr
TOTAL DISCHARGE 50 GPM
as above
as above
as above
TOTAL DISCHARGE 100 GPM
Ss, vf, slty, arg, brn-gy, microchips
Clyst, slty, sndy, brn-gy
Ss, vf, lt gy, sil cmt, hd
LT RD DISCHARGE @ 205 FT BGS
(Kootenai Fm)
as above; tr Clyst/Sltst rd-brn
Ss, vf, slty, arg, dk brn gy
Ss, vf, yel-gy; rd Sltst/Clyst
BRT RD DISCHARGE @ 235 FT BGS
TOTAL DISCHARGE 130 GPM
Ss, vf, med-gy, arg, slty
as above
STOPPED DRILLING 256 FT, 1610 HRS, 11/2/20
START DRILLING 0915 HRS, 11/3/2020
130
140
150
160
170
180
190
200
210
220
230
240
250

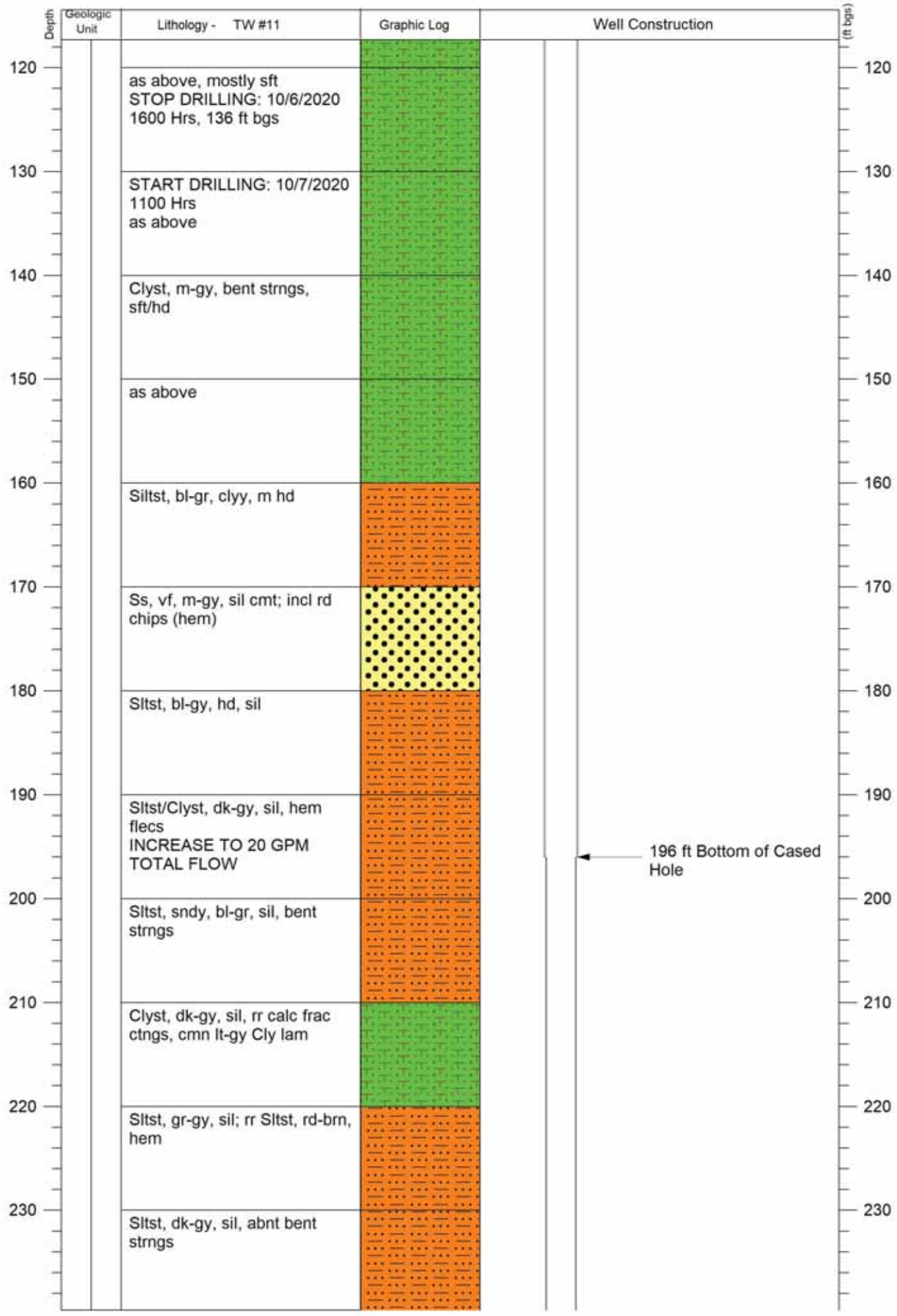

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
Clyst(Sh), dk prpl gy, rd-brn ctngs
Ss, vf, slty, m-lt gy, sil cmt
Ss, vf slty, m gy, sil cmt, rr calc frac ctngs
TOTAL DISCHARGE 150 GPM
Ls, m gy, micrite
TOTAL DISCHARGE 200 GPM
Ls, brn gy, abnt calc vlets, grnstn, ool
as above
Strong H2S Odor
Ls, tan - lt gy, calc frac ctngs
as above; occ blk flecs (FeS?)
Ls, brn gy, grnstn, ool
as above
Sltst, sndy(vf), gr & prpl, sil
as above; arg
as above; arg; Sltst, rd
STOP DRILLING 385', 1300 HRS, 11/3/2020
TOH FOR BIT CHANGE
START DRILLING: 1030 HRS, 11/4/2020
Ss, m, lt gy, tr hem, sil cmt
260
270
280
290
300
310
320
330
340
350
360
370
380

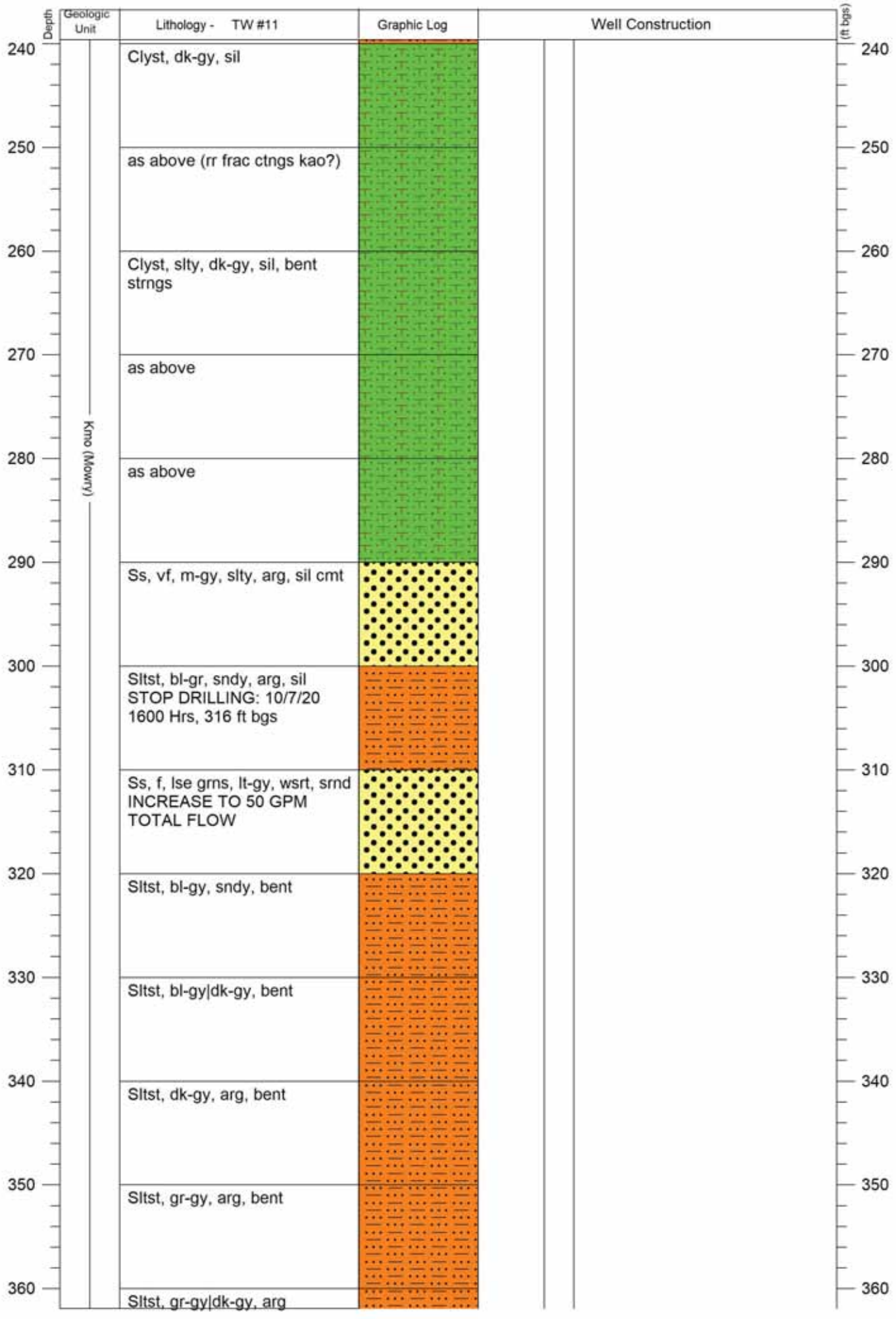

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
(Ls grns)
TOTAL DISCHARGE 200+ GPM
Slight H2S Odor
as above
as above
Sltst, var col, sil (poor recovery)
Clyst, brn-rd, wk calc
RED DISCHARGE
Clyst, brn rd
Clyst, brn rd, inclu sft cly
as above
as above
Sltst, m gy, sndy(vf), sil, pyr; Clyst, prpl
Ls, lt brn gy, trans (micrite)
as above (alt: Clyst, calc - mod HCl rxn)
Clyst, bl gy, sil
Clyst, rd prpl
SL RED DISCHARGE 250+ GPM
Kk (Kootenai Fm)
6-inch Borehole
390
400
410
420
430
440
450
460
470
480
490
500
510

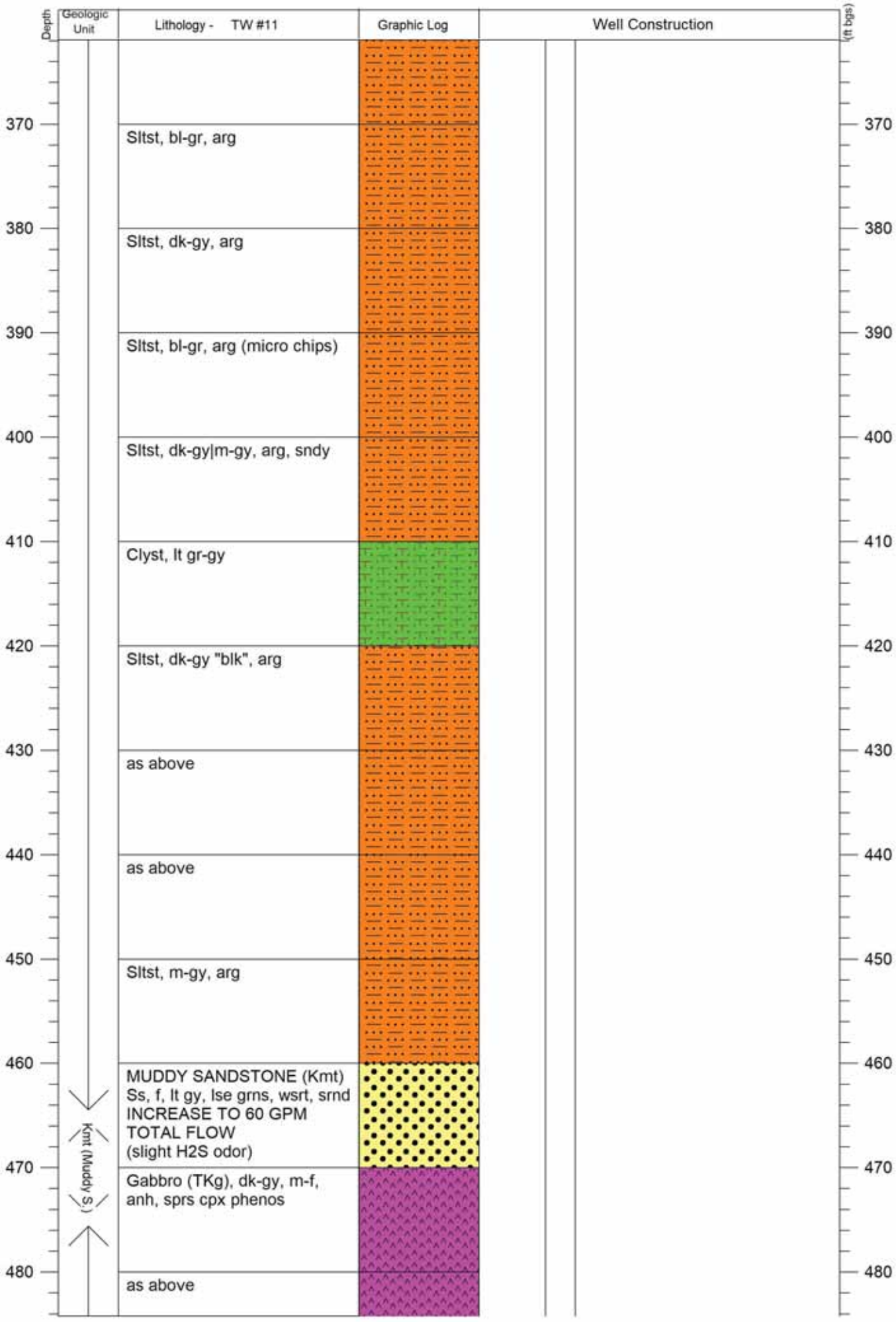

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
520
530
540
550
560
570
580
590
600
610
620
630
640
Clyst, bl gy
Clyst, brn rd, slty
Clyst, m gy (microchips)
Clyst, bl gy, gr gy, slty, sil
Sltst/Ss(vf), lt gy, sil cmt, hd
STOP DRILLING 576FT,
1630HRS, 11/4
Ss, f, lt gy, sil, hd
Sltst, brn rd, sndy
Ss, vf, lt gy, sil, hd
Sltst, brn rd, sndy; Ss, vf, lt gy, slty
Sltst, lt gy, arg, sndy; Ss (as above)
Ss, f-vf, lt gy, slty, arg, sil, hd
Ss, f-vf, lt gy, sil, hd, calc frac ctngs
Ss, m-c, f-vf, m gy, s&p

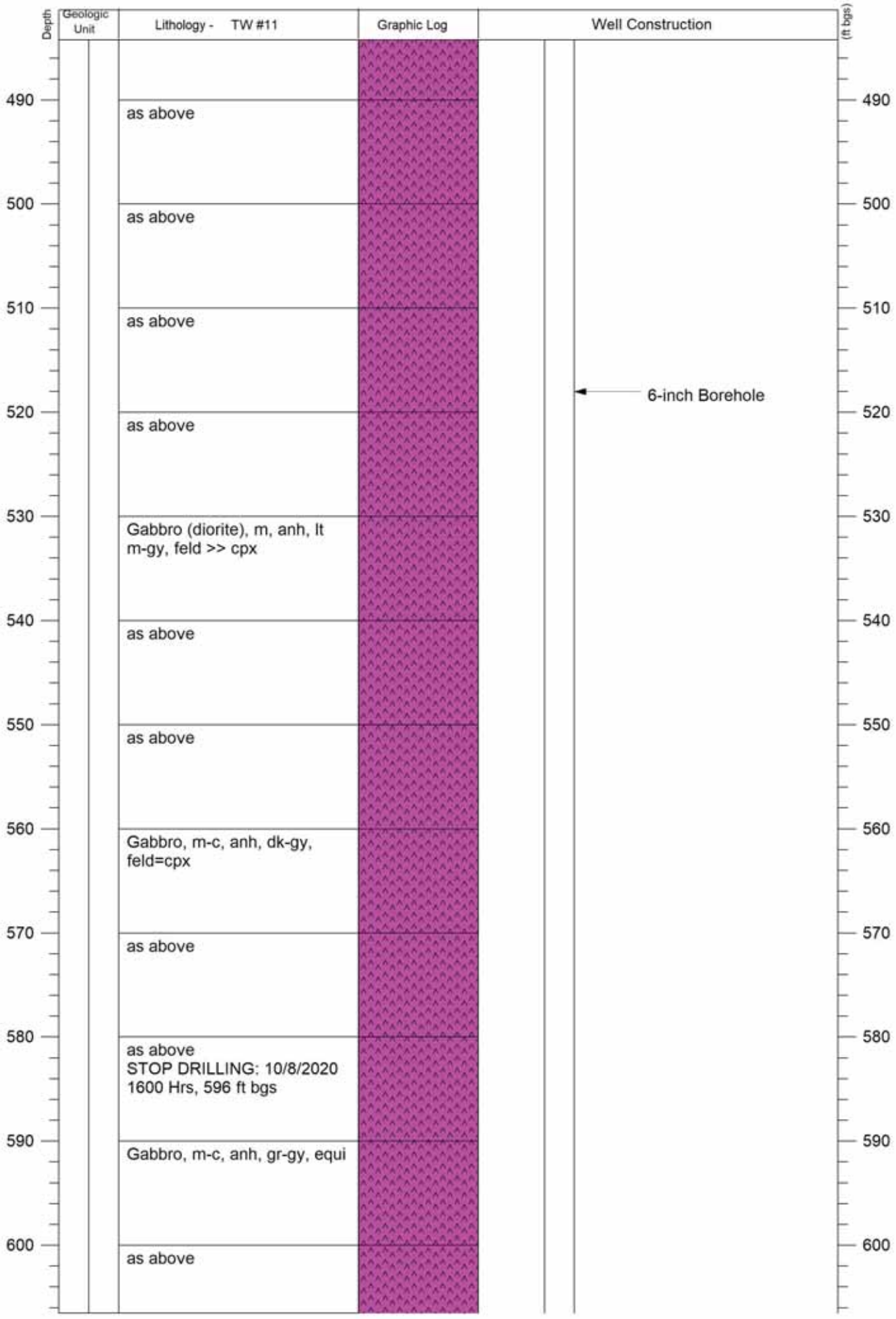

Depth
Geologic Unit
Lithology - TW #7
Graphic Log
Well Construction
(ft bgs)
650
660
670
680
690
700
710
720
730
740
Ss, m, m gy; Clyst, ol gy, pry
Ss, m-c, m gy, s Ss, f-vf, lt gy, slty, arg
Ss, m-c, m gy, s&p, kao cmt
Ss, m, m gy, lt m gy, sil cmt
Ss, m-c, dk gy, s Clyst, brn, pyr
Ss, m-k, m gy, s Clyst, brn, pyr
Sh, dk gy (microchips) (presumed Morrison - poor sample quality)
as above
Sh, dk gy; Ss, lse grns
BOTTOM BOREHOLE 730 FT BGS, 1030 HRS, 11/6/2020
Jm (Morrison Fm)
730 ft

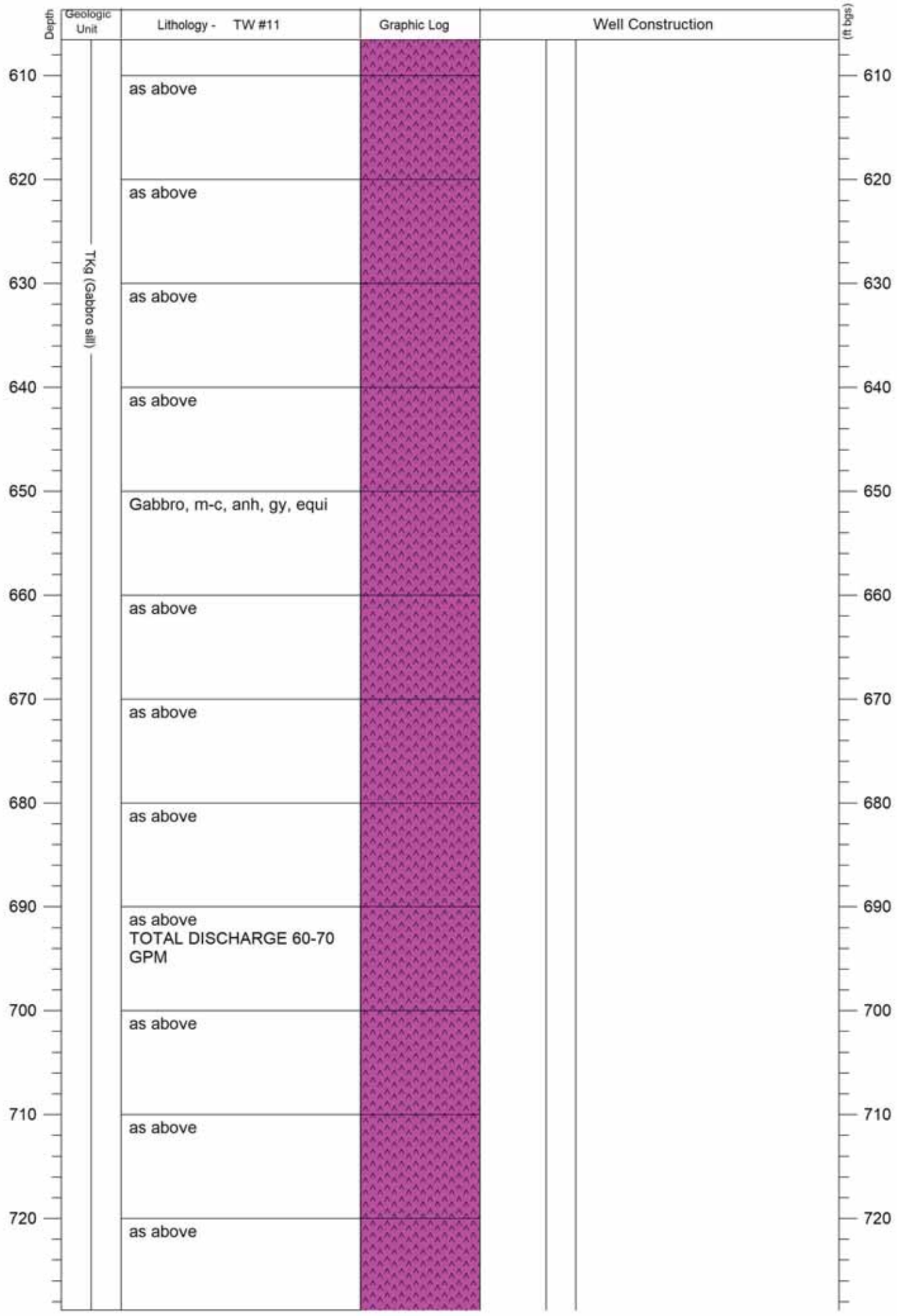

Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at bottom of depth interval.
START DRILLING: 10/6/2020 1200 Hrs
0 GPM FLOW - ADDING WATER TO DRILL
Gravel, sndy, slty, clyy, brn (TILL)
as above
as above
as above
as above
as above
as above
as above
as above
MOWRY FM (Kmo)
Clyst, dk-gy, hd, fracs w/Fe ctngs
Clyst, ol-gy, hd; Clyst, ol-gy, sft
as above, mostly sft
Qgt (Till)
Welded Lid
Bentonite powder (continuous feed)
20 ft
6-5/8 inch Steel Casing 17 lb/ft, 0.25 inch wall
SWL 100 ft bgs 10/12/2020
0
10
20
30
40
50
60
70
80
90
100
110

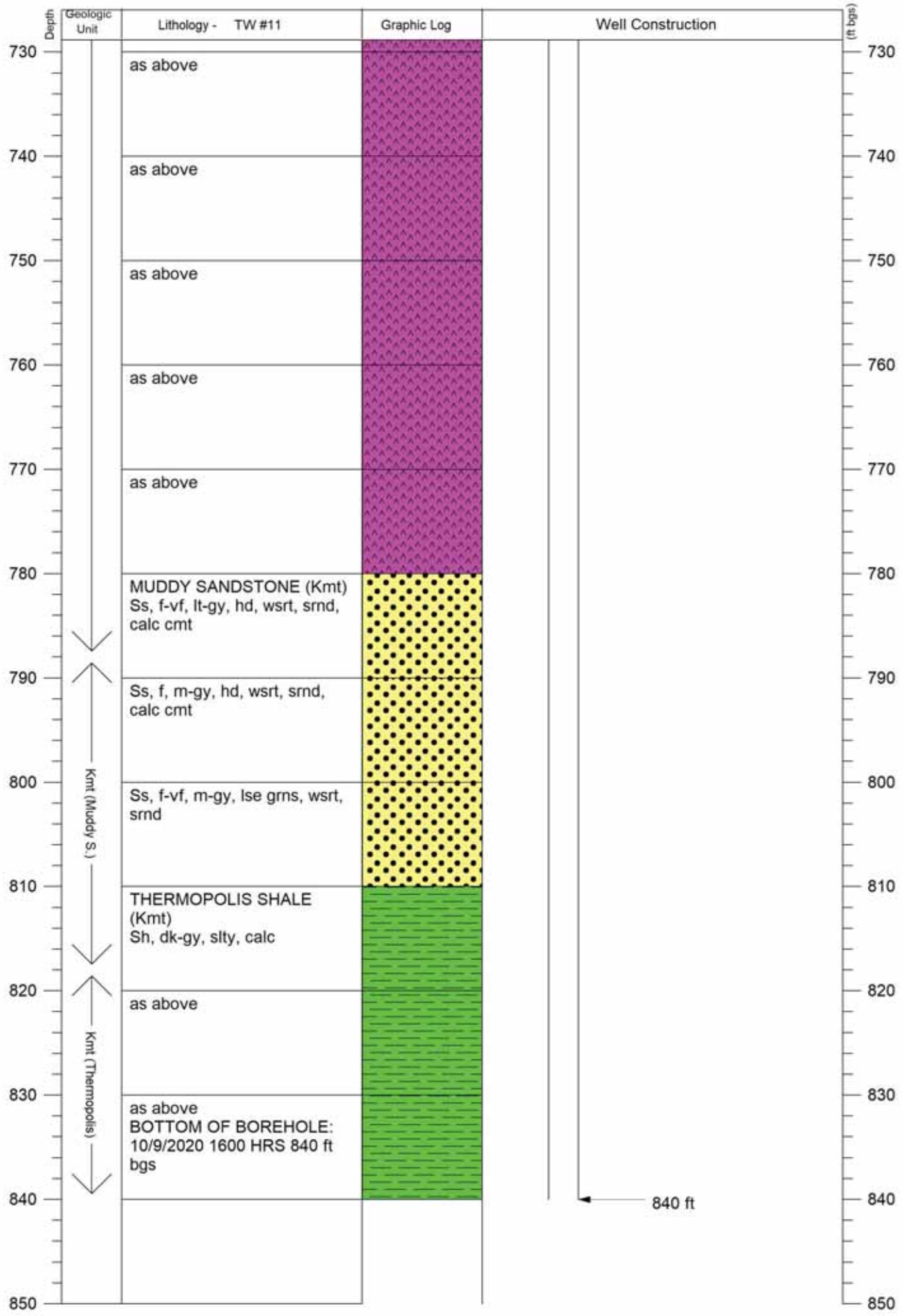

Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
120
130
140
150
160
170
180
190
200
210
220
230
as above, mostly sft
STOP DRILLING: 10/6/2020
1600 Hrs, 136 ft bgs
START DRILLING: 10/7/2020
1100 Hrs
as above
Clyst, m-gy, bent strngs, sft/hd
as above
Siltst, bl-gr, clyy, m hd
Ss, vf, m-gy, sil cmt; incl rd chips (hem)
Sltst, bl-gy, hd, sil
Sltst/Clyst, dk-gy, sil, hem flecs
INCREASE TO 20 GPM TOTAL FLOW
Sltst, sndy, bl-gr, sil, bent strngs
Clyst, dk-gy, sil, rr calc frac ctngs, cmn lt-gy Cly lam
Sltst, gr-gy, sil; rr Sltst, rd-brn, hem
Sltst, dk-gy, sil, abnt bent strngs
196 ft Bottom of Cased Hole


Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
240
250
260
270
280
290
300
310
320
330
340
350
360
Kmo (Mowry)
Clyst, dk-gy, sil
as above (rr frac ctngs kao?)
Clyst, slty, dk-gy, sil, bent strngs
as above
as above
Ss, vf, m-gy, slty, arg, sil cmt
Sltst, bl-gr, sndy, arg, sil
STOP DRILLING: 10/7/20
1600 Hrs, 316 ft bgs
Ss, f, lse grns, lt-gy, wsrt, srnd
INCREASE TO 50 GPM
TOTAL FLOW
Sltst, bl-gy, sndy, bent
Sltst, bl-gy|dk-gy, bent
Sltst, dk-gy, arg, bent
Sltst, gr-gy, arg, bent
Sltst, gr-gy|dk-gy, arg


Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
370
380
390
400
410
420
430
440
450
460
470
480
Sltst, bl-gr, arg
Sltst, dk-gy, arg
Sltst, bl-gr, arg (micro chips)
Sltst, dk-gy|m-gy, arg, sndy
Clyst, lt gr-gy
Sltst, dk-gy "blk", arg
as above
as above
Sltst, m-gy, arg
MUDDY SANDSTONE (Kmt)
Ss, f, lt gy, lse grns, wsrt, srnd
INCREASE TO 60 GPM
TOTAL FLOW
(slight H2S odor)
Gabbro (TKg), dk-gy, m-f,
anh, sprs cpx phenos
as above
Kmt (Muddy S.)


Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
490
as above
500
as above
510
as above
520
as above
530
Gabbro (diorite), m, anh, lt m-gy, feld >> cpx
540
as above
550
as above
560
Gabbro, m-c, anh, dk-gy, feld=cpx
570
as above
580
as above
STOP DRILLING: 10/8/2020 1600 Hrs, 596 ft bgs
590
Gabbro, m-c, anh, gr-gy, equi
600
as above
6-inch Borehole

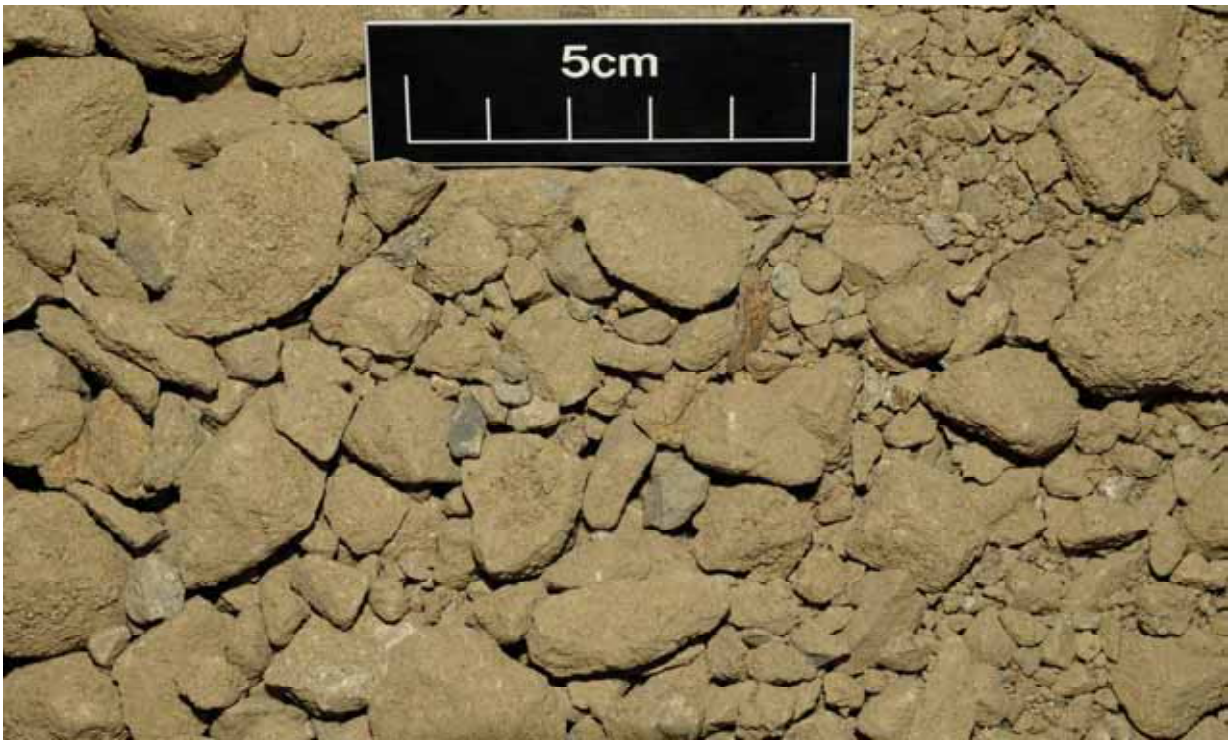

Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
TKg (Gabbro sill)
610
620
630
640
650
660
670
680
690
700
710
720
as above
as above
as above
as above
Gabbro, m-c, anh, gy, equi
as above
as above
as above
as above
TOTAL DISCHARGE 60-70 GPM
as above
as above
as above


Depth
Geologic Unit
Lithology - TW #11
Graphic Log
Well Construction
(ft bgs)
730
740
750
760
770
780
790
800
810
820
830
840
850
as above
as above
as above
as above
as above
MUDDY SANDSTONE (Kmt)
Ss, f-vf, lt-gy, hd, wsrt, srnd, calc cmt
Ss, f, m-gy, hd, wsrt, srnd, calc cmt
Ss, f-vf, m-gy, lse grns, wsrt, srnd
THERMOPOLIS SHALE (Kmt)
Sh, dk-gy, slty, calc
as above
as above
BOTTOM OF BOREHOLE: 10/9/2020 1600 HRS 840 ft bgs
Kmt (Muddy S.)
Kmt (Thermopolis)
840 ft

TEST WELL #3

DEPTH: 5 FT

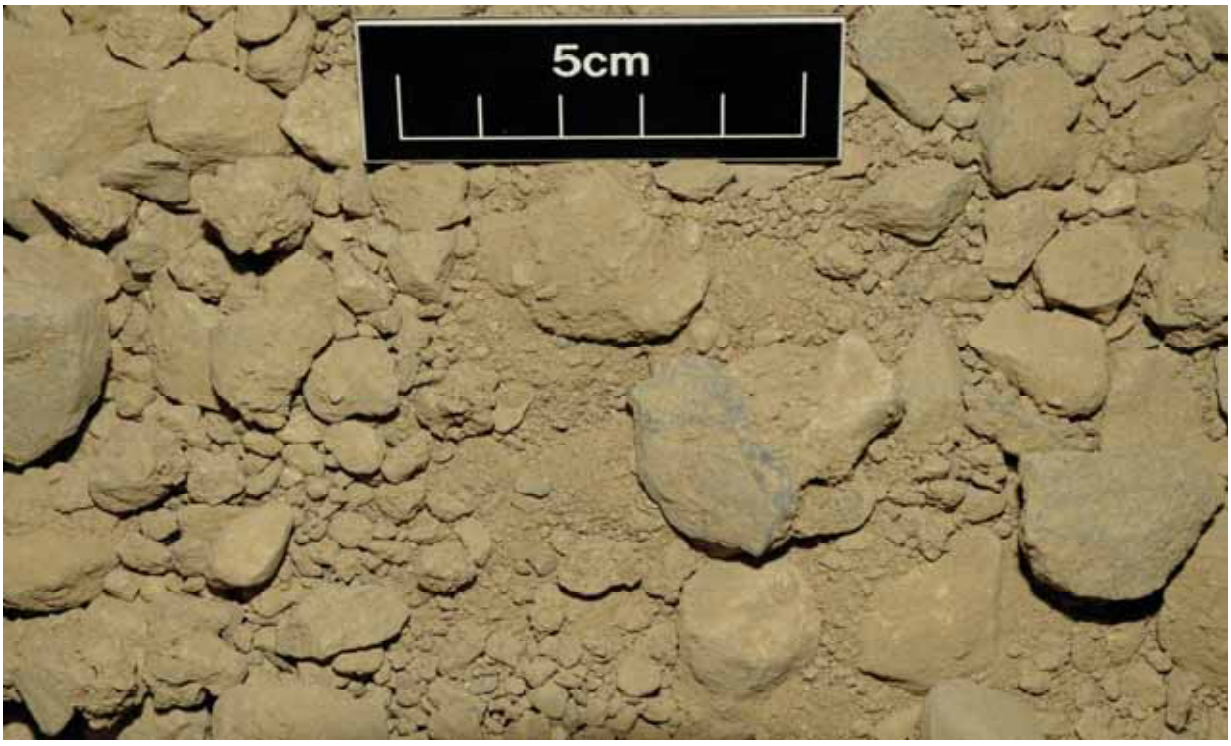
DEPTH: 10 FT



TEST WELL #3

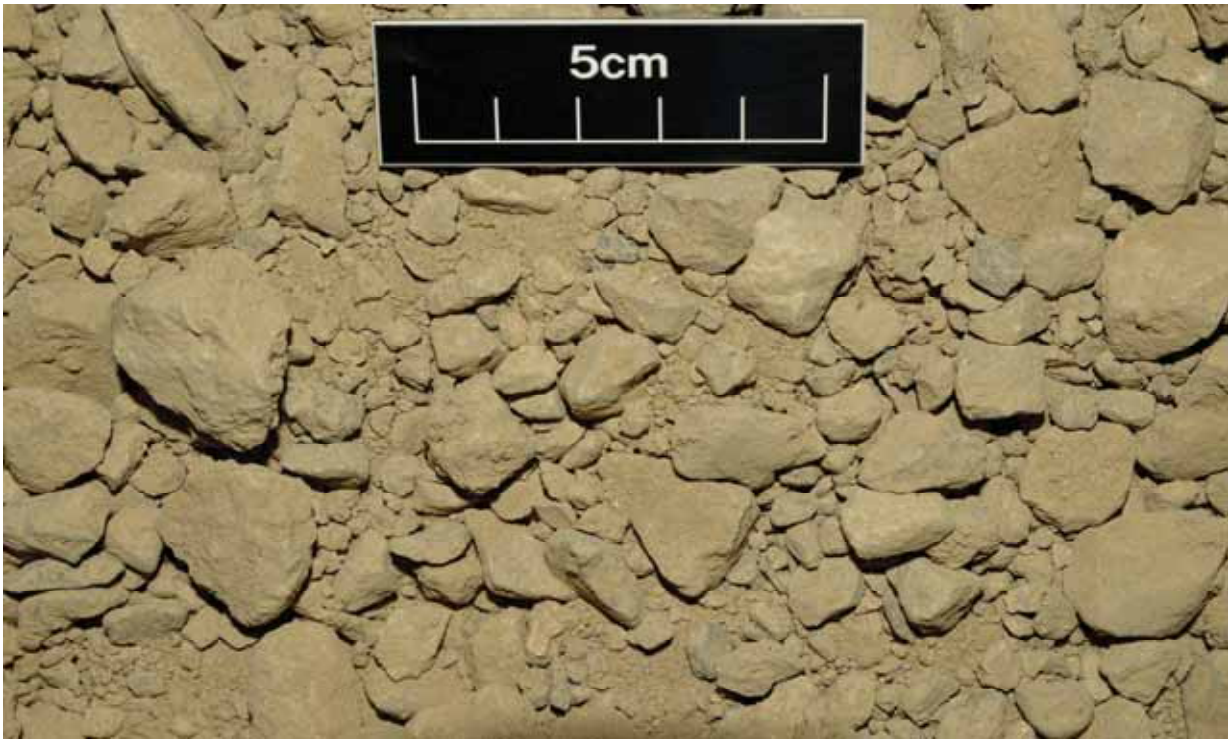
DEPTH: 15 FT

DEPTH: 20 FT

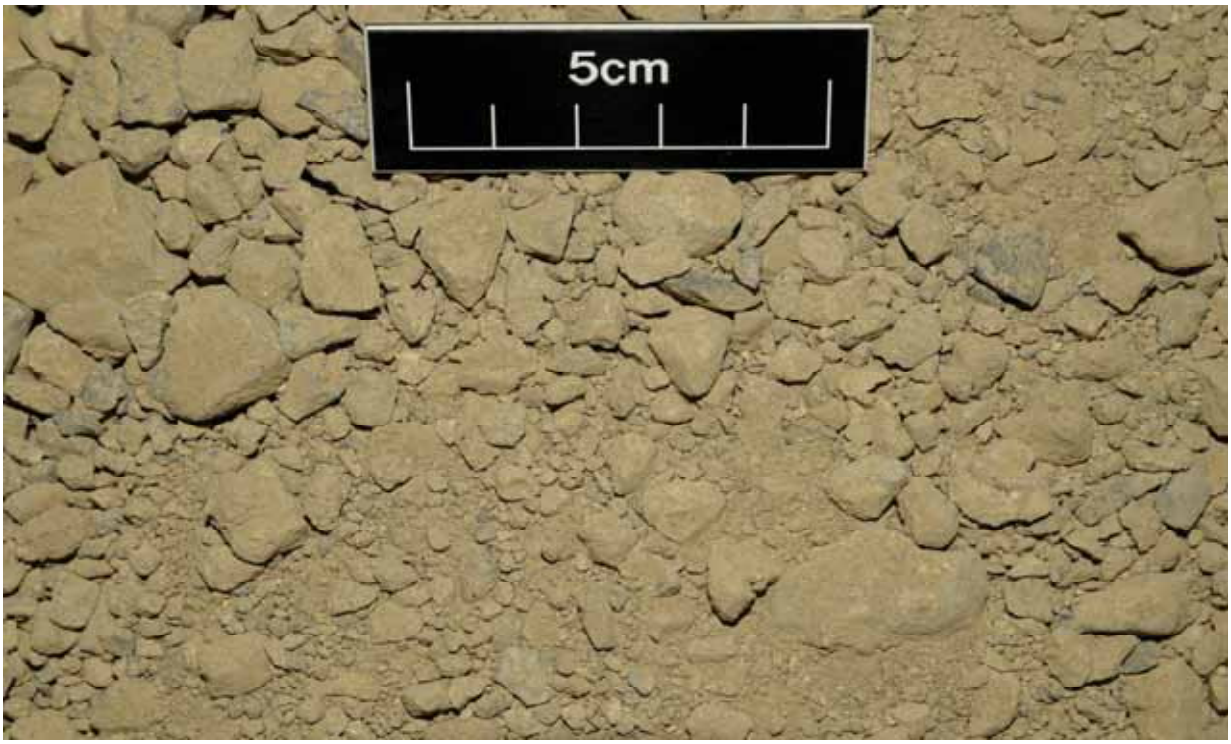


TEST WELL #3

DEPTH: 25 FT

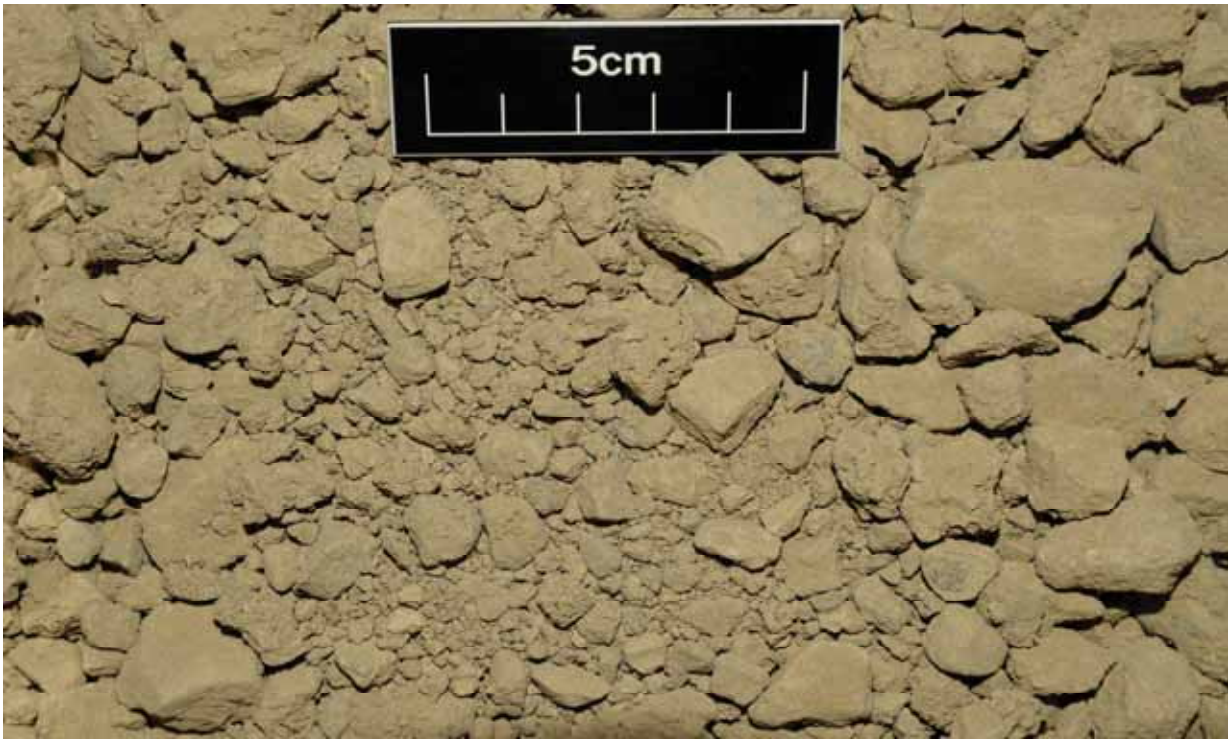


DEPTH: 30 FT

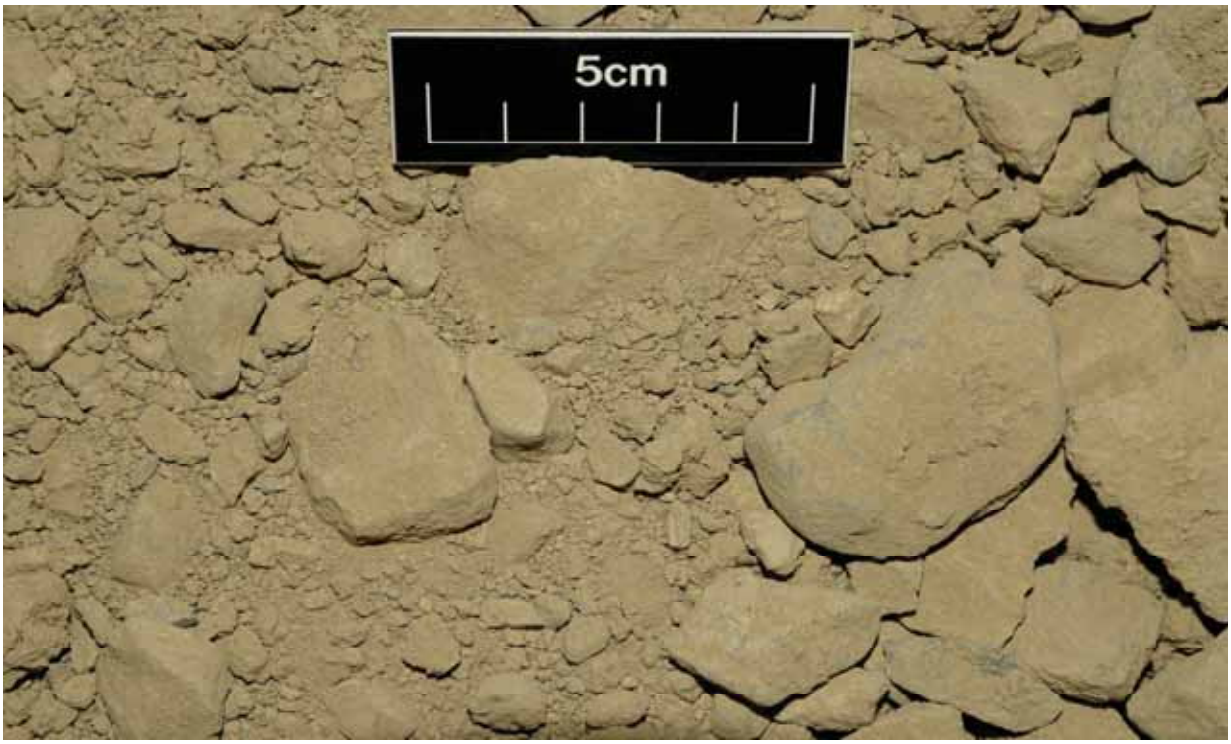


TEST WELL #3

DEPTH: 35 FT



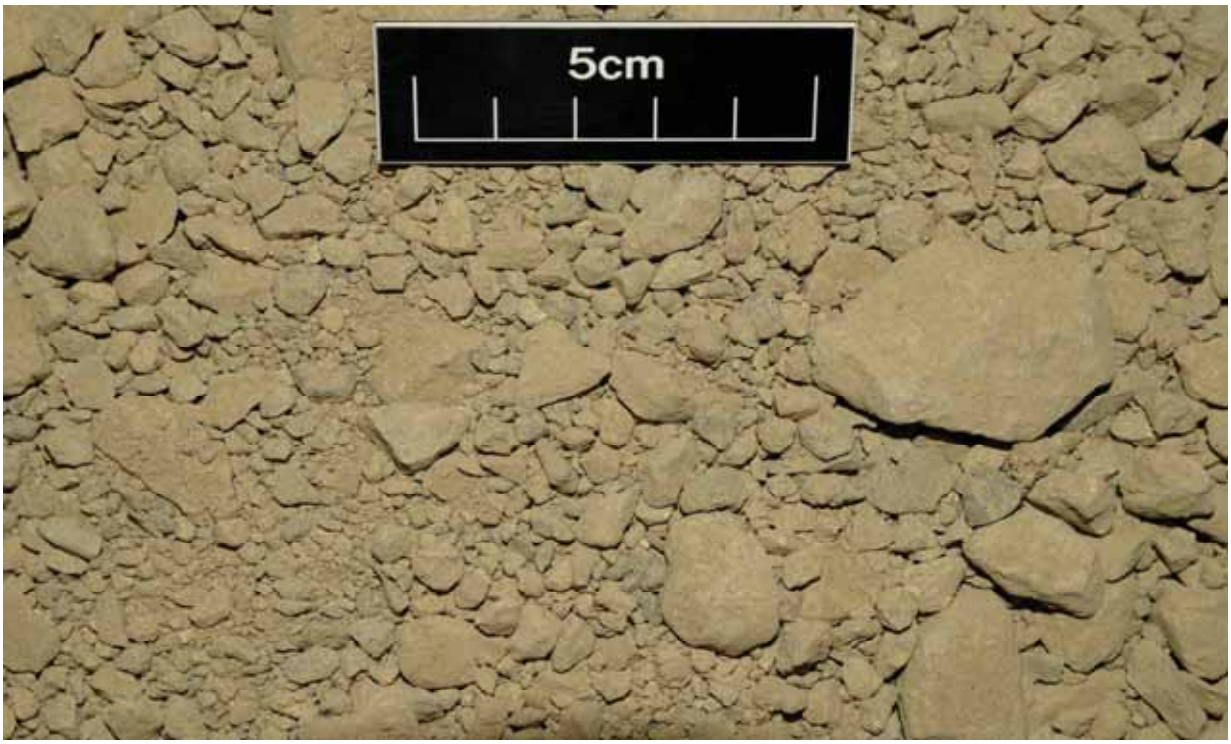
DEPTH: 40 FT



TEST WELL #3

DEPTH: 45 FT

DEPTH: 50 FT



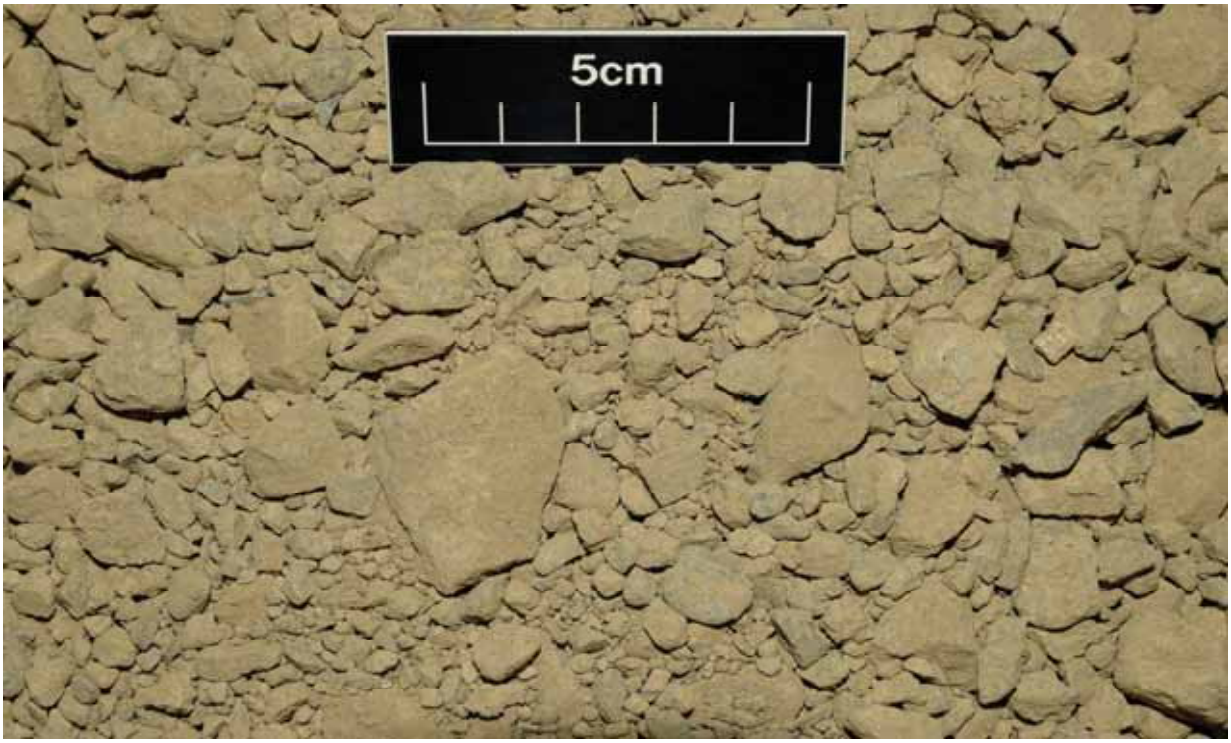
TEST WELL #3

DEPTH: 55 FT

DEPTH: 60 FT

TEST WELL #3

DEPTH: 65 FT



DEPTH: 70 FT

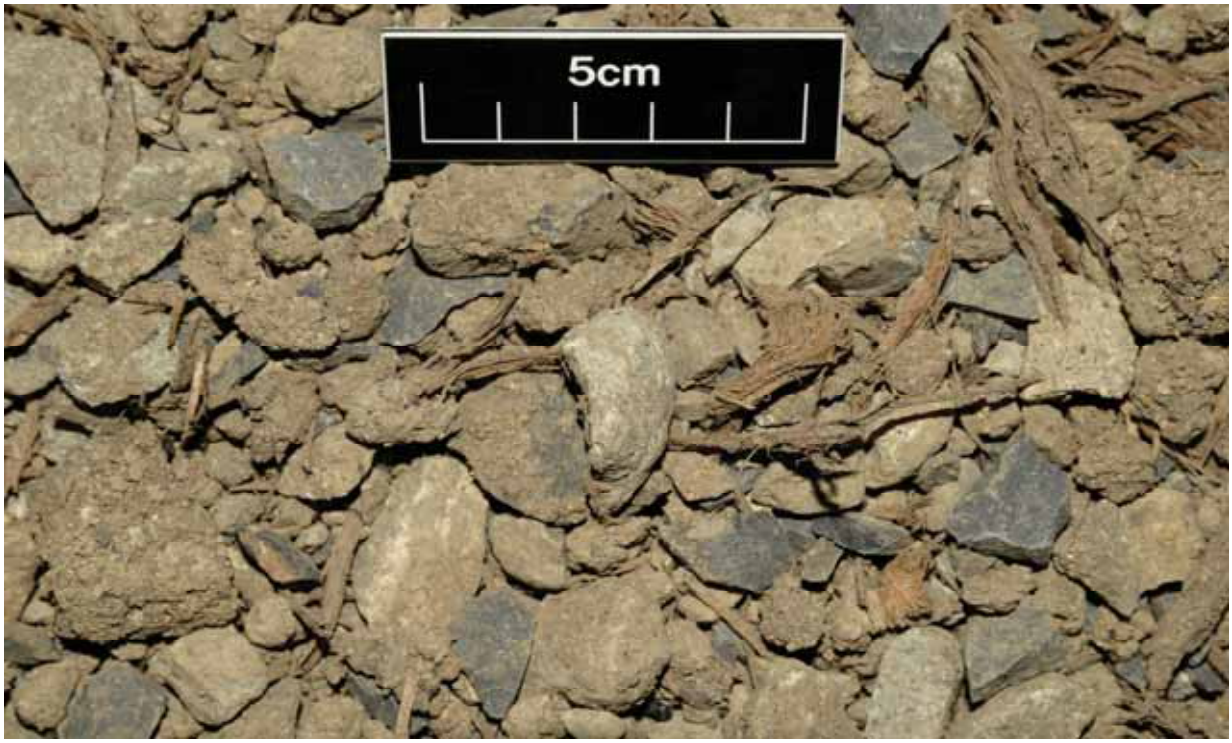
TEST WELL #3

DEPTH: 75 FT

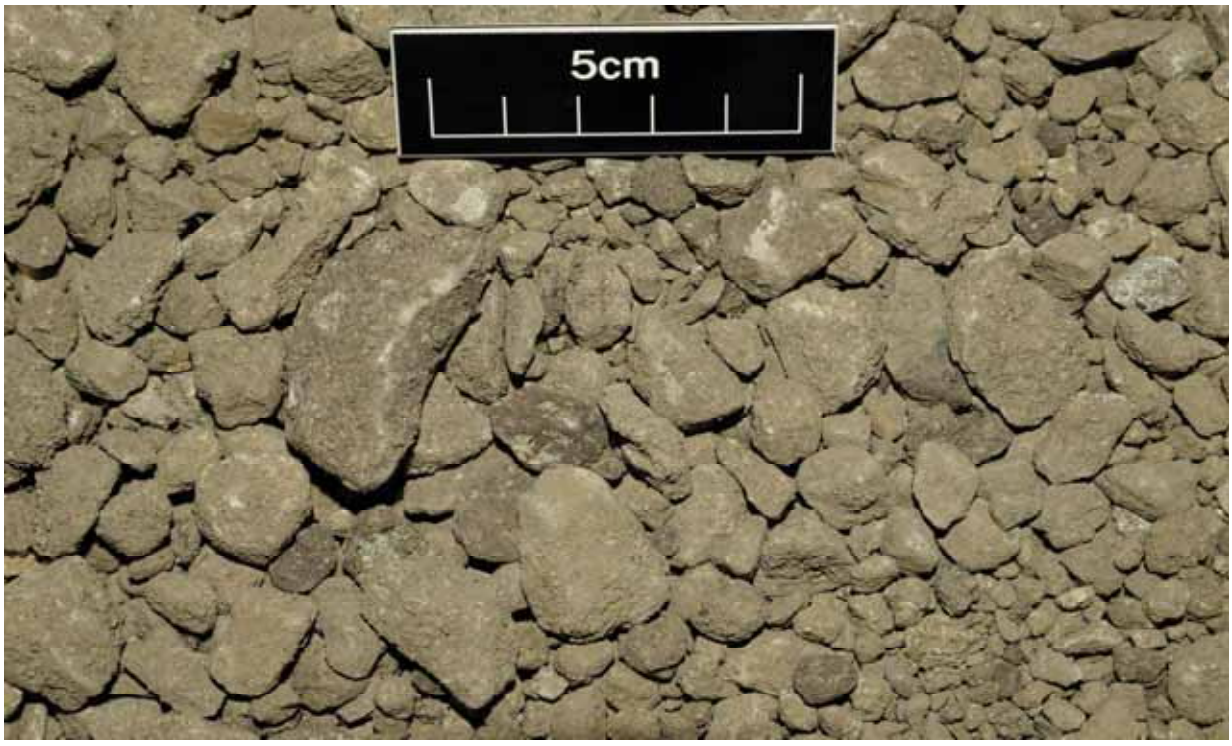
DEPTH: 80 FT

TEST WELL #4

DEPTH: 5 FT

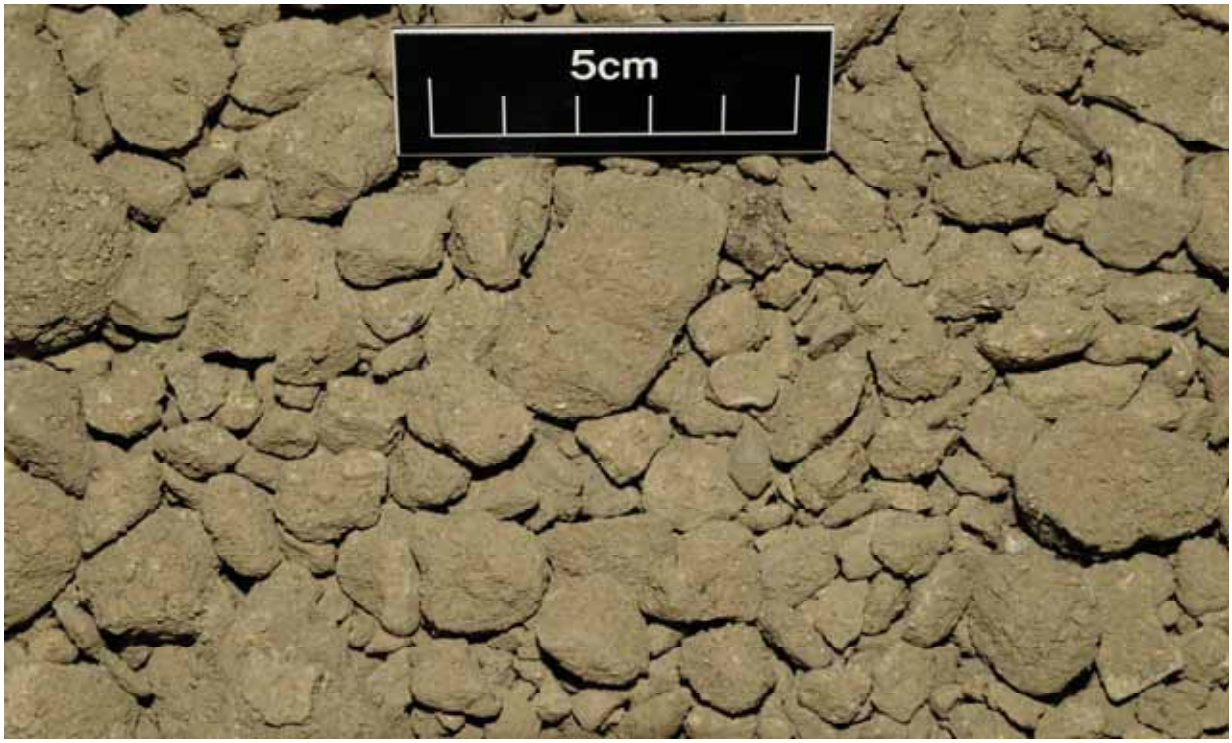


DEPTH: 10 FT

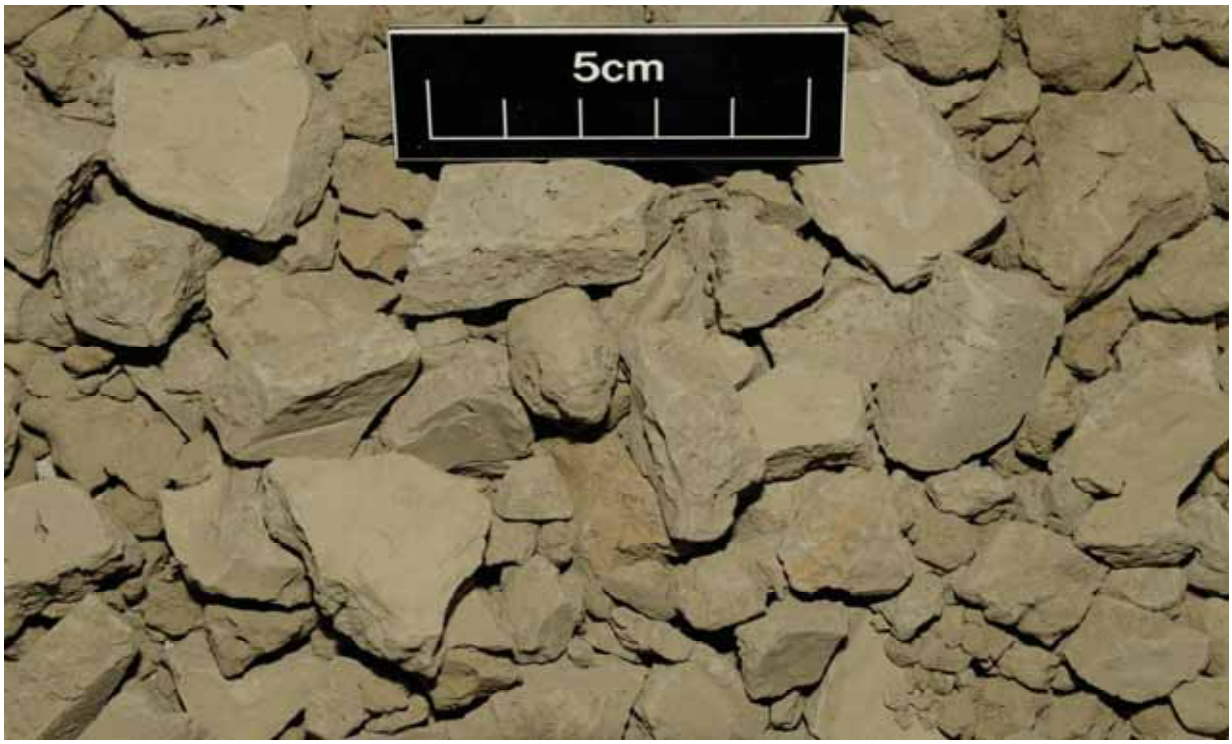


TEST WELL #4

DEPTH: 15 FT

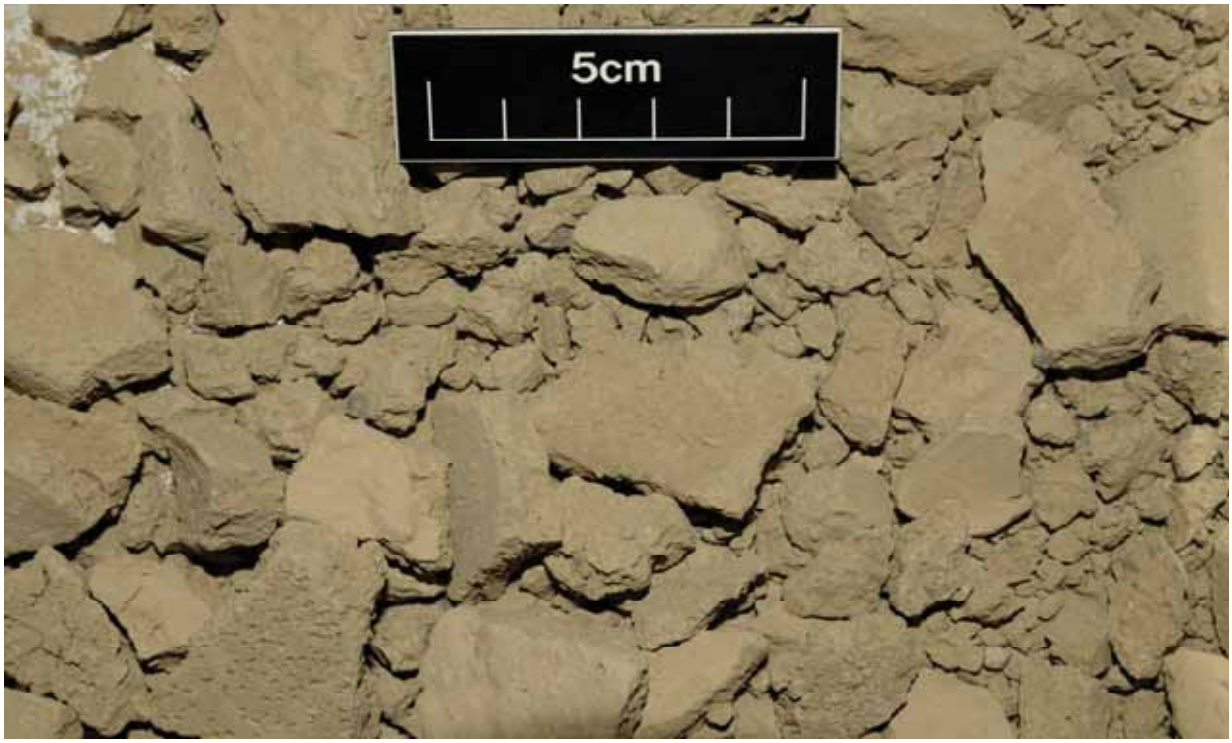


DEPTH: 20 FT

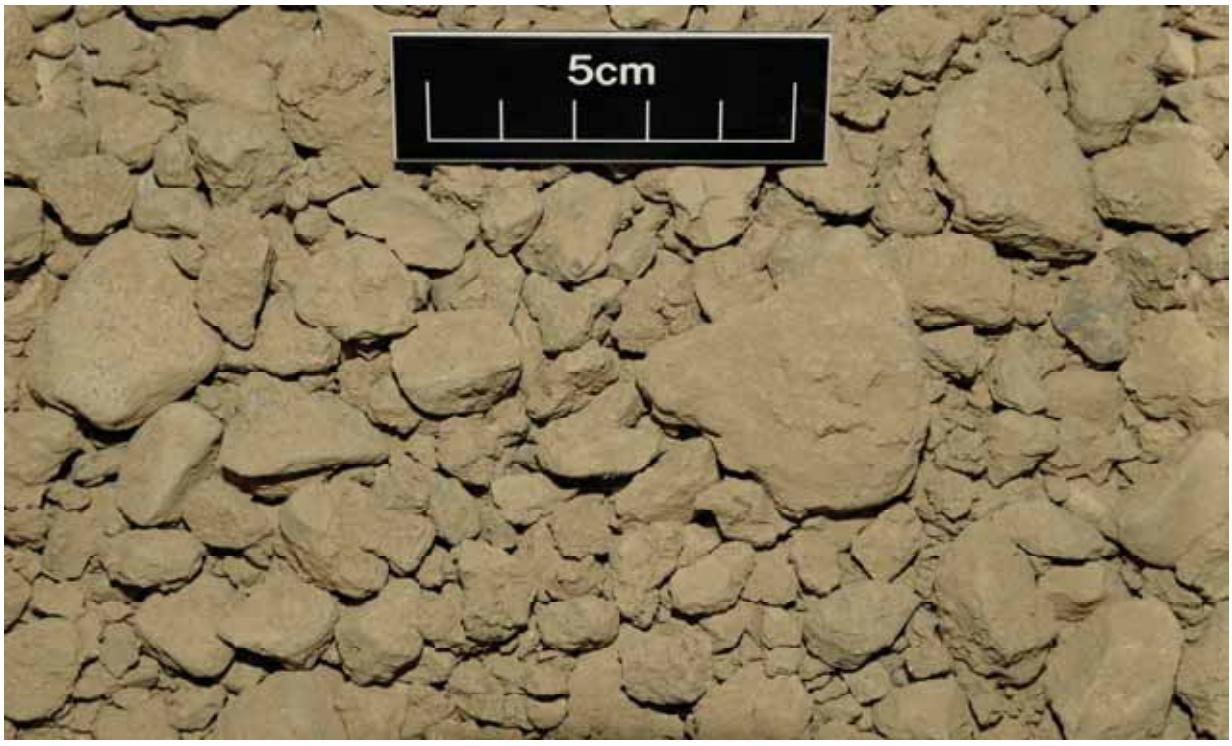


TEST WELL #4

DEPTH: 25 FT

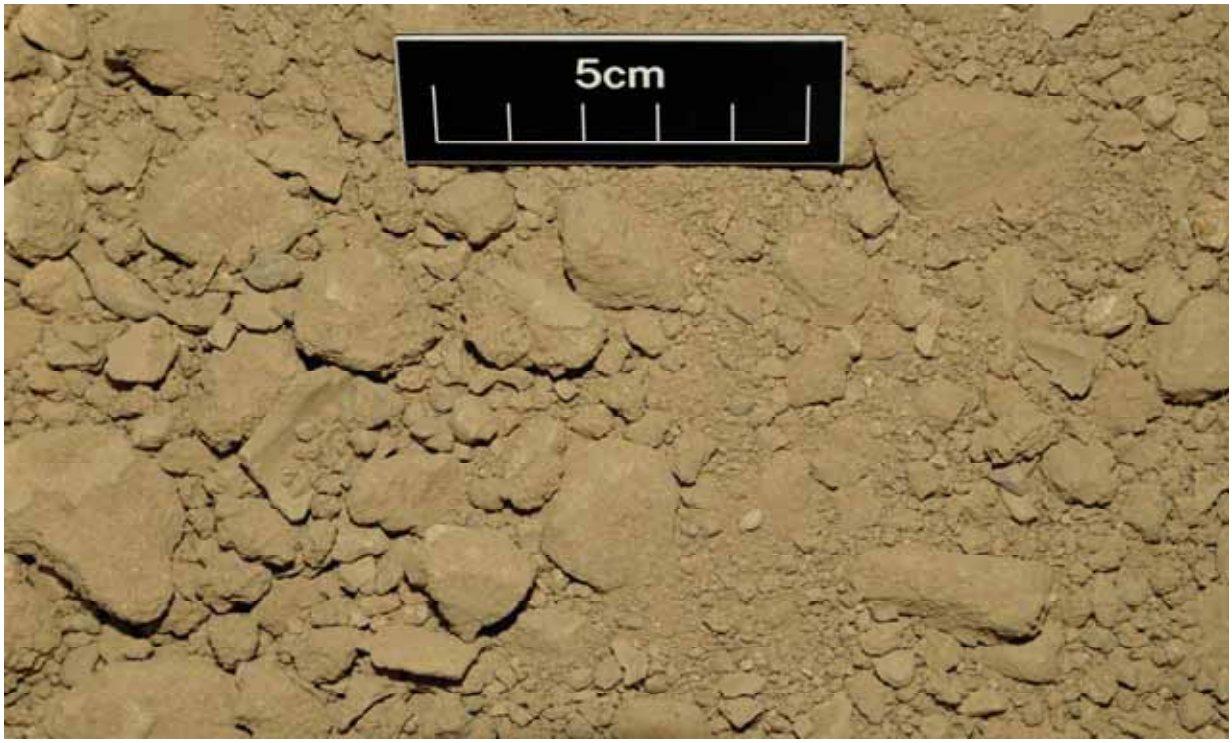


DEPTH: 30 FT



TEST WELL #4

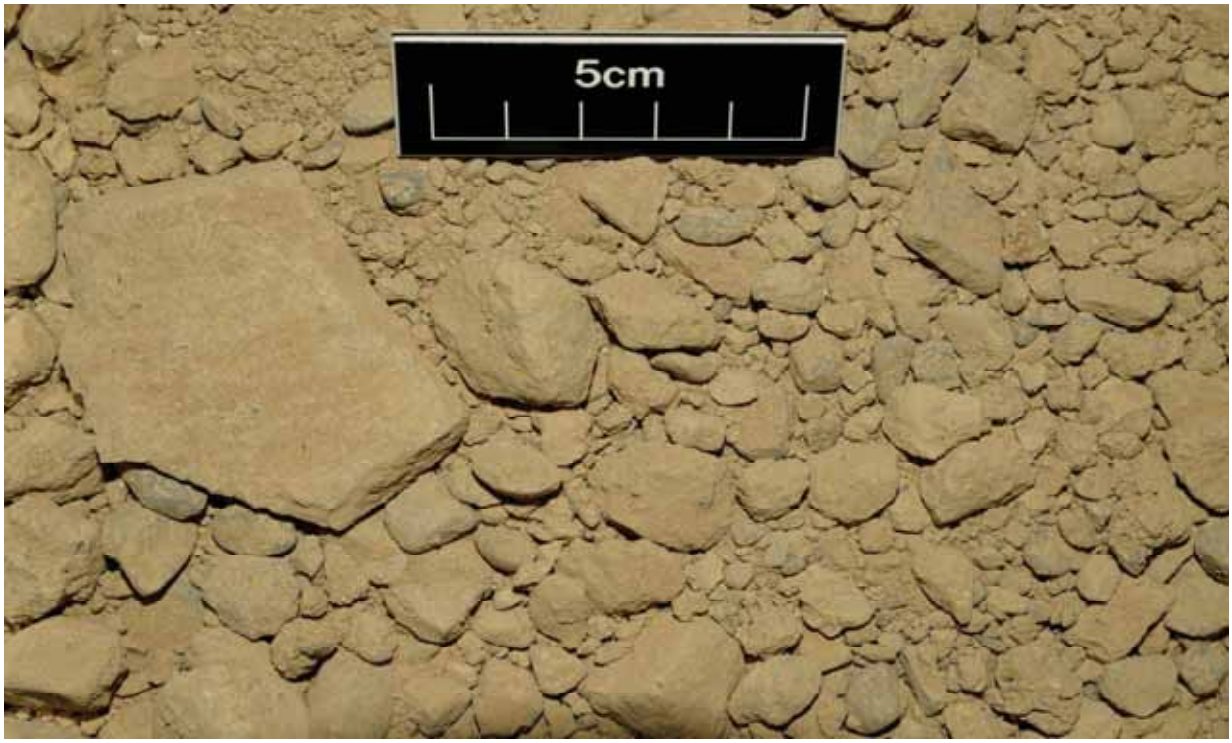
DEPTH: 35 FT



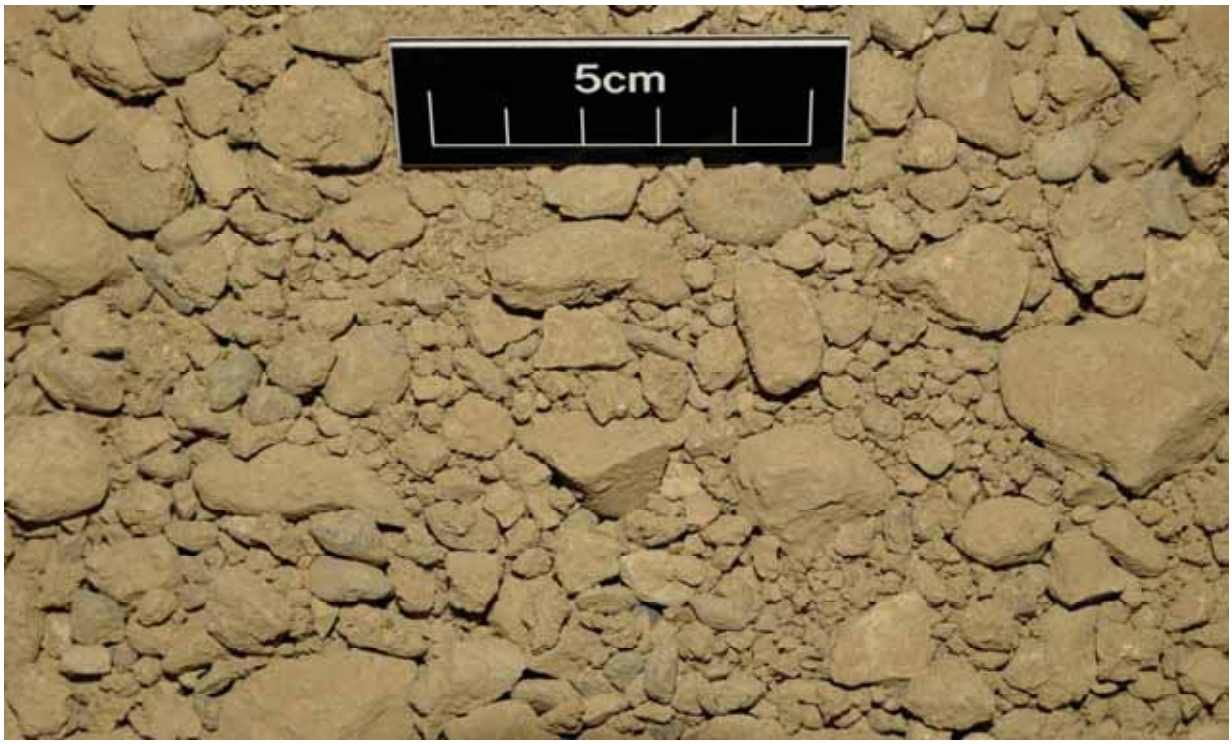
DEPTH: 40 FT

TEST WELL #4

DEPTH: 45 FT

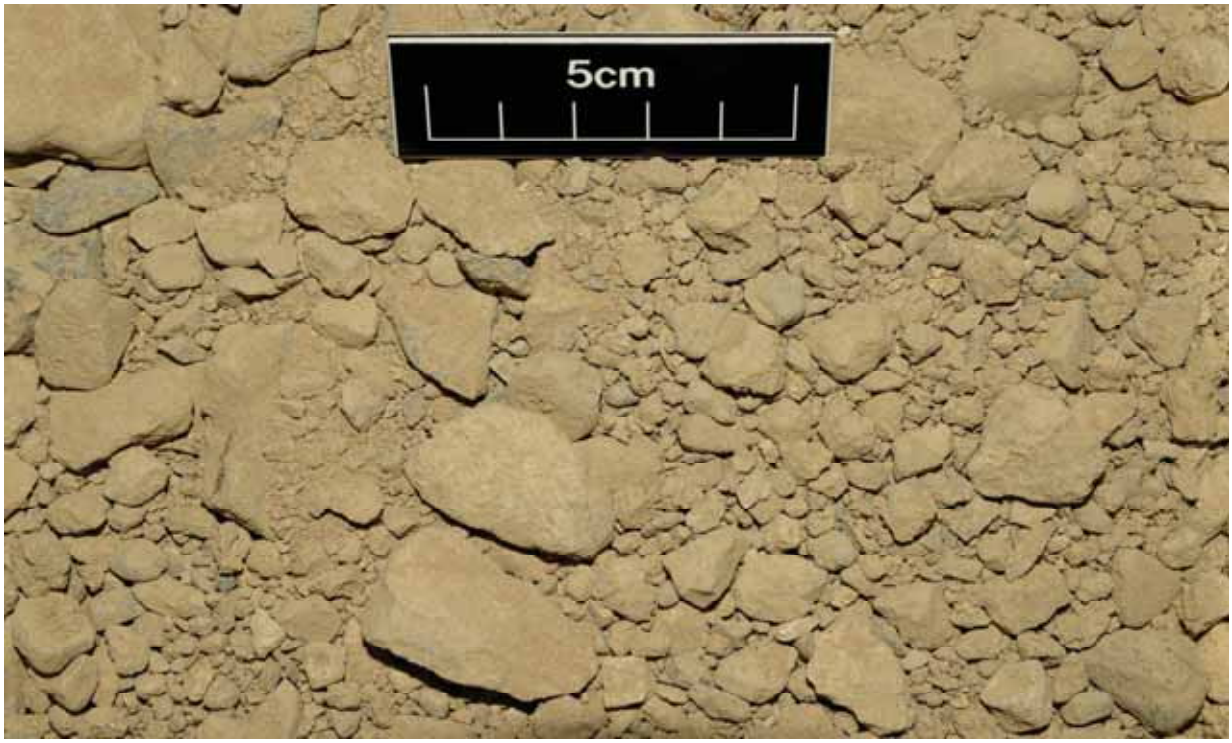


DEPTH: 50 FT



TEST WELL #4

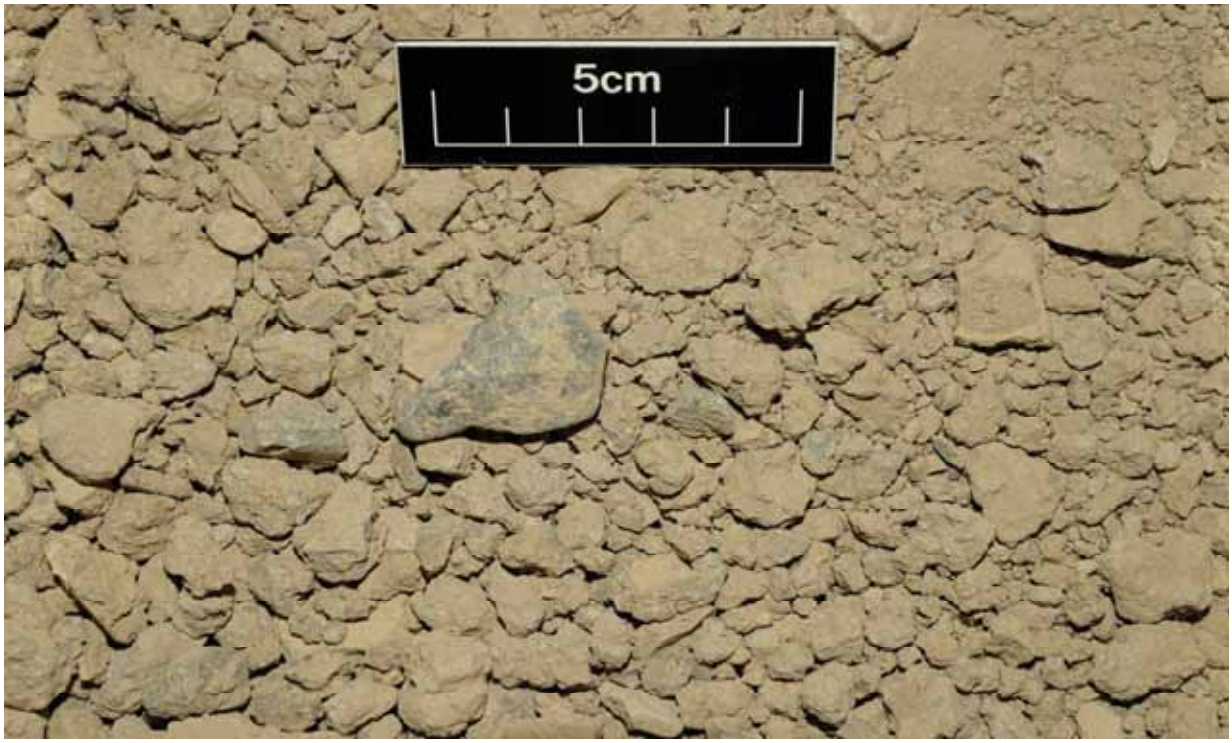
DEPTH: 55 FT



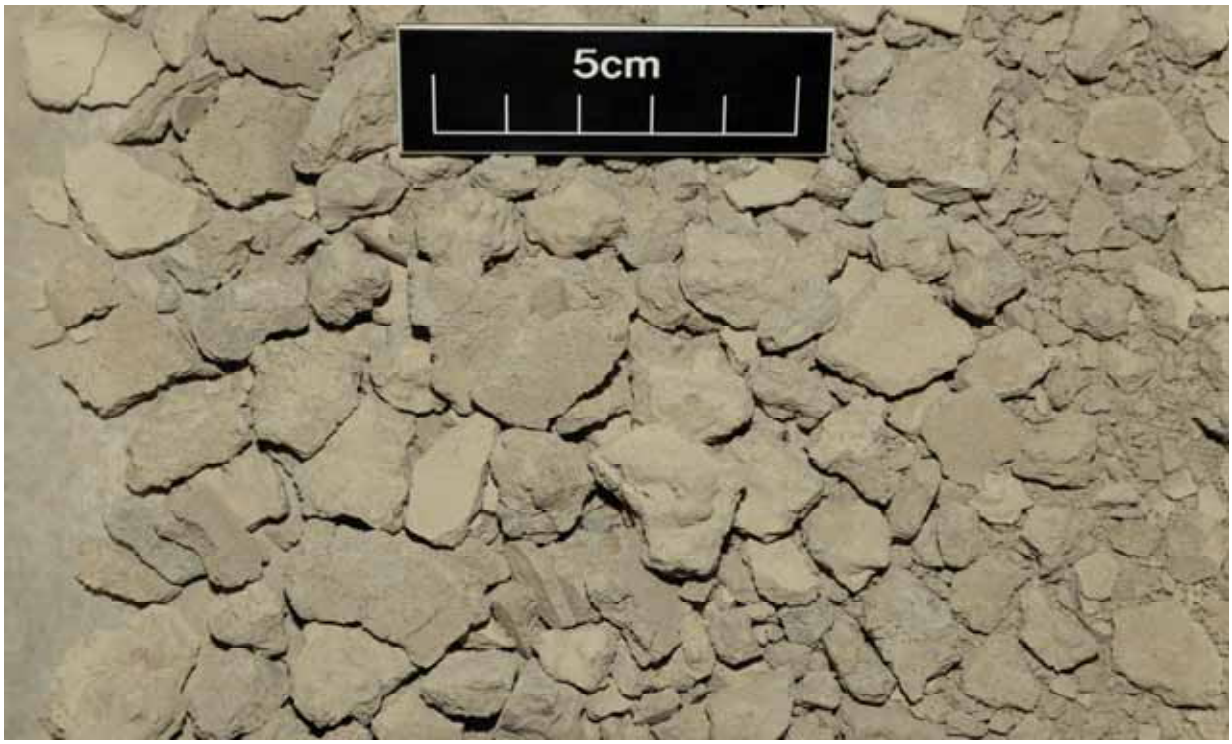
DEPTH: 60 FT

TEST WELL #4

DEPTH: 65 FT

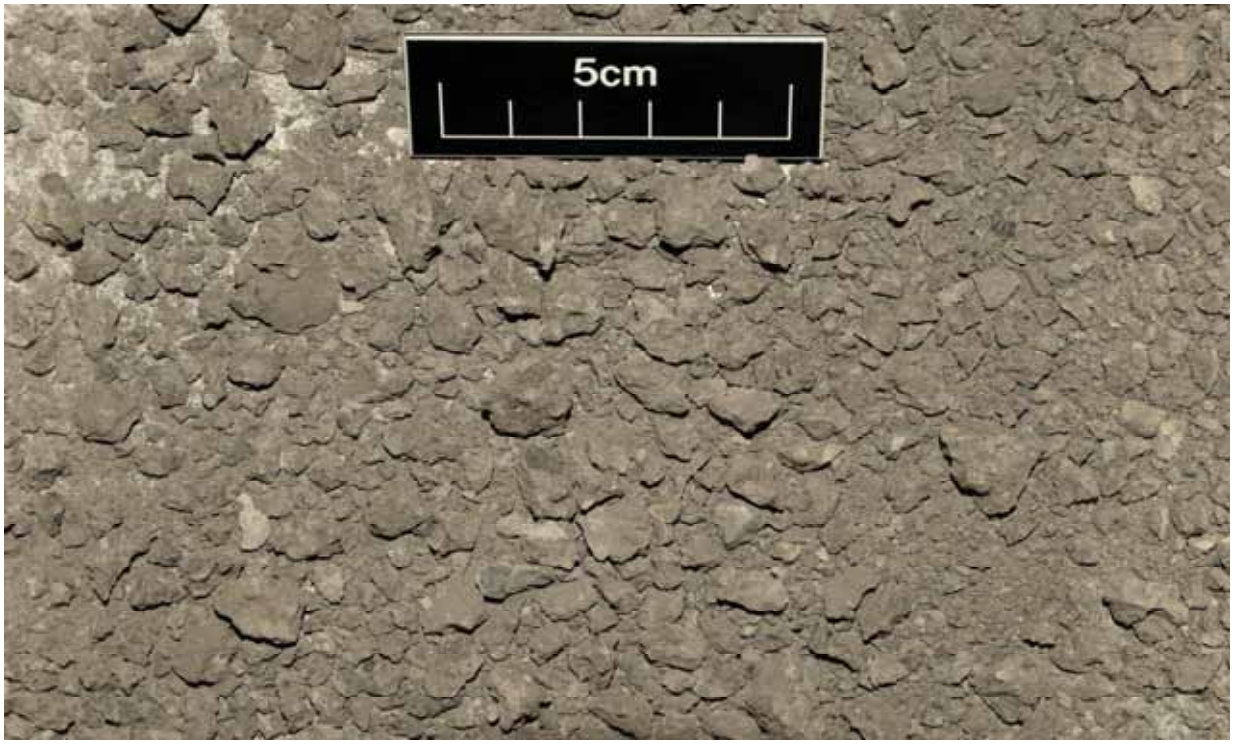


DEPTH: 70 FT



TEST WELL #4

DEPTH: 75 FT



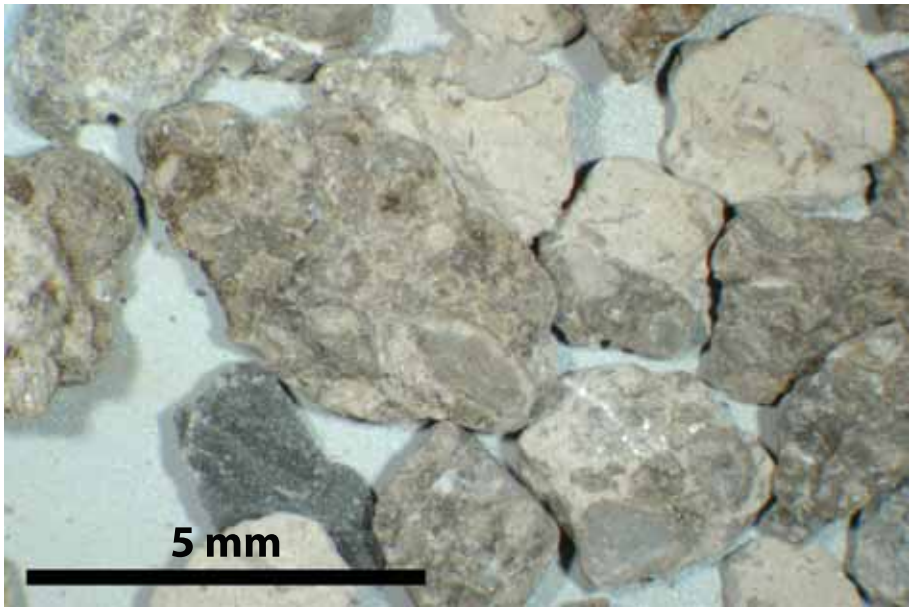


Exhibit 1-1 Kootenai formation oolitic limestone (1000 ft bgs)

Limestone chips with visible oolites, peloids, and shell fragments. 10X magnification, stereo microscope image.

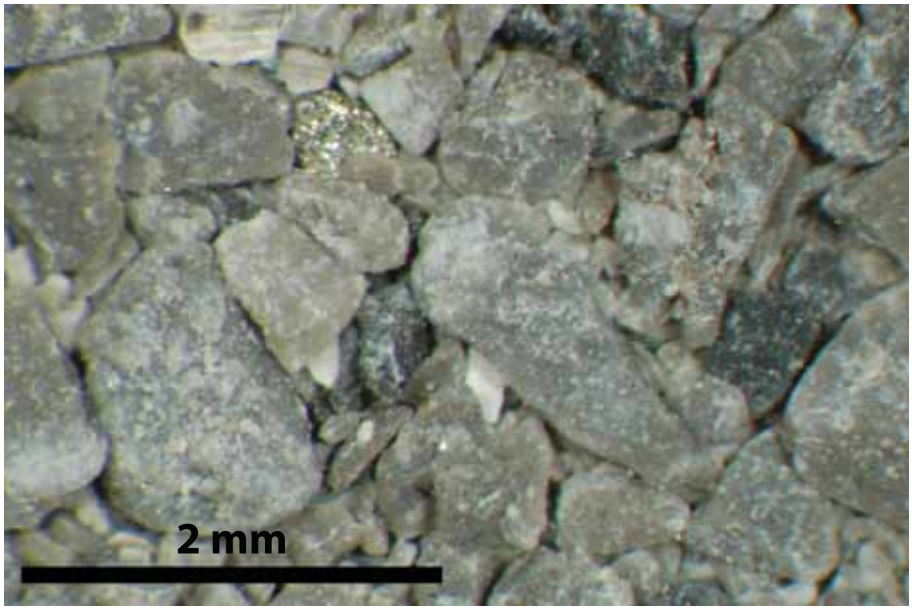


Exhibit 1-2 Kootenai formation, micritic limestone (1000 ft bgs)

Limestone mud, or otherwise known as micrite. A shiny gold pyrite fragment is located in the viewer upper left. 26X magnification, stereo microscope image.

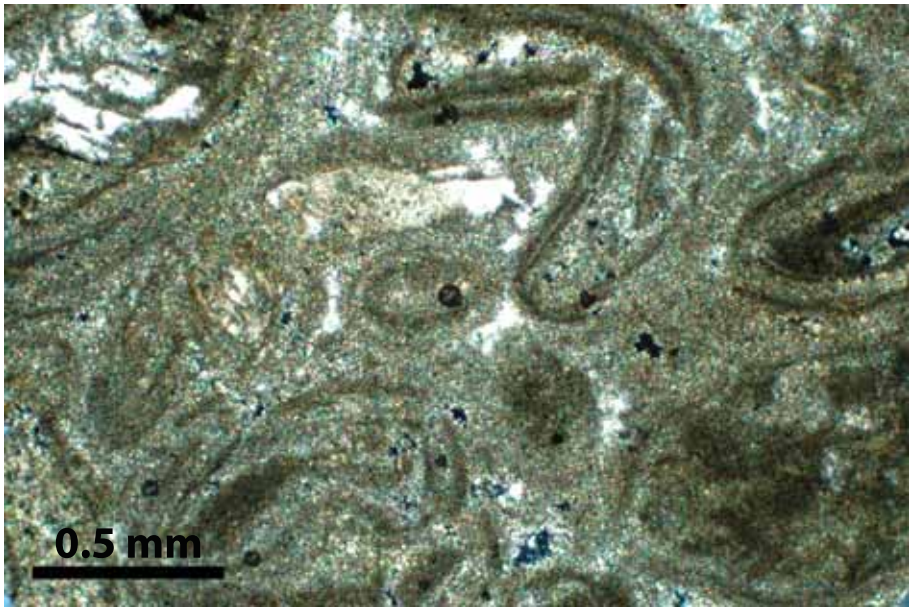


Exhibit 1-3 Kootenai formation, oolitic limestone (1000 ft bgs)

Oolitic, peloidal limestone with shell fragments cemented with calcite, forming a freshwater limestone. 40X magnification, polarizing microscope, crossed polarized light image.

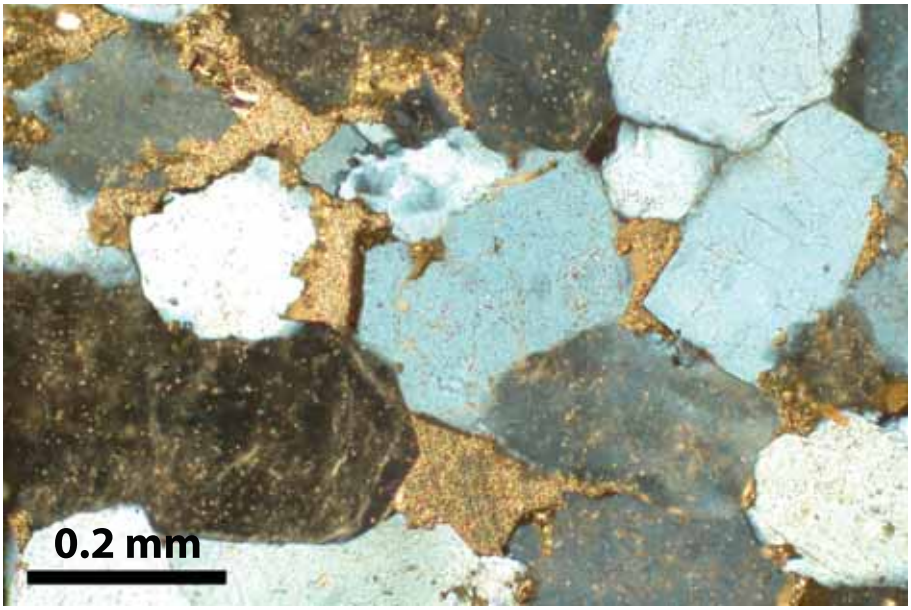


Exhibit 1-4 Thermopolis formation, basal sandstone (TW #6, 160 ft bgs)

Angular to sub-angular quartz grains cemented by pyrite.
100X magnification, polarizing microscope with combined crossed polarized and reflected light image.

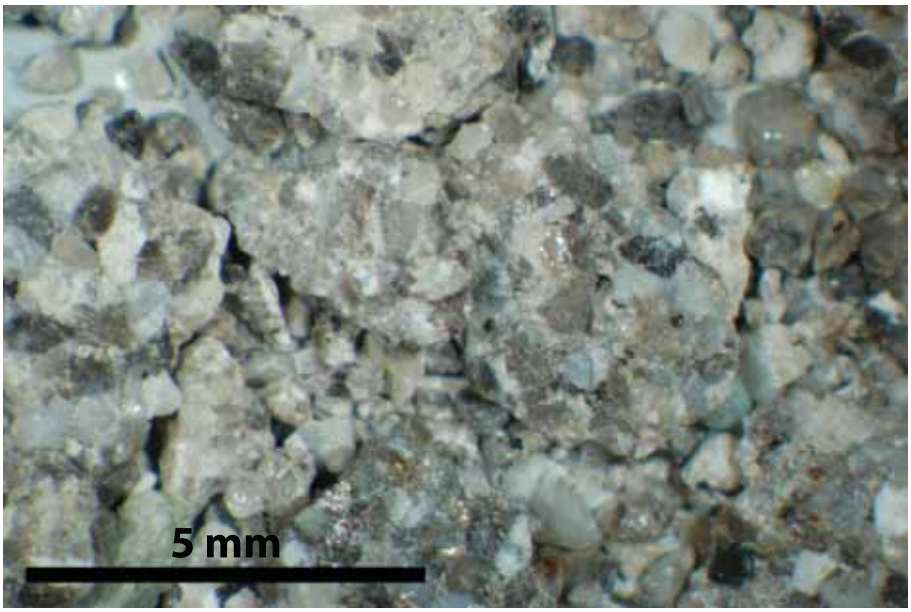


Exhibit 1-5 Kootenai formation, basal sandstone (TW #6, 680 ft bgs)

Medium to coarse grained quartz sandstone with presumed kaolinite clay cementation. 10X magnification, stereo microscope image.

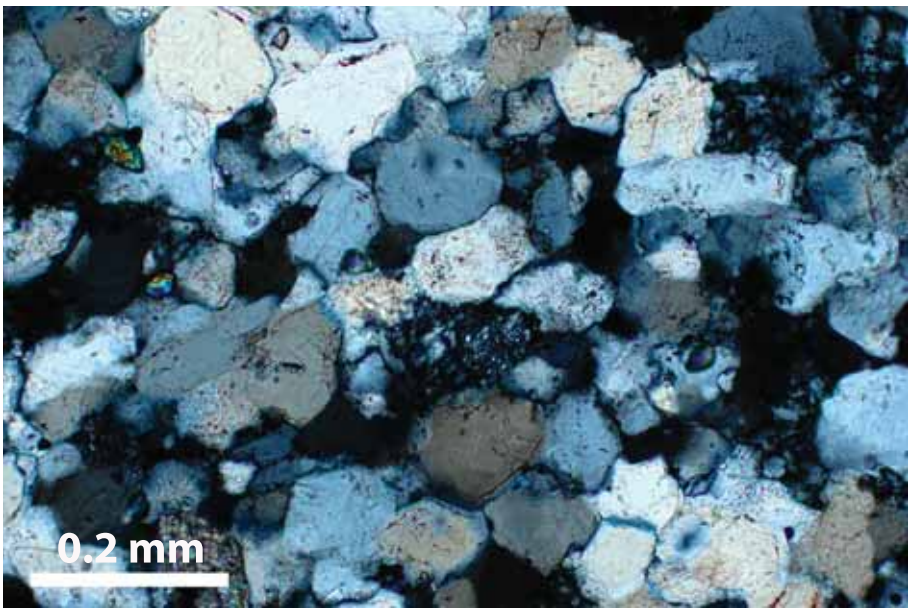


Exhibit 1-6 Kootenai formation, basal sandstone (TW #6, 680 ft bgs)

Medium to coarse grained quartz sandstone with presumed kaolinite clay cementation. 100X magnification, polarizing microscope, crossed polarized light image.

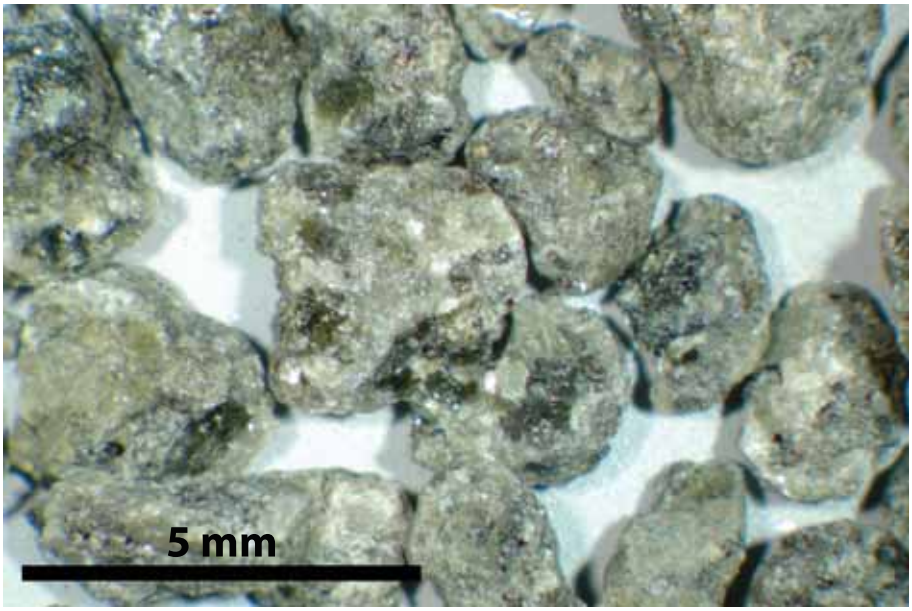


Exhibit 1-7 Gabbro Sill (TW #11, 660 ft bgs)

Gabbro has the same mineralogy as basalt, but has crystallized below ground with much slower quenching allowing larger crystal growth. Medium to coarse grained, equant crystals of plagioclase feldspar and augite pyroxene, with trace minerals. 10X magnification, stereo microscope image.

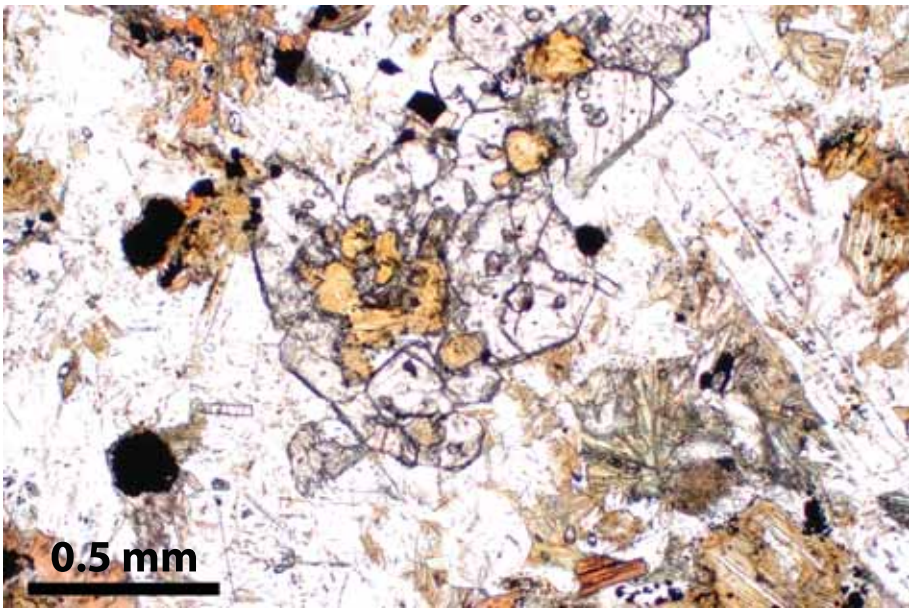


Exhibit 1-8 Gabbro Sill (TW #11, 660 ft bgs)

Medium to coarse grained, equant crystals of plagioclase (white elongate prisms) and augite (high relief, darker blocky crystals), magnetite (opaque grains), biotite mica (brown alteration mineral). 40X magnification, polarizing microscope, plane polarized light image.

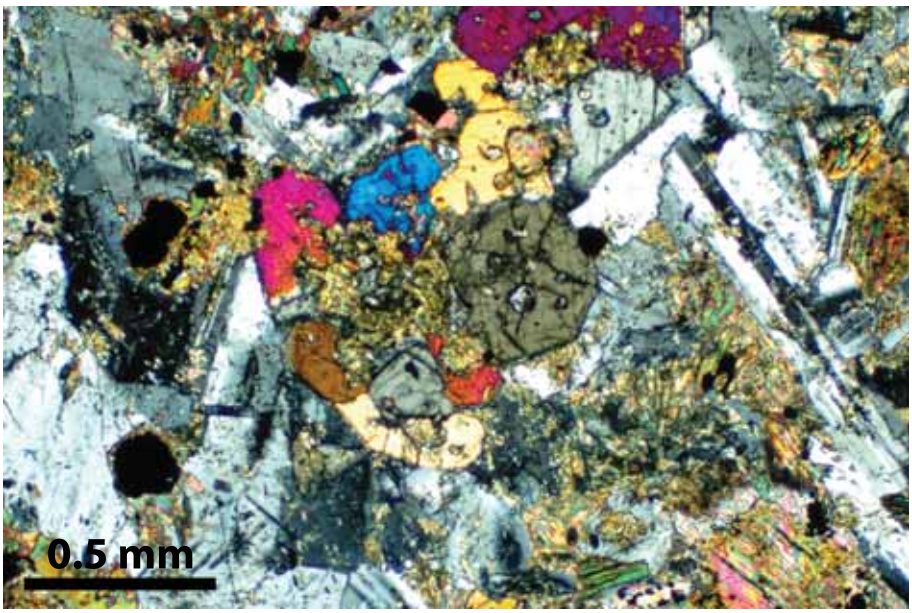


Exhibit 1-9 Gabbro Sill (TW #11, 660 ft bgs)

Same image as above, but with crossed polarized light. Augite crystals exhibit vibrant colors. Plagioclase are the white and gray prisms. Magnetite remains opaque. 40X magnification, polarizing microscope, crossed polarized light image.

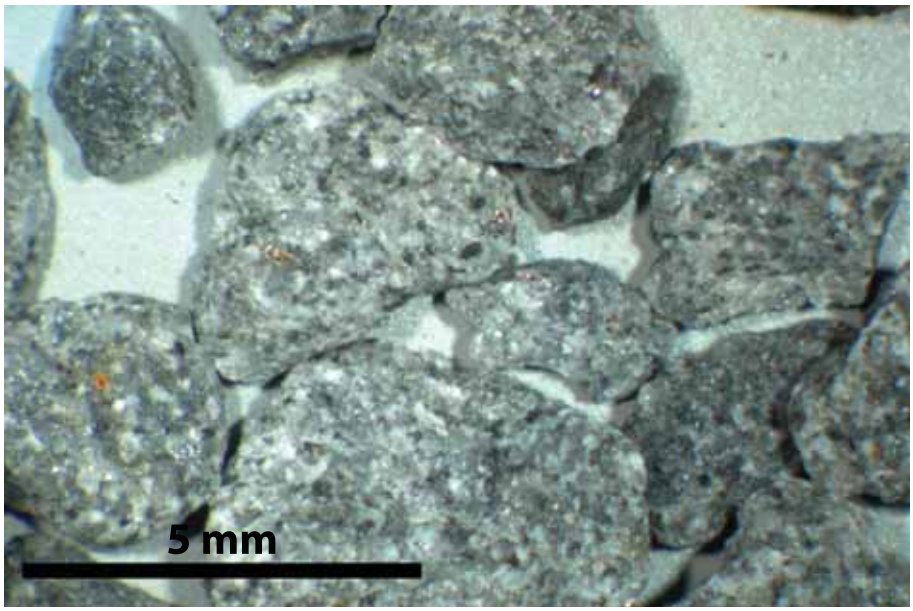


Exhibit 1-10 Muddy Sandstone (TW #11, 800 ft bgs)

Very fine to fine grained chips of Muddy Sandstone, predominantly quartz grains with calcite and silica cement. Sparse metallic flecks are most likely pyrite. 10X magnification, stereo microscope image.

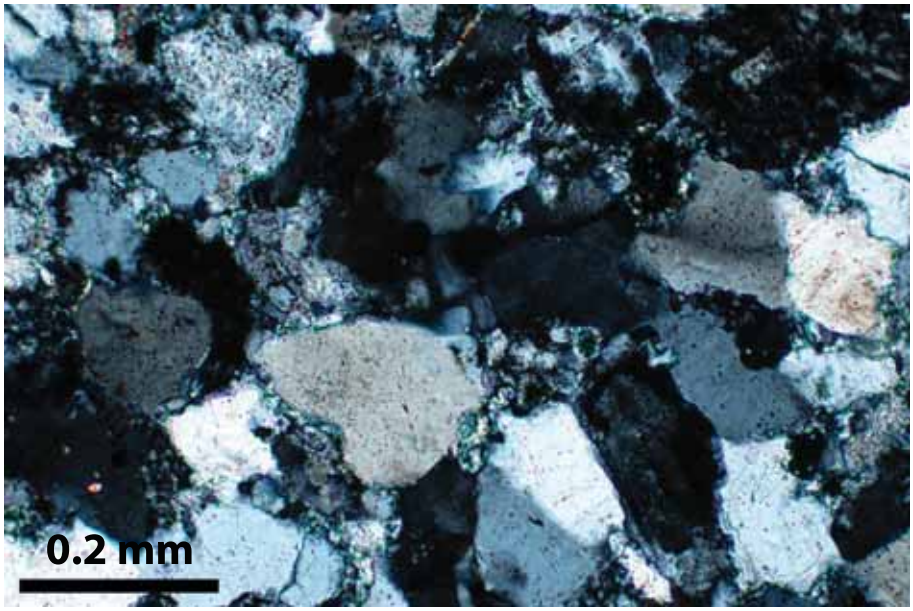


Exhibit 1-11 Muddy Sandstone (TW #11, 800 ft bgs)

Very fine to fine grained, well sorted and sub-rounded to rounded quartz grains with silica and calcite cement. 100X magnification, polarizing microscope, crossed polarized light image.

HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

OWNER:	Big Sky County Water & Sewer District #363		
	Big Sky, MT		
	Jim Muscat (406) 581-6138		
	Ron Edwards (406) 995-2660		
HYDROGEOLOGIST:	Western Groundwater Services, LLC		
	Bozeman, MT (406) 585-5947		
	Mark Cunnane (406) 579-1493		
CONTRACTOR:	Bridger Drilling, Inc.		
	Bozeman, MT (406) 388-7227		
	Tyler Sampson (406) 581-1205		
	Curt Sampson (406) 581-4292		
NOTICE TO PROCEED:	**9/15/2020**		**Bold = payable quantity**
CONTRACT TIME:	**365**		
TOTAL FEES TO-DATE:	**$ 117,059.00**		

DATE	DAY	TIME	ACTIVITY
09/15/20	Tue	1	TEST WELL #3 (ALLUVIAL WELL) **B-3.1 Mobilization 1 EA; B-3.2 Drilling 6" With Casing 80 LF**
09/16/20	Wed	2	**C1 Well Abandonment 80 LF** (TW#3)**;** TEST WELL #4 (ALLUVIAL WELL) **B-3.1 Mobilization 1 EA; B-3.2 Drilling 6" With Casing 55 LF**
09/17/20	Thu	3	No site work completed (Contractor attending MT Water Well Contractor's Board Meeting -- as Board Member)
09/18/20	Fri	4	**B-3.2 Drilling 6" With Casing 22 LF** (Total Casing 77 LF)
09/19/20	Sat	5	No site work completed
09/20/20	Sun	6	No site work completed
09/21/20	Mon	7	TEST WELL #5 (INTRUSIVE near tank) **B-1.1 Mobilization 1 EA; B-1.2 6" Drilling with Casing 100 LF**
09/22/20	Tue	8	**B-1.2 6" Drilling with Casing 80 LF; B-1.3 6" Drilling Open Hole 217 LF** (Total Depth 397 ft bgs)
09/23/20	Wed	9	**B-1.3 6" Drilling Open Hole 341 LF** (Total Depth 738 ft bgs)
09/24/20	Thu	10	TEST WELL #6 **B-1.1 Mobilization 1 EA**
09/25/20	Fri	11	**B-1.2 6" Drilling with Casing 60 LF** (Total Depth 60 ft bgs)
09/26/20	Sat	12	No site work completed
09/27/20	Sun	13	No site work completed
09/28/20	Mon	14	**B-1.2 6" Drilling with Casing 140 LF** (Total Depth 196 ft bgs)
09/29/20	Tue	15	**B-1.3 6" Drilling Open Hole 320 LF** (Total Depth 516 ft bgs)
09/30/20	Wed	16	**B-1.3 6" Drilling Open Hole 180 LF** (Total Depth 696 ft bgs)
10/01/20	Thu	17	**B-1.3 6" Drilling Open Hole 240 LF** (Total Depth 936 ft bgs)
10/02/20	Fri	18	**B-1.3 6" Drilling Open Hole 104 LF** (Total Depth 1040 ft bgs); **B-1.4 Development 1 HRS**
10/03/20	Sat	19	No site work completed
10/04/20	Sun	20	No site work completed
10/05/20	Mon	21	TEST WELL #11 (Sedimentary/Instrusive near YC Booster) **B-1.1 Mobilization 1 EA**
10/06/20	Tue	22	**B-1.2 6" Drilling with Casing 140 LF** (Total Depth 136 ft bgs)
10/07/20	Wed	23	**B-1.2 6" Drilling with Casing 60 LF; B-1.3 6" Drilling Open Hole 120 LF** (Total Depth 320 ft bgs)
10/08/20	Thu	24	**B-1.3 6" Drilling Open Hole 280 LF** (Total Depth 600 ft bgs)
10/09/20	Fri	25	**B-1.3 6" Drilling Open Hole 240 LF** (Total Depth 840 ft bgs)
10/10/20	Sat	26	No site work completed
10/11/20	Sun	27	No site work completed
10/12/20	Mon	28	TEST WELL #7 (Kootenai, West Ski Parking Lot) **B-2.1 Mobilization 1 EA**
10/13/20	Tue	29	Mobilization
10/14/20	Wed	30	Mobilization, **B-2.2 10" Drilling with Casing 20 LF**
10/15/20	Thu	31	**B-2.2 10" Driling with Casing 80 LF**
10/16/20	Fri	32	**B-2.2 10" Driling with Casing 22 LF** (Total Depth 121.5 ft)
10/17/20	Sat	33	No site work completed

HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

DATE	DAY	TIME	ACTIVITY
10/18/20	Sun	34	No site work completed
10/19/20	Mon	35	Set 6-inch casing; Emplaced plug at base of casing.
10/20/20	Tue	36	10-inch temporary casing would not pull for grouting; pulled 6-inch casing; flushed grout out of hole
10/21/20	Wed	37	No site work completed; ordered tool adapter to cut 10-inch casing shoe
10/22/20	Thu	38	No site work completed
10/23/20	Fri	39	No site work completed
10/24/20	Sat	40	No site work completed
10/25/20	Sun	41	No site work completed
10/26/20	Mon	42	No site work completed
10/27/20	Tue	43	No site work completed
10/28/20	Wed	44	No site work completed
10/29/20	Thu	45	**C3-2 Downhole Casing Cutting 1 EA**; Set 6" casing in hole
10/30/20	Fri	46	**B-2.3 Set and Cement 6" Casing 122 LF**
10/31/20	Sat	47	No site work completed
11/01/20	Sun	48	No site work completed
11/02/20	Mon	49	**C3-1 Wellhead Valve 1 EA; B-2.4 6" Drilling Open Hole 134 LF**
11/03/20	Tue	50	**B-2.4 6" Drilling Open Hole 129 LF** (TOH FOR BIT CHANGE),(Total Depth 385 ft)
11/04/20	Wed	51	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 576 ft)
11/05/20	Thu	52	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 716 ft)
11/06/20	Fri	53	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 730 ft); **B-2.5 Development 3 HRS** (END DRILLING FOR 2020)

BIG SKY MTN VILLAGE TEST WELLS 2020

BEDROCK - NON-ARTESIAN					JOB TOTAL---------->			$ 117,059.00	TD (ft)	80	77	738	1040	730			840
									BUDGET	$ 5,170.00	$ 5,170.00	$ 24,250.00	$ 24,250.00	$ 28,210.00	$ 28,210.00	$ 28,210.00	$ 24,250.00
									ACTUAL	$ 5,480.00	$ 3,772.00	$ 21,988.00	$ 30,315.00	$ 30,664.00			$ 24,840.00
									B-A	$ (310.00)	$ 1,398.00	$ 2,262.00	$ (6,065.00)	$ (2,454.00)			
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total		TW#3	TW#4	TW#5	TW#6	TW#7	TW#8	TW#10	TW#11
B-1.1	Mobilization	3	LS	$ 1,000.00	$ 3,000.00		3	$ 3,000.00				1	1				1
B-1.2	6" Drilling with Casing	240	LF	$ 36.00	$ 8,640.00		580	$ 20,880.00				180	200				200
B-1.3	6" Drilling Open Hole	2160	LF	$ 26.00	$ 56,160.00		2038	$ 52,988.00				558	840				640
B-1.4	Development	18	HR	$ 275.00	$ 4,950.00		1	$ 275.00					1				
				TOTAL	$ 72,750.00			$ 77,143.00									
BEDROCK - ARTESIAN												$ 21,988.00	$ 30,315.00				$ 24,840.00
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
B-2.1	Mobilization	4	LS	$ 1,000.00	$ 4,000.00		1	$ 1,000.00						1			
B-2.2	10" Drilling with Casing	320	LF	$ 50.00	$ 16,000.00		122	$ 6,100.00						122			
B-2.3	Set and Cement 6" Casing	320	LF	$ 35.50	$ 11,360.00		122	$ 4,331.00						122			
B-2.4	6" Drilling Open Hole	2880	LF	$ 26.00	$ 74,880.00		608	$ 15,808.00						608			
B-2.5	Development	24	HR	$ 275.00	$ 6,600.00		3	$ 825.00						3			
				TOTAL	$ 112,840.00			$ 28,064.00						$ 28,064.00			
ALLUVIUM																	
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
B-3.1	Mobilization	2	LS	$ 1,000.00	$ 2,000.00		2	$ 2,000.00		1	1						
B-3.2	6" Drilling with Casing	140	LF	$ 36.00	$ 5,040.00		157	$ 5,652.00		80	77						
B-3.3	Development	12	HR	$ 275.00	$ 3,300.00		0	$ -									
				TOTAL	$ 10,340.00			$ 7,652.00									
				TOTAL AS BID	**$ 195,930.00**					$ 3,880.00	$ 3,772.00						
CHANGE ORDERS																	
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
C1	Contract time extension	0	NA	$ -	$ -												
C2	TW#3 Well Abandonment	80	LF	$ 20.00	$ 1,600.00		80	$ 1,600.00		80							
C3-1	Wellhead Valve	1	EA	$ 1,100.00	$ 1,100.00		1	$ 1,100.00						1			
C3-2	Downhole casing cutting	1	EA	$ 1,500.00	$ 1,500.00		1	$ 1,500.00						1			
				TOTAL	$ 4,200.00			$ 4,200.00		$ 1,600.00				$ 2,600.00			
		TOTAL WITH CHANGE ORDERS			**$ 200,130.00**												

ATTACHMENT B
WATER QUALITY LAB REPORTS

Pace Analytical® Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Date: 10/16/2020

CLIENT: Western Groundwater Services
Project: Big Sky MTN TWs 2020
Lab Order: S2010075

CASE NARRATIVE

Report ID: S2010075001

Sample TW#6 100220 MC was received on October 6, 2020.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Pace Analytical (Formerly Inter-Mountain Laboratories) except as indicated in this case narrative.

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical®
Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 10/16/2020
Report ID: S2010075001

Work Order: S2010075
Collection Date: 10/2/2020 2:30:00 PM
Date Received: 10/6/2020 10:27:00 AM
Sampler: MC
Matrix: Water
COC: 180998

Project: Big Sky MTN TWs 2020
Lab ID: S2010075-001
Client Sample ID: TW#6 100220 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.4	0.1		s.u.	10/13/2020 08:08 ACE	SM 4500 H B
Electrical Conductivity	457	5		µmhos/cm	10/13/2020 08:08 ACE	SM 2510B
Alkalinity, Total (As CaCO3)	171	5		mg/L	10/13/2020 08:08 ACE	SM 2320B
Silica as SiO2	7.8	0.1		mg/L	10/07/2020 11:59 DG	EPA 200.7
Anions						
Alkalinity, Bicarbonate as HCO3	203	5		mg/L	10/13/2020 08:08 ACE	SM 2320B
Alkalinity, Carbonate as CO3	ND	5		mg/L	10/13/2020 08:08 ACE	SM 2320B
Chloride	31	1		mg/L	10/13/2020 12:21 AB	EPA 300.0
Fluoride	2.3	0.1		mg/L	10/13/2020 08:08 ACE	SM 4500FC
Sulfate	3	1		mg/L	10/12/2020 21:46 AB	EPA 300.0
Cations						
Calcium	17	1		mg/L	10/07/2020 11:59 DG	EPA 200.7
Magnesium	9	1		mg/L	10/07/2020 11:59 DG	EPA 200.7
Potassium	7	1		mg/L	10/07/2020 11:59 DG	EPA 200.7
Sodium	66	1		mg/L	10/07/2020 11:59 DG	EPA 200.7
Dissolved Metals						
Arsenic	0.011	0.005		mg/L	10/07/2020 00:37 MS	EPA 200.8
Iron	ND	0.05		mg/L	10/07/2020 11:59 DG	EPA 200.7
Manganese	ND	0.02		mg/L	10/07/2020 11:59 DG	EPA 200.7

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
D	Report limit raised due to dilution
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
U	Analyte below method detection limit
C	Calculated Value
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical
Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Date: 11/23/2020

CLIENT: Western Groundwater Services
Project: Big Sky Mtn Test Wells 2020
Lab Order: S2011168

CASE NARRATIVE

Report ID: S2011168001

Sample TW#7 110620 MC was received on November 11, 2020.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Pace Analytical (Formerly Inter-Mountain Laboratories) except as indicated in this case narrative.

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical
Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 11/23/2020
Report ID: S2011168001

Work Order: S2011168
Collection Date: 11/6/2020 11:00:00 AM
Date Received: 11/11/2020 11:52:00 AM
Sampler:
Matrix: Water
COC: 184275

Project: Big Sky Mtn Test Wells 2020
Lab ID: S2011168-001
Client Sample ID: TW#7 110620 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.5	0.1		s.u.	11/12/2020 06:00 ACE	SM 4500 H B
Electrical Conductivity	582	5		µmhos/cm	11/12/2020 06:00 ACE	SM 2510B
Alkalinity, Total (As CaCO3)	181	5		mg/L	11/12/2020 06:00 ACE	SM 2320B
Silica as SiO2	7.0	0.1		mg/L	11/17/2020 12:26 DG	EPA 200.7
Anions						
Alkalinity, Bicarbonate as HCO3	210	5		mg/L	11/12/2020 06:00 ACE	SM 2320B
Alkalinity, Carbonate as CO3	5	5		mg/L	11/12/2020 06:00 ACE	SM 2320B
Chloride	7	1		mg/L	11/13/2020 23:22 AB	EPA 300.0
Fluoride	0.9	0.1		mg/L	11/16/2020 16:07 ACE	SM 4500FC
Sulfate	106	1		mg/L	11/13/2020 23:22 AB	EPA 300.0
Cations						
Calcium	57	1		mg/L	11/17/2020 12:26 DG	EPA 200.7
Magnesium	22	1		mg/L	11/17/2020 12:26 DG	EPA 200.7
Potassium	8	1		mg/L	11/17/2020 12:26 DG	EPA 200.7
Sodium	33	1		mg/L	11/17/2020 12:26 DG	EPA 200.7
Dissolved Metals						
Arsenic	ND	0.005		mg/L	11/13/2020 03:40 MS	EPA 200.8
Iron	ND	0.05		mg/L	11/17/2020 12:26 DG	EPA 200.7
Manganese	0.06	0.02		mg/L	11/17/2020 12:26 DG	EPA 200.7

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

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G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
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C	Calculated Value
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical
Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Date: 1/14/2021

CLIENT: Western Groundwater Services
Project:
Lab Order: S2012045

CASE NARRATIVE

Report ID: S2012045002
(Replaces S2012045001)

Sample TW #7 120220 MC was received on December 3, 2020.

All samples were received and analyzed within the EPA recommended holding times, except those noted below in this case narrative. Samples were analyzed using the methods outlined in the following references:

"Standard Methods For The Examination of Water and Wastewater", approved method versions
Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition
40 CFR Parts 136 and 141
40 CFR Part 50, Appendices B, J, L, and O
Methods indicated in the Methods Update Rule published in the Federal Register Friday, May 18, 2012
ASTM approved and recognized standards

All Quality Control parameters met the acceptance criteria defined by EPA and Pace Analytical (Formerly Inter-Mountain Laboratories) except as indicated in this case narrative.

S2012045002 was issued to change the metals analyses to Dissolved Metals and to add Fe and Mn. It replaces report S2012045001.

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical
Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 1/14/2021
Report ID: S2012045002
(Replaces S2012045001)
Work Order: S2012045
Collection Date: 12/2/2020 11:30:00 AM
Date Received: 12/3/2020 8:57:00 AM
Sampler:
Matrix: Water
COC: 183109

Project:
Lab ID: S2012045-001
Client Sample ID: TW #7 120220 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.4	0.1		s.u.	12/04/2020 00:46 ACE	SM 4500 H B
Electrical Conductivity	548	5		µmhos/cm	12/04/2020 00:46 ACE	SM 2510B
Total Dissolved Solids (180)	320	10		mg/L	12/03/2020 14:34 MA	SM 2540
Alkalinity, Total (As CaCO3)	187	5		mg/L	12/04/2020 00:46 ACE	SM 2320B
Hardness, Calcium/Magnesium (As CaCO3)	204	1		mg/L	01/13/2021 09:05 JJ	SM 2340B
Silica as SiO2	6	1		mg/L	12/03/2020 17:22 DG	EPA 200.7
Sulfide as H2S	ND	0.01		mg/L	12/03/2020 10:21 KB	HACH 8131
Anions						
Alkalinity, Bicarbonate as HCO3	223	5		mg/L	12/04/2020 00:46 ACE	SM 2320B
Alkalinity, Carbonate as CO3	ND	5		mg/L	12/04/2020 00:46 ACE	SM 2320B
Alkalinity, Hydroxide as OH	ND	5		mg/L	12/04/2020 00:46 ACE	SM 2320B
Chloride	5	1		mg/L	12/04/2020 00:08 AB	EPA 300.0
Fluoride	0.9	0.1		mg/L	12/04/2020 00:46 ACE	SM 4500FC
Nitrogen, Nitrate-Nitrite (as N)	ND	0.1		mg/L	12/23/2020 08:09 AMB	EPA 353.2
Sulfate	83	1		mg/L	12/04/2020 00:08 AB	EPA 300.0
Cations						
Calcium	48	1		mg/L	12/03/2020 17:22 DG	EPA 200.7
Magnesium	21	1		mg/L	12/03/2020 17:22 DG	EPA 200.7
Potassium	8	1		mg/L	12/03/2020 17:22 DG	EPA 200.7
Sodium	30	1		mg/L	12/03/2020 17:22 DG	EPA 200.7
Radiochemistry						
Gross Alpha	3.5 ± 0.9	2		pCi/L	01/07/2021 10:21 AEF	SM 7110B
Gross Alpha MDC	2.00			pCi/L	01/07/2021 10:21 AEF	SM 7110B
Gross Beta	ND	5		pCi/L	01/07/2021 10:21 AEF	SM 7110B
Radium 226	1.0 ± 0.2	0.2		pCi/L	12/28/2020 14:18 WN	SM 7500 Ra-B
Total Radium 228	ND	1		pCi/L	01/06/2021 11:52 WN	Ga-Tech

These results apply only to the samples tested.

RL - Reporting Limit

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J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
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C	Calculated Value
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

Pace Analytical
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1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 1/14/2021
Report ID: S2012045002
(Replaces S2012045001)
Work Order: S2012045
Collection Date: 12/2/2020 11:30:00 AM
Date Received: 12/3/2020 8:57:00 AM
Sampler:
Matrix: Water
COC: 183109

Project:
Lab ID: S2012045-001
Client Sample ID: TW #7 120220 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
Dissolved Metals						
Antimony	ND	0.005		mg/L	12/05/2020 00:37 MS	EPA 200.8
Arsenic	0.010	0.005		mg/L	12/05/2020 00:37 MS	EPA 200.8
Barium	ND	0.1		mg/L	12/05/2020 00:37 MS	EPA 200.8
Beryllium	ND	0.001		mg/L	12/07/2020 16:50 DG	EPA 200.7
Cadmium	ND	0.001		mg/L	12/05/2020 00:37 MS	EPA 200.8
Chromium	ND	0.01		mg/L	12/07/2020 16:50 DG	EPA 200.7
Iron	0.07	0.05		mg/L	12/07/2020 16:50 DG	EPA 200.7
Manganese	0.03	0.02		mg/L	12/07/2020 16:50 DG	EPA 200.7
Mercury	ND	0.001		mg/L	12/23/2020 13:01 BEG	EPA 245.1
Nickel	ND	0.01		mg/L	12/07/2020 16:50 DG	EPA 200.7
Selenium	ND	0.005		mg/L	12/05/2020 00:37 MS	EPA 200.8
Thallium	0.001	0.001		mg/L	12/05/2020 00:37 MS	EPA 200.8

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
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G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
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E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
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S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

ATTACHMENT D – TEST WELLS TW#8 AND TW#10

MEMORANDUM

To: Ron Edwards, Jim Muscat
Big Sky County Water and Sewer District No. 363

Fr: Mark Cunnane

Re: 2021 Mountain Village Test Wells

WESTERN GROUNDWATER SERVICES
6595 Bear Claw Lane • Bozeman, MT 59715
(406) 585-5947

1. INTRODUCTION

Big Sky County Water and Sewer District No. 363 (District) completed 10 test wells for water supply evaluations at Mountain Village from 2019 to 2021. This memorandum is reporting on the final two test wells completed in 2021 and designated TW#8 and TW#10 (**Figure 1**). Reporting of prior test wells is provided in two earlier memos.[1]

1.1 Summary

- Test Wells #8 (TW#8) and #10 (TW#10) were drilled in summer 2021. Test Well #9 was not drilled due to a lack of a suitable site for drilling and also reconsideration of the aquifer target. TW#9 was targeting intrusive rocks, which have been shown to be nonproductive in several earlier test wells.

- TW#8 was drilled to 396 feet below ground penetrating the shale and the basal sandstone of the Thermopolis formation. The borehole was terminated at the contact with the underlying Kootenai formation. Air-lift discharge during drilling exceeded 250 gpm. A pumping test was subsequently completed at rates up to 300 gpm. Testing data indicate a partially bounded aquifer response with uncertain long-term yield potential. Based on the testing data, a design rate of 110 gpm and annual volume of 56 acre-feet was estimated. Water quality data indicated non-detectable arsenic, but significant iron (0.49 mg/L), and manganese (0.06 mg/L).[2]

- TW#8 could be completed for the public water system with risk of diminishing capacity during prolonged use. Blending of the water sources (with lower Fe/Mn) may be used to mitigate aesthetic impacts from dissolved iron and manganese. Treatment is not required, as both ions are not regulated. Special completion issues exist due to a shallow static water level (disinfection required) and proximity of sanitary sewer (deviation required). The well is producing groundwater from a confined aquifer, which should avoid disinfection. If DEQ would not approve a deviation for proximity to the sanitary sewer, a new well could be drilled on the same parcel with greater offset.

- Test Wells #7 and #2 both responded substantially to pumping in TW#8. Given these interference effects, there would be reduced capacity if both TW#7 and TW#8 were pumped simultaneously. If TW#8 were completed for use, it may be feasible to complete TW#7 at a future time pending review of additional water level data.

1 Memorandum, 1/21/2021, Re: 2020 Mountain Village Test Wells
Memorandum, 2/14/2019, Re: 2019 Mountain Village Test Wells

2 Secondary MCLs are 0.3 mg/L (Iron), and 0.05 mg/L (Manganese).

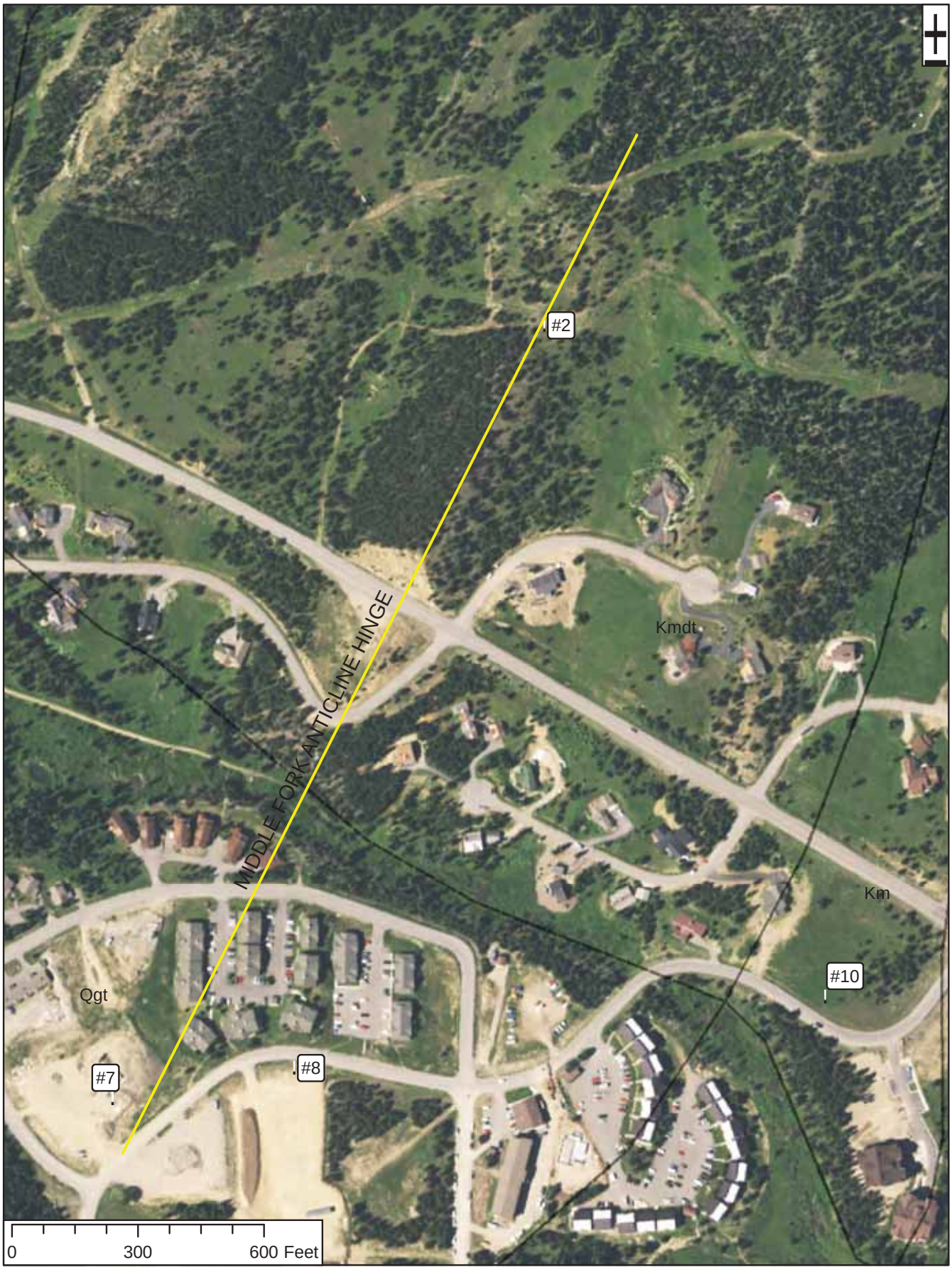


Figure 1. Well Location Map

- TW#10 was drilled to 662 feet below ground into the top of the Thermopolis formation. The well was targeting intrusive rock and penetrated 220 ft of gabbro sill. The intrusive rock was nonproductive. Total air-lift discharge from the well was about 40 gpm. No further drilling or testing at this location is recommended.

2. CONTRACTOR SERVICES

Drilling work was completed by Bridger Drilling, Inc. under the contract for the 2020 Mountain Village Test Wells project. A final history of hole and budget detail for the entire test well project is provided in **Attachment A** (Test Wells #3 - #11). TW#8, including drilling and pump testing, resulted in total contractor fees of $32,716. TW#10 resulted in fees of $19,212.

3. WELL CONSTRUCTION

3.1 Test Well #8

TW#8 was drilled on a parcel owned by Big Sky Resort LLC that is presently used for ski area parking. The well was located along the north side of the parcel adjacent to Sitting Bull Road in order to minimize impact to the property use.

TW#8 was initially drilled to 136 ft below ground surface (bgs) at 10-inch diameter (**Figure 2**). A 6-inch steel casing was set into the borehole and cemented in place. Drilling below the casing was completed as open hole at 6-inch diameter to the total depth of 396 ft bgs. Although the well location and construction were not submitted for approval to Montana DEQ, this well construction is suitable for a public water supply well. The location would require a deviation due to proximity of the sanitary sewer. If a deviation was not granted, a replacement well could be drilled to the south.

During drilling, borehole samples were collected at 10-ft intervals. A field log with borehole sample descriptions is provided in **Attachment B**. Photos of the samples at 20-ft intervals are also included in the attachment.

TW#8 was drilled into the east limb of the Middle Fork Anticline (**Figure 1**). Unconsolidated till was encountered from surface to about 85-ft bgs. Below this depth, the borehole penetrated the Thermopolis formation. Drilling was terminated at 396 ft bgs at the contact with the underlying Kootenai formation.

Weathered shale occurred from 85-ft bgs to about 110-ft bgs, and then dark gray shale occurred to about 315 ft bgs. Very hard, silica cemented sandstone continued to about 390 ft bgs (Thermopolis basal sandstone). Disseminated pyrite occurred within both the shale and sandstone beds. At about 390 ft bgs the borehole entered moderately soft varicolored shale formation resulting in reddish discharge, and identified as the top of the Kootenai formation.

Drilling was terminated at the top of the Kootenai to reduce interference potential with TW#7, which had been drilled through the Kootenai. TW#8 was also producing an impressive air-lift discharge in excess of 250-gpm, indicating it could be a viable water supply well at the current depth.

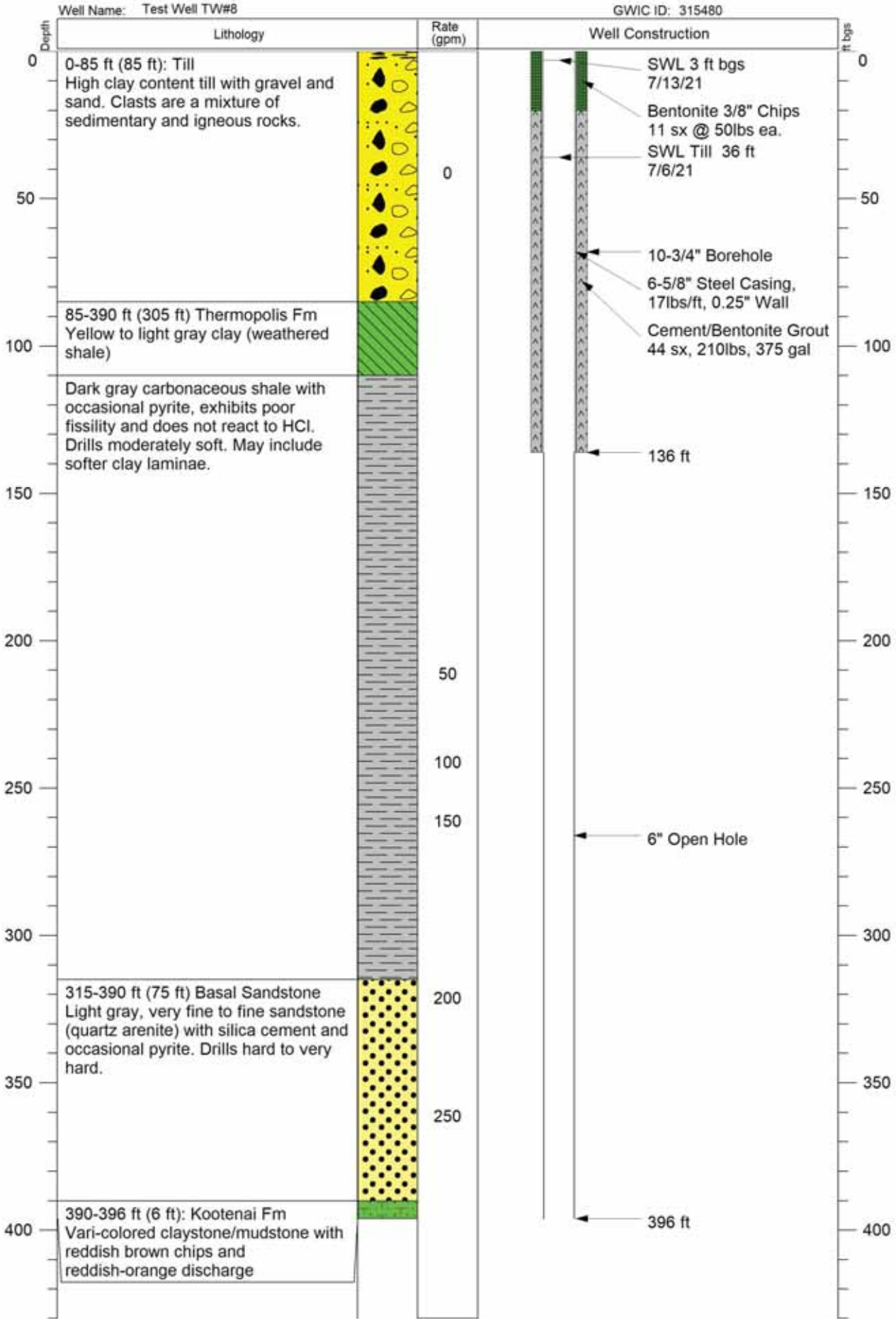


Figure 2. Test Well #8 As-Built Log

The first significant water developed from the borehole occurred at about 215 ft bgs. Up to about 200-gpm was air-lifted from the shale overlying the basal sandstone. Additional capacity of possibly 50- to 75-gpm was developed through the sandstone. It is likely that most water production is occurring from fractured shale and to a lesser degree fractured sandstone.

The Middle Fork anticline was also explored by test wells TW#2 and TW#7. Existing wells Mountain Village #5 (Mtn#5) and Mountain Village #6 (Mtn#6) also penetrate this same structure. Mtn#6 penetrates the west limb and produces from fractured shale in the Thermopolis formation, whereas Mtn#5 penetrates the east limb and is estimated to produce from the Thermopolis basal sandstone. TW#2 and TW#7 both appear to penetrate on or near to the hinge line and fully penetrate the Kootenai formation. The anticline structure trends NE and has a flat hinge line (approximately 0° plunge). These wells encounter permeable formation resulting in relatively high short-term capacity, but also exhibit flow limiting boundary conditions, which ultimately curtails the rates for long-term use.

3.2 Test Well #10

TW#10 was also drilled on a parcel owned by Big Sky Resort LLC. TW#10 was targeting intrusive rock in similar geology as existing wells Mountain Village #4 (Mtn#4) and Mountain Village #7 (Mtn#7).

TW#10 was drilled at 6-inch diameter with 6-inch casing to a depth of 96-ft bgs (**Figure 3**). A continuous feed bentonite seal was formed during drilling of the cased borehole to a depth of 20-ft bgs. Below 96-ft bgs, the borehole was an open-hole completion to the total depth of 662-ft bgs.

The borehole penetrated moderately steeply dipping rocks on the west limb of the syncline fold between the Middle Fork and Andesite Mountain anticlines. Where drilled, it was projected based on neighboring outcrops, the dip was about 56° southeast (strike 22°NE). This dip results in increased drilling thickness of about 1.8 times the true thickness. The drilled bedrock thickness of 607-ft penetrated about 340-ft of formation.

A field log for the borehole and sample photos are provided in **Attachment C**. The borehole geology consisted of till to 55-ft bgs, which overlayed the Mowry formation. The Mowry consisted of soft, gray to green claystone, with bentonite laminae, and occasional sandstone and siltstone interbeds. At 265-ft bgs, the Muddy Sandstone formation was encountered and continued to a depth of 345-ft bgs where the borehole penetrated gabbro sill. This occurrence of the gabbro sill, splitting the Muddy Sandstone, was also observed in Test Wells #1, #5, #6, and #11. The gabbro sill was drilled to 565-ft bgs, where the borehole re-entered the lower part of the Muddy Sandstone. At 595-ft bgs, the borehole entered the Thermopolis formation, consisting of uniform dark-gray, carbonaceous shale. Drilling was terminated at 662-ft bgs.

Air-lift discharge from the bottom of the borehole was about 40-gpm. Most of the discharge was derived from the upper and lower parts of the Muddy Sandstone on either side of the gabbro sill. There was no significant increase in water production realized through the gabbro sill section of the borehole. No additional testing or drilling is recommended for this location.

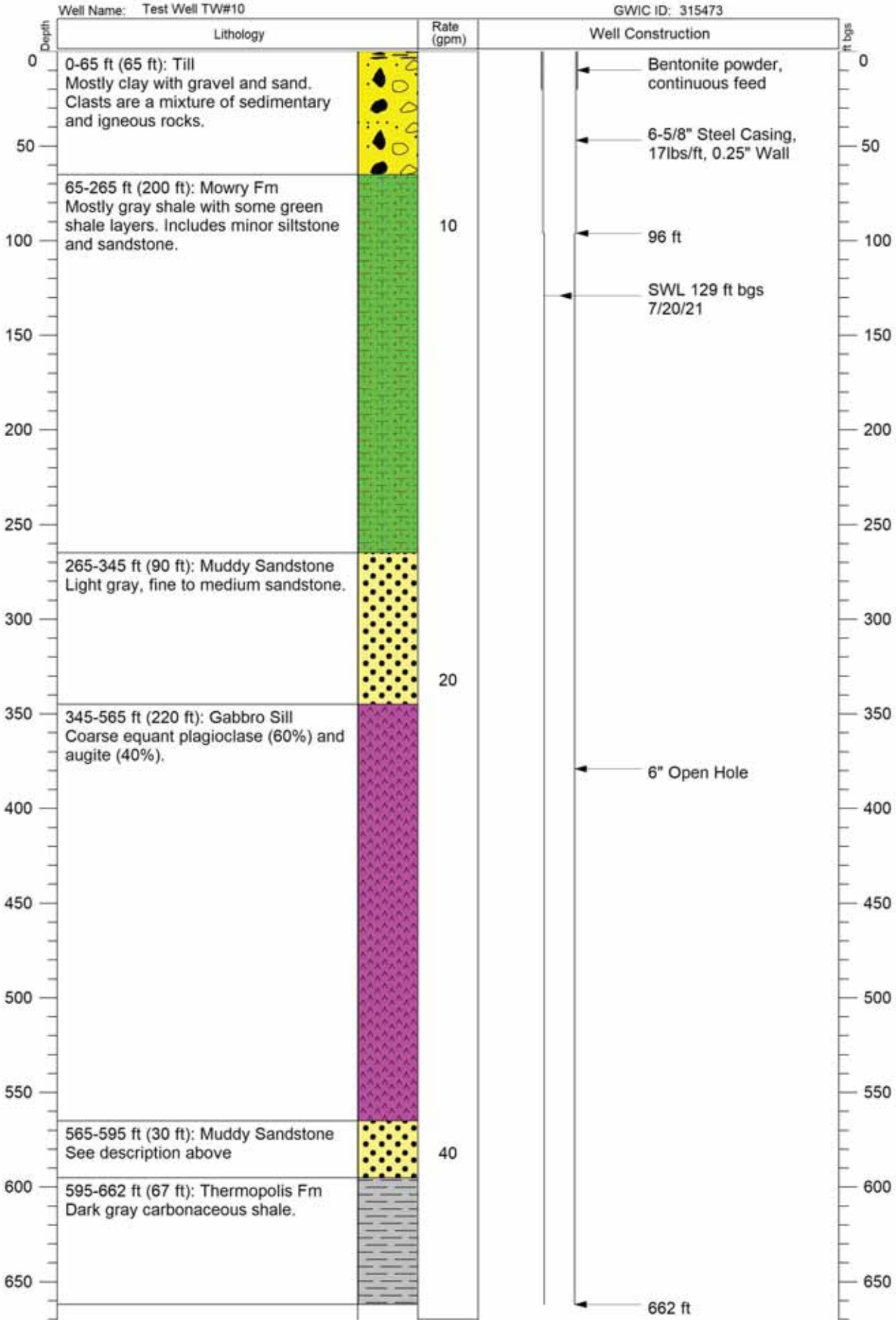


Figure 3. Test Well #10 As-Built Log

4. PUMPING TEST

TW#8 was pump tested to evaluate yield potential and to evaluate water quality. The testing schedule conformed to the Montana DNRC aquifer testing rules (**Table 1**).

Discharge rate was measured using a Siemens FUP1010 ultrasonic flow meter with computer logging. Rate and pumped volume measurements were recorded at 1-minute intervals. Water level data were collected also at 1-minute intervals in TW#8, TW#7, and TW#2 using In-Situ, Inc. LevelTROLL 500 pressure transducers rated to 100 psig. These sensors are owned by the District and are being used for long-term monitoring at one reading every 15-minutes.

Table 1. Pumping Test Schedule

Test Type	Start	End	Duration (hrs)
SR-pumping	9/22/21 10:14 AM	9/22/21 2:14 PM	4.00
Pre-Test	9/22/21 6:14 PM	9/27/21 11:30 AM	113.27
CR-pumping	9/27/21 11:30 AM	9/30/21 11:31 AM	72.02
CR-recovery	9/30/21 11:31 AM	10/3/21 11:30 AM	71.98
SR – step rate; CR – constant rate; Pre-Test – static monitoring period before CR.			

4.1 Step Rate Pumping Test

The step rate pumping test is used to evaluate a suitable rate for the constant rate pumping test, and also to determine a turbulent head loss coefficient for the well. Four one-hour steps were run ranging from 65- to 299-gpm (**Figure 4**). Test data were analyzed by the Hantush- Bierschenk method (**Figure 5**, **Figure 6**), determining a low turbulent head loss coefficient of 8e-5 ft/gpm^2. A rate of 200- to 225-gpm was estimated for the constant rate test.

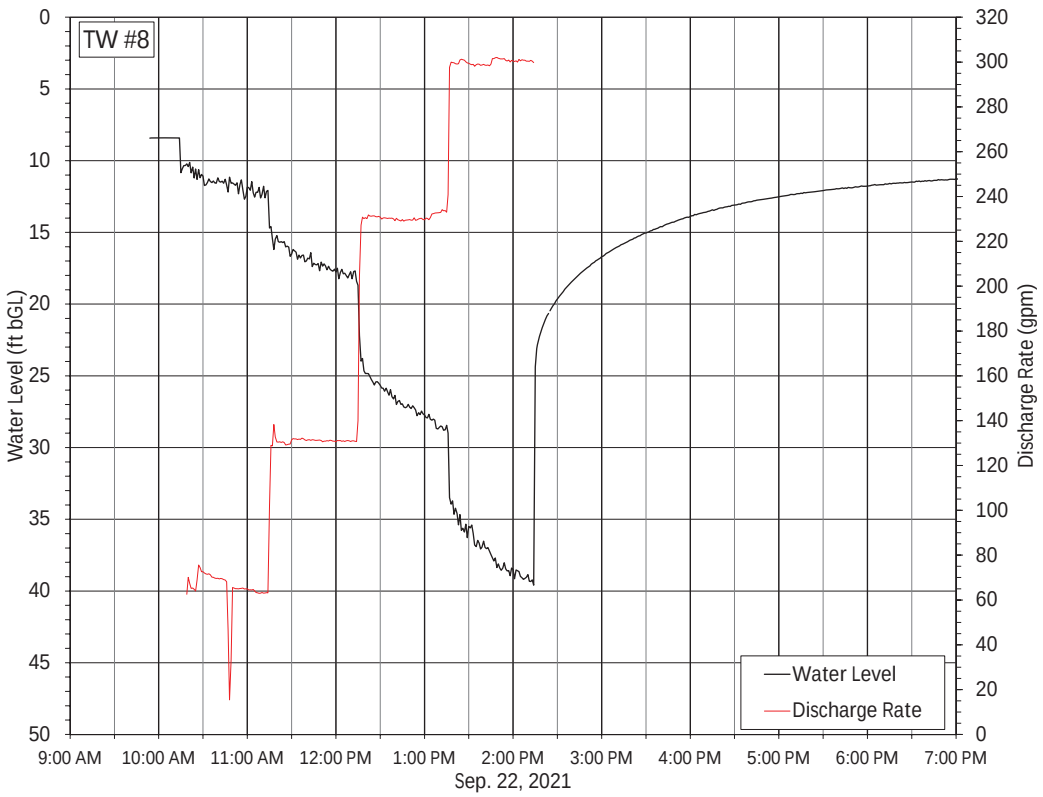


Figure 4. Step Rate Test Hydrograph

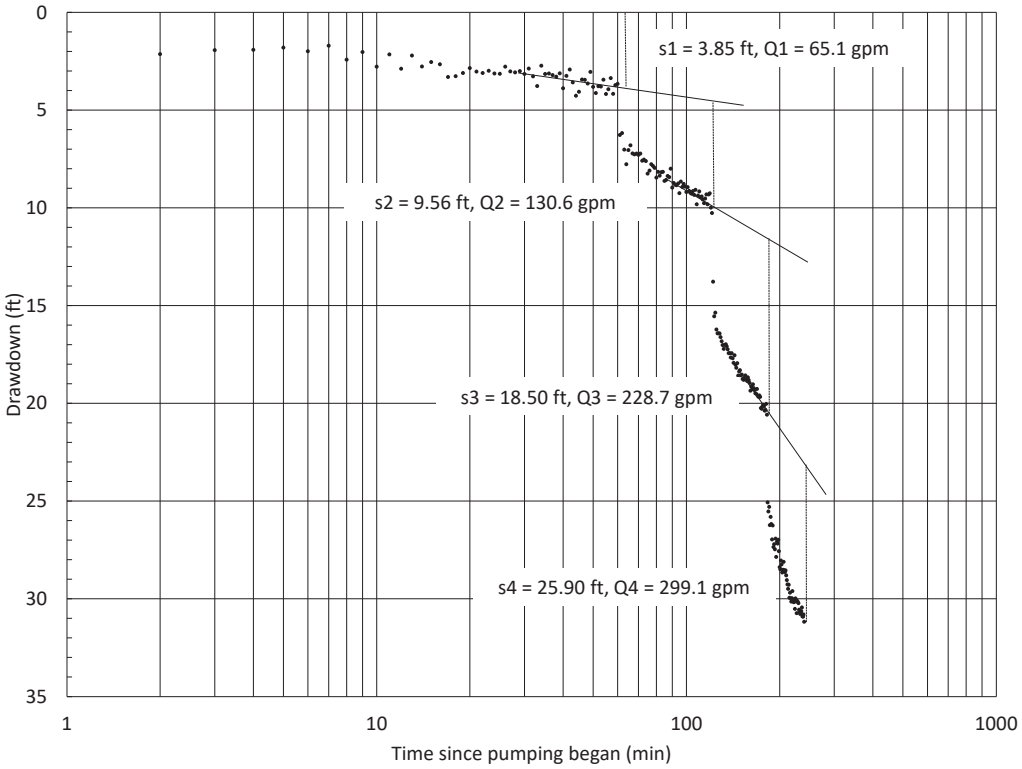


Figure 5. Step Rate Test Analysis Plot

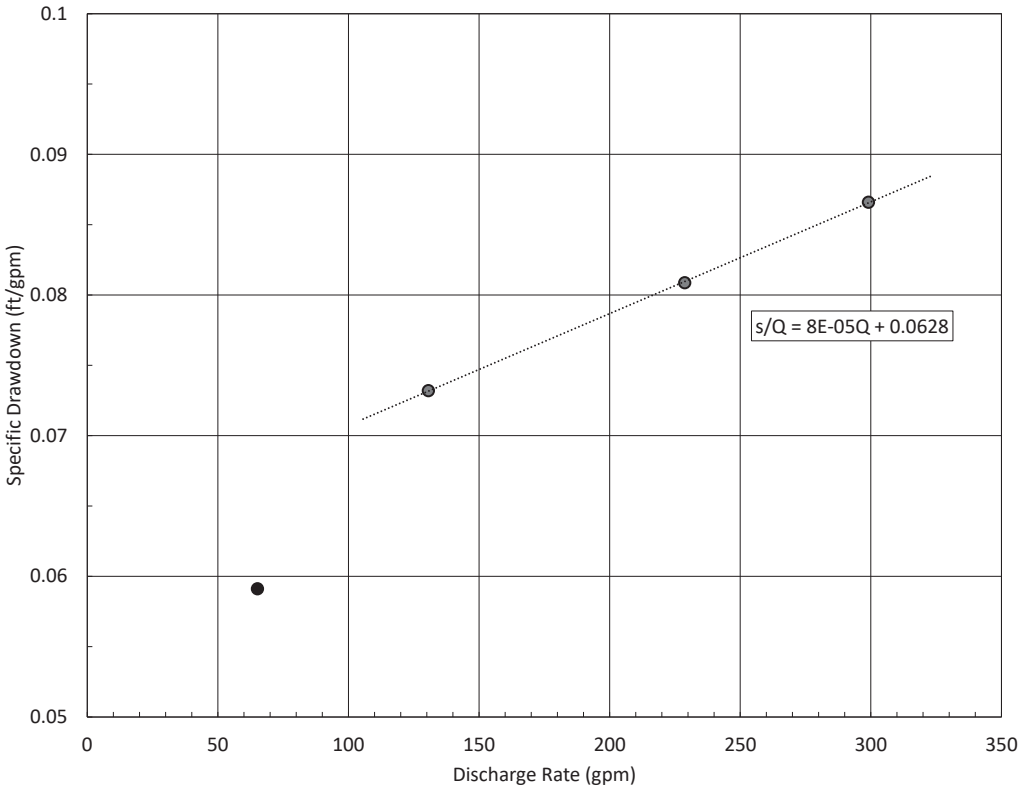


Figure 6. Step Rate Test Regression Plot

4.2 Constant Rate Pumping Test

Static water level in TW#8 immediately prior to starting the constant rate test was 8.7-ft bgs. Circular DEQ-1 requires disinfection for wells with static water levels less than 25-ft below ground. A provision exists for confined aquifers to avoid disinfection treatment. TW#8 should qualify as a well producing groundwater from a confined aquifer.

The 72-hour pumping phase was run at 220-gpm. Maximum drawdown in the well at the end of pumping was 47-ft, resulting in a 72-hour specific capacity of 4.7 gpm/ft (**Figure 7**). After 72-hours of recovery, residual drawdown in the well was 12.5-ft (21.2 ft bgs), which is a large value indicating poor recharge to the well.

Both TW#7 and TW#2 responded to pumping (**Figure 8**). TW#7 is located 440-ft west of TW#8 (bearing 261°). Maximum drawdown in TW#7 was 27-ft. TW#2 is located 1,865 ft north of TW#8 (bearing 19°). Maximum drawdown in TW#2 was 25-ft. After 72-hours of recovery, residual drawdowns were 12.7-ft and 13.1-ft in TW#7 and TW#2, respectively. These large residual drawdowns are also indicating poor recharge overall to the aquifer.

Hydraulic analysis of testing data was completed to evaluate the aquifer response to pumping (**Figure 9**). [3] The log-log plot (**A**) shows the slope of the drawdown (derivative) continuing to increase during pumping. This condition indicates at least two flow-limiting boundaries are present. Aquifer boundaries are also indicated in the semi-log plot (**B**) by the deviation of the drawdown data from the straight line. A hydraulic model was fit to the TW#8 data with parallel boundaries offset to either side of the pumping well 1,000 ft (**C**). The boundaries were oriented parallel to the Middle Fork anticline hinge line. The model fit is visually reasonable and matches the late time data for both drawdown and derivative. With minor adjustment, the same model was reasonably fit to the monitoring well data sets, TW#7 and TW#2 (**D**).

Design capacity for TW#8 was estimated using the hydraulic model fit to the TW#8 data. The design rate for the well was based on achieving a maximum drawdown of 133-ft in 180-days of continuous pumping. This rate was determined to be 110-gpm. The annual volume was estimated based on achieving the maximum drawdown in 5-years of continuous pumping. The annual volume was estimated at 56-acre-ft per year, which equates to a continuous pumping rate of 35-gpm.

3 Hydraulic analysis and modeling was completed using AQTESOLV, HydroSOLVE, Inc.

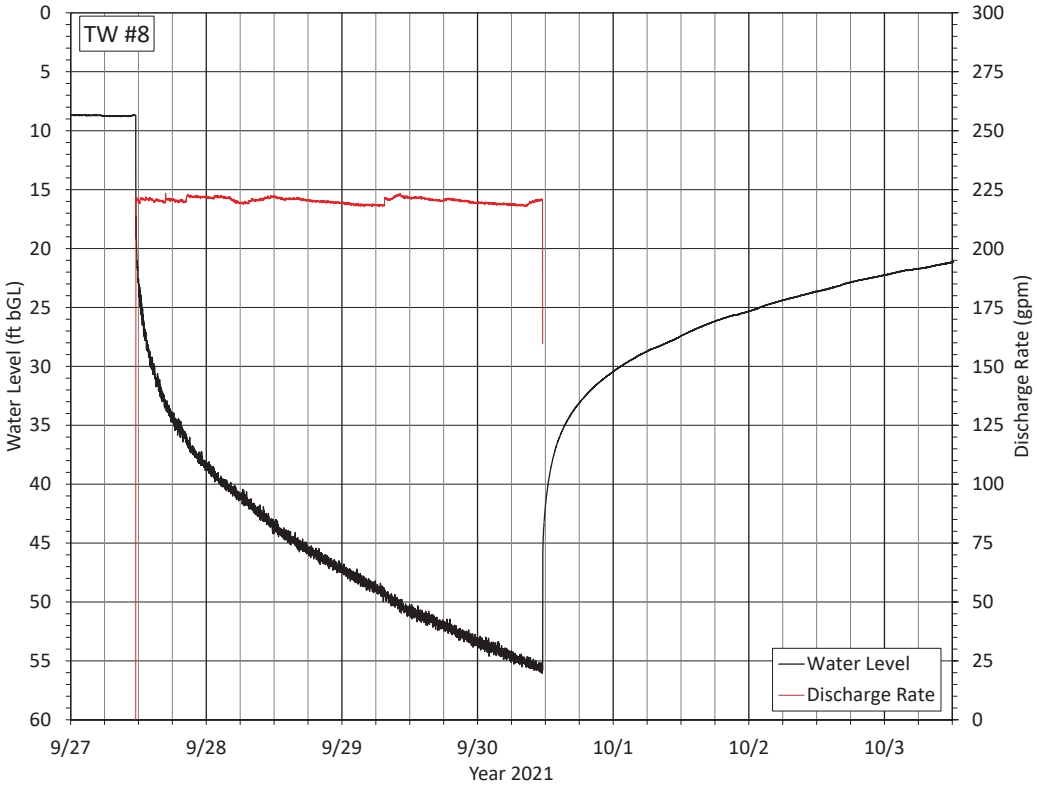


Figure 7. Constant Rate Test Pumping Well Hydrograph

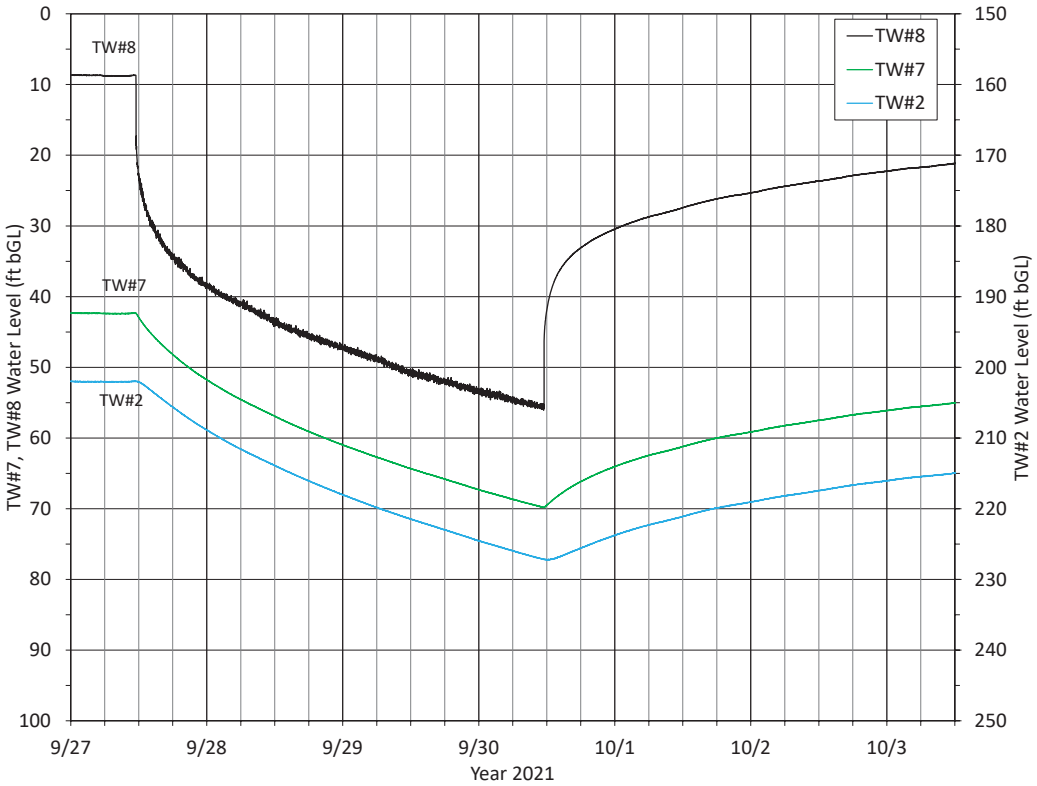
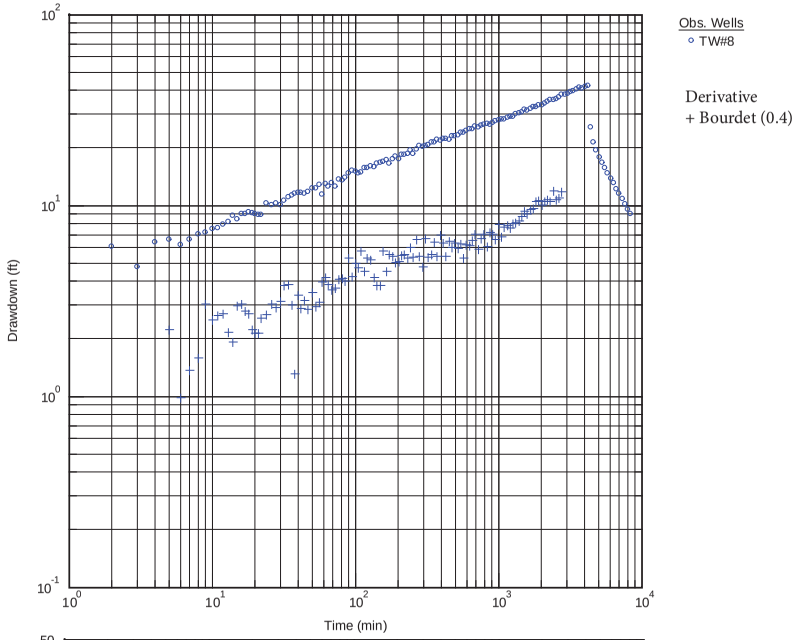
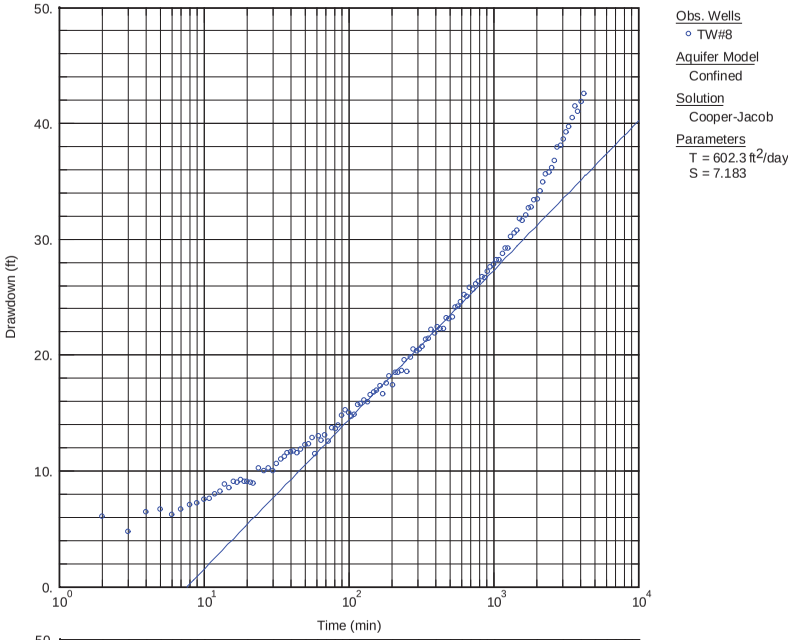


Figure 8. Constant Rate Test Water Level Hydrographs

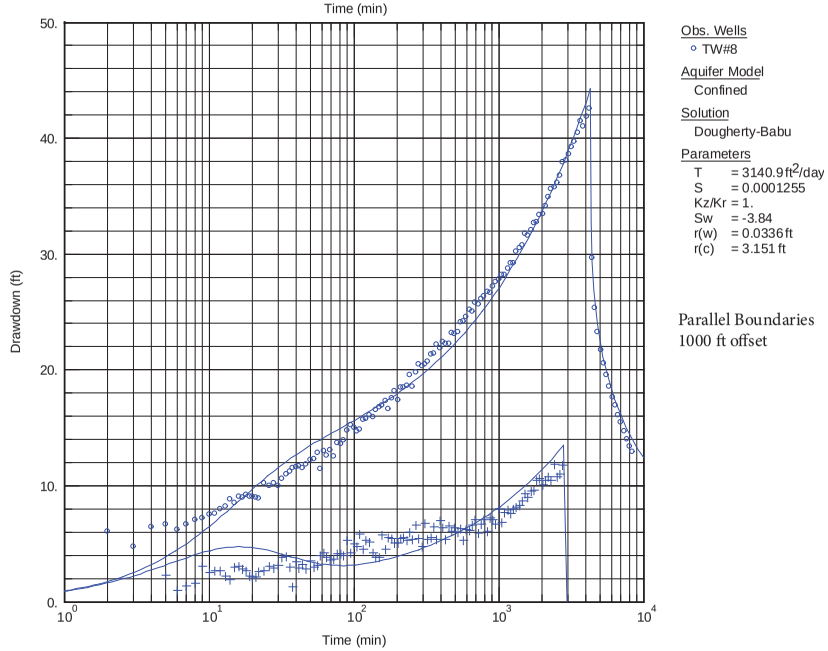
A.



B.



C.



D.

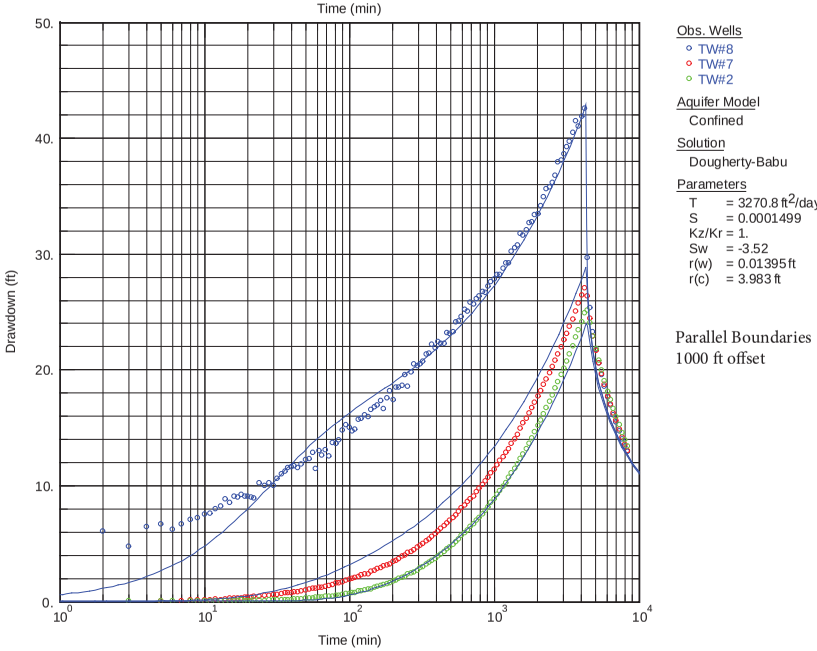


Figure 9. Constant Rate Test Analysis and Modeling Plots

5. WATER QUALITY

Water sampling was completed on September 30, 2021 after 71-hours of continuous pumping from TW#8. Field and laboratory parameters were analyzed. Water quality data were not collected from TW#10.

5.1 Field Parameters

Field parameters were measured using a calibrated Horiba U52 multi-sensor set into a flow cell connected to the discharge pipeline at the wellhead (**Table 2**). These data indicate a weakly acidic groundwater with relatively low dissolved mineral content, and which is devoid of dissolved oxygen. High turbidity measured in the discharge is attributed to gas bubbles liberating from the groundwater. The gas is determined to be carbon dioxide (see below). Water clarity was otherwise excellent, and the water was odorless.

Table 2. Field Water Quality Parameters (TW#8)

T (°F)	pH	Eh (V)	SC (µS/cm)	Turb (NTU)	DO (mg/L)
48.81	6.88	0.178	383	192	0.00
T – temperature; Eh – oxidation reduction potential relative to hydrogen; SC – specific conductance; Turb – turbidity; DO – dissolved oxygen					

5.2 Lab Parameters

Sample bottles were filled from a smooth-nose chrome tap installed into the discharge pipeline at the wellhead. The sample for metals was field filtered at 0.45 µm using a filter fitting in place of the chrome tap. Samples were shipped next-day air on the same day as collection to Pace Analytical, Sheridan, WY. Analysis parameters included general water quality, major ions, selected trace metals, radionuclides, and regulated metals. The laboratory report is provided in **Attachment B**.

The degassed sample was measured to have a substantially alkaline pH of 8.1, a common occurrence for groundwaters with substantial dissolved carbon dioxide. The water is classified has Hard, although the water also contains significant sodium. Sulfide and arsenic were non-detect. Iron was detected at 0.49 mg/L and manganese was detected at 0.06 mg/L. These levels exceed the secondary standard, indicating groundwater from TW#8 could have aesthetic impacts to users, typically consisting of staining of toilets and sinks. If the District can blend the water with a source of lower iron and manganese concentrations (and devoid of oxygen), the aesthetic impact may be mitigated. The standards below which aesthetic impacts are generally not realized are 0.3 mg/L for iron and 0.05 mg/L for manganese. Radionuclides were absent or detected at low levels.

5.3 Geochemistry Equilibrium Modeling

Water quality data were used as input to the U.S. Geological Survey program PHREEQC for equilibrium modeling of minerals and dissolved species. Model output is provided in **Attachment B**. This analysis indicates a pore water predominantly in equilibrium with quartz and possibly calcite. Dissolved carbon dioxide (CO_2) was estimated at 0.03 atm, or 100 times the atmospheric level (0.03 atm v. 0.0003 atm). Elevated CO_2 concentrations in groundwater are common, as CO_2 is dissolved into recharge water when it passes through the root zone.

Iron and manganese occurring in the +2 oxidation state were partially complexed, mostly with bicarbonate ion (FeHCO3+, MnHCO3+). About 25% of the dissolved ion was in the complexed form. Complexation effectively reduces the concentration of the dissolved ion in the water, which is favorable for water quality aesthetics. Equilibrium with atmospheric oxygen was also simulated, as this process occurs in storage tanks and household fixtures. In the presence of atmospheric oxygen iron converts to the +3 oxidation state and manganese converts to the +4 oxidation state. Both of these species will form solid precipitates. Iron precipitates more quickly and the solid phase can then enhance precipitation of manganese.

Treatment for iron and manganese can use a sequestering chemical that prevents precipitation for a period of time with the intention of preventing precipitation in the distribution system. Removal of the dissolved ions is normally carried out with deliberate oxidation to a solid phase and then removal by filtration. Mixing with water that does not contain iron and manganese, and which is devoid of oxygen could also be a treatment alternative. Mixing with oxygenated groundwater, however, such at Mountain Village Well No. 3 would tend to oxidize both iron and manganese and result in precipitation.

ATTACHMENT A
HISTORY OF HOLE AND BUDGET DETAIL

HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

OWNER:	Big Sky County Water & Sewer District #363		
	Big Sky, MT		
	Jim Muscat (406) 581-6138		
	Ron Edwards (406) 995-2660		
HYDROGEOLOGIST:	Western Groundwater Services, LLC		
	Bozeman, MT (406) 585-5947		
	Mark Cunnane (406) 579-1493		
CONTRACTOR:	Bridger Drilling, Inc.		Potts Drilling Inc. (TW#7 Pumping Test, Nov-Dec, 2020)
	Bozeman, MT (406) 388-7227		
	Tyler Sampson (406) 581-1205		
	Curt Sampson (406) 581-4292		
NOTICE TO PROCEED:	**9/15/2020**		**Bold = payable quantity**
CONTRACT TIME:	**365**		
TOTAL FEES TO-DATE:	**$ 182,509.50**		

DATE	DAY	TIME	ACTIVITY
09/15/20	Tue	1	TEST WELL #3 (ALLUVIAL WELL) **B-3.1 Mobilization 1 EA; B-3.2 Drilling 6" With Casing 80 LF**
09/16/20	Wed	2	**C1 Well Abandonment 80 LF** (TW#3)**;** TEST WELL #4 (ALLUVIAL WELL) **B-3.1 Mobilization 1 EA; B-3.2 Drilling 6" With Casing 55 LF**
09/17/20	Thu	3	No site work completed (Contractor attending MT Water Well Contractor's Board Meeting -- as Board Member)
09/18/20	Fri	4	**B-3.2 Drilling 6" With Casing 22 LF** (Total Casing 77 LF)
09/19/20	Sat	5	No site work completed
09/20/20	Sun	6	No site work completed
09/21/20	Mon	7	TEST WELL #5 (INTRUSIVE near tank) **B-1.1 Mobilization 1 EA; B-1.2 6" Drilling with Casing 100 LF**
09/22/20	Tue	8	**B-1.2 6" Drilling with Casing 80 LF; B-1.3 6" Drilling Open Hole 217 LF** (Total Depth 397 ft bgs)
09/23/20	Wed	9	**B-1.3 6" Drilling Open Hole 341 LF** (Total Depth 738 ft bgs)
09/24/20	Thu	10	TEST WELL #6 **B-1.1 Mobilization 1 EA**
09/25/20	Fri	11	**B-1.2 6" Drilling with Casing 60 LF** (Total Depth 60 ft bgs)
09/26/20	Sat	12	No site work completed
09/27/20	Sun	13	No site work completed
09/28/20	Mon	14	**B-1.2 6" Drilling with Casing 140 LF** (Total Depth 196 ft bgs)
09/29/20	Tue	15	**B-1.3 6" Drilling Open Hole 320 LF** (Total Depth 516 ft bgs)
09/30/20	Wed	16	**B-1.3 6" Drilling Open Hole 180 LF** (Total Depth 696 ft bgs)
10/01/20	Thu	17	**B-1.3 6" Drilling Open Hole 240 LF** (Total Depth 936 ft bgs)
10/02/20	Fri	18	**B-1.3 6" Drilling Open Hole 104 LF** (Total Depth 1040 ft bgs); **B-1.4 Development 1 HRS**
10/03/20	Sat	19	No site work completed
10/04/20	Sun	20	No site work completed
10/05/20	Mon	21	TEST WELL #11 (Sedimentary/Instrusive near YC Booster) **B-1.1 Mobilization 1 EA**
10/06/20	Tue	22	**B-1.2 6" Drilling with Casing 140 LF** (Total Depth 136 ft bgs)
10/07/20	Wed	23	**B-1.2 6" Drilling with Casing 60 LF; B-1.3 6" Drilling Open Hole 120 LF** (Total Depth 320 ft bgs)
10/08/20	Thu	24	**B-1.3 6" Drilling Open Hole 280 LF** (Total Depth 600 ft bgs)
10/09/20	Fri	25	**B-1.3 6" Drilling Open Hole 240 LF** (Total Depth 840 ft bgs)
10/10/20	Sat	26	No site work completed
10/11/20	Sun	27	No site work completed
10/12/20	Mon	28	TEST WELL #7 (Kootenai, West Ski Parking Lot) **B-2.1 Mobilization 1 EA**
10/13/20	Tue	29	Mobilization
10/14/20	Wed	30	Mobilization, **B-2.2 10" Drilling with Casing 20 LF**
10/15/20	Thu	31	**B-2.2 10" Driling with Casing 80 LF**
10/16/20	Fri	32	**B-2.2 10" Driling with Casing 22 LF** (Total Depth 121.5 ft)
10/17/20	Sat	33	No site work completed

HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

OWNER:	Big Sky County Water & Sewer District #363		
	Big Sky, MT		
	Jim Muscat (406) 581-6138		
	Ron Edwards (406) 995-2660		
HYDROGEOLOGIST:	Western Groundwater Services, LLC		
	Bozeman, MT (406) 585-5947		
	Mark Cunnane (406) 579-1493		
CONTRACTOR:	Bridger Drilling, Inc.		Potts Drilling Inc. (TW#7 Pumping Test, Nov-Dec, 2020)
	Bozeman, MT (406) 388-7227		
	Tyler Sampson (406) 581-1205		
	Curt Sampson (406) 581-4292		
NOTICE TO PROCEED:	**9/15/2020**		**Bold = payable quantity**
CONTRACT TIME:	**365**		
TOTAL FEES TO-DATE:	**$ 182,509.50**		

DATE	DAY	TIME	ACTIVITY
10/18/20	Sun	34	No site work completed
10/19/20	Mon	35	Set 6-inch casing; Emplaced plug at base of casing.
10/20/20	Tue	36	10-inch temporary casing would not pull for grouting; pulled 6-inch casing; flushed grout out of hole
10/21/20	Wed	37	No site work completed; ordered tool adapter to cut 10-inch casing shoe
10/22/20	Thu	38	No site work completed
10/23/20	Fri	39	No site work completed
10/24/20	Sat	40	No site work completed
10/25/20	Sun	41	No site work completed
10/26/20	Mon	42	No site work completed
10/27/20	Tue	43	No site work completed
10/28/20	Wed	44	No site work completed
10/29/20	Thu	45	**C3-2 Downhole Casing Cutting 1 EA**; Set 6" casing in hole
10/30/20	Fri	46	**B-2.3 Set and Cement 6" Casing 122 LF**
10/31/20	Sat	47	No site work completed
11/01/20	Sun	48	No site work completed
11/02/20	Mon	49	**C3-1 Wellhead Valve 1 EA; B-2.4 6" Drilling Open Hole 134 LF**
11/03/20	Tue	50	**B-2.4 6" Drilling Open Hole 129 LF** (TOH FOR BIT CHANGE),(Total Depth 385 ft)
11/04/20	Wed	51	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 576 ft)
11/05/20	Thu	52	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 716 ft)
11/06/20	Fri	53	**B-2.4 6" Drilling Open Hole 129 LF** (Total depth 730 ft); **B-2.5 Development 3 HRS** (END DRILLING FOR 2020)
7/6/2021	Tue	295	TEST WELL #8 (Kootenai, East Ski Parking Lot) **B-2.1 Mobilization 1 EA; B-2.2 10" Drilling with Casing 140 LF** (Total Depth 136 ft)
7/7/2021	Wed	296	Setting 6" Casing
7/8/2021	Thu	297	Setting 6" Casing
7/9/2021	Fri	298	**B-2.3 Set and Cement 6" Casing 140 LF; C3-1 Wellhead Valve 0.2 EA**
7/10/2021	Sat	299	Waiting on cement
7/11/2021	Sun	300	Waiting on cement
7/12/2021	Mon	301	**B-2.4 6" Drilling Open Hole 200 LF; B-2.5 Development 0.5 HRS**
7/13/2021	Tue	302	**B-2.4 6" Drilling Open Hole 56 LF**
7/14/2021	Wed	303	TEST WELL #10 (Intrusive, Sitting Bull Rd) **B-1.1 Mobilization 1 EA; B-1.2 6" Drilling with Casing 100 LF**
7/15/2021	Thu	304	**B-1.3 6" Drilling Open Hole 300 LF**
7/16/2021	Fri	305	**B-1.3 6" Drilling Open Hole 262 LF** (Total Depth 662 ft) END DRILLING FOR 2021
7/17/2021	Sat	306	No site work completed
7/18/2021	Sun	307	No site work completed
7/19/2021	Mon	308	Postponed drilling TW#11 - resort construction at drill site

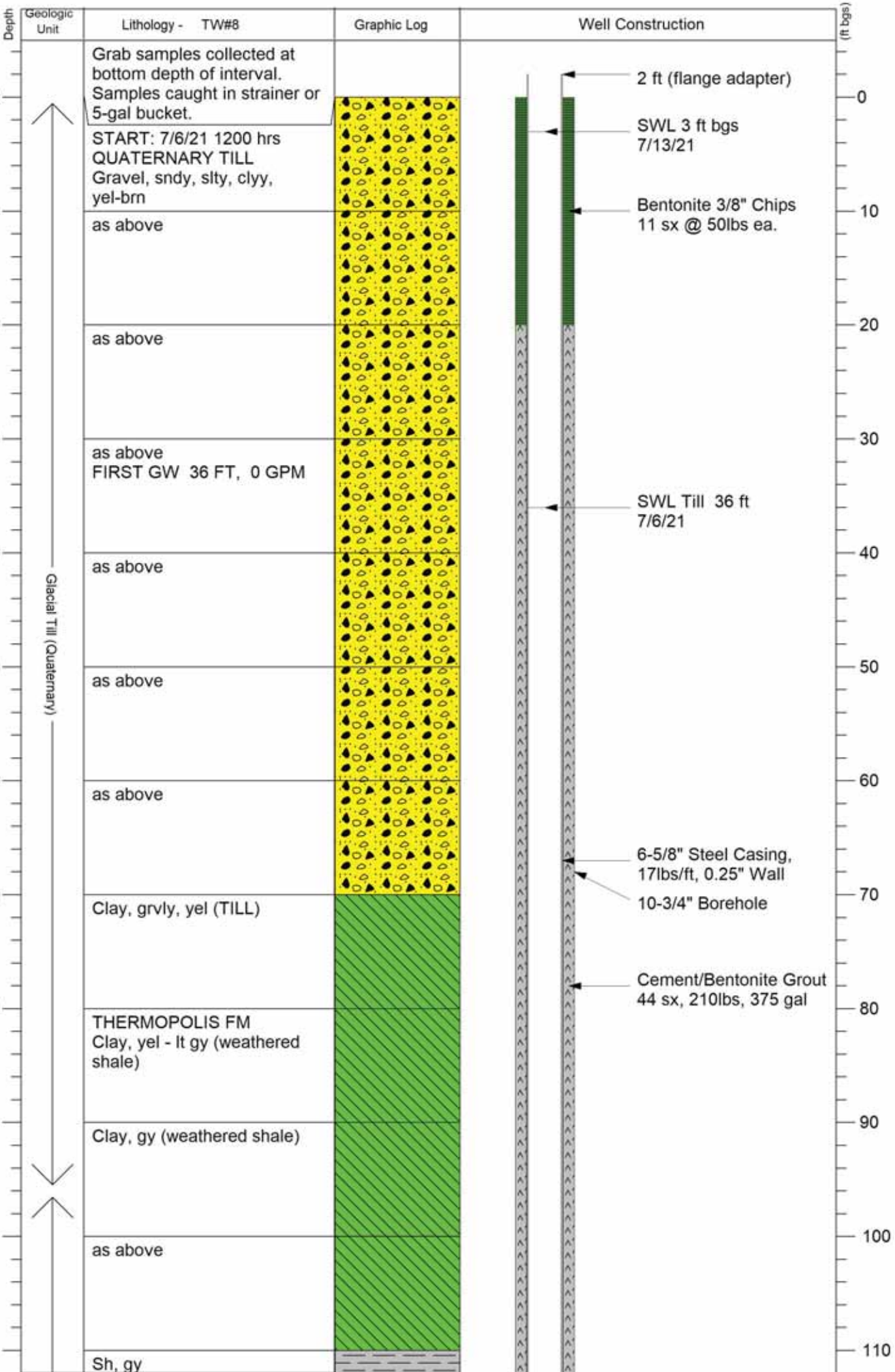
HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

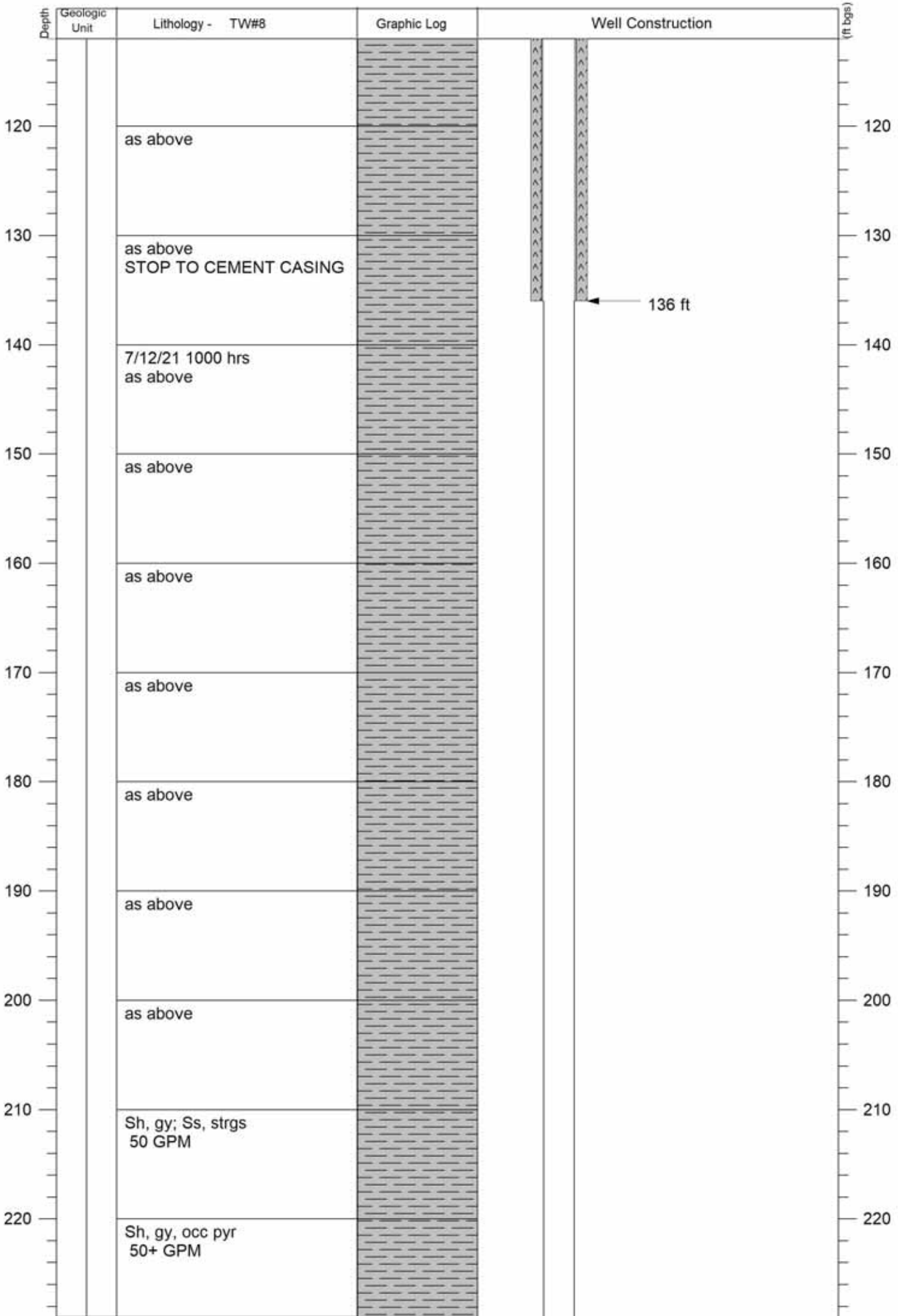
OWNER:	Big Sky County Water & Sewer District #363		
	Big Sky, MT		
	Jim Muscat (406) 581-6138		
	Ron Edwards (406) 995-2660		
HYDROGEOLOGIST:	Western Groundwater Services, LLC		
	Bozeman, MT (406) 585-5947		
	Mark Cunnane (406) 579-1493		
CONTRACTOR:	Bridger Drilling, Inc.		Potts Drilling Inc. (TW#7 Pumping Test, Nov-Dec, 2020)
	Bozeman, MT (406) 388-7227		
	Tyler Sampson (406) 581-1205		
	Curt Sampson (406) 581-4292		
NOTICE TO PROCEED:	**9/15/2020**		**Bold = payable quantity**
CONTRACT TIME:	**365**		
TOTAL FEES TO-DATE:	**$ 182,509.50**		
DATE	DAY	TIME	ACTIVITY
9/20/2021	Mon	371	TW#8 Pumping Test Install temporary pumping system
9/21/2021	Tue	372	Install temporary pumping system; **C4-2 Pumping Test Hourly 4 HRS** (Step rate pumping test)
9/22/2021	Wed	373	No site work completed - well recovery period
9/23/2021	Thu	374	No site work completed - well recovery period
9/24/2021	Fri	375	No site work completed - well recovery period
9/25/2021	Sat	376	No site work completed - well recovery period
9/26/2021	Sun	377	No site work completed - well recovery period
9/27/2021	Mon	378	Constant rate pumping test
9/28/2021	Tue	379	Constant rate pumping test
9/29/2021	Wed	380	Constant rate pumping test
9/30/2021	Thu	381	Constant rate pumping test; **C4-2 Pumping Test Hourly 72 HRS** (Total 76-hours); **C4-1 Temporary Pumping System 1 EA**
10/1/2021	Fri	382	No site work completed - well recovery period
10/2/2021	Sat	383	No site work completed - well recovery period
10/3/2021	Sun	384	No site work completed - well recovery period
10/4/2021	Mon	385	No site work completed - well recovery period
10/5/2021	Tue	386	No site work completed - well recovery period
10/6/2021	Wed	387	Remove temporary pumping system; Install **Sounding Tube and Well Seal** for long-term water level data collection
			END HISTORY REPORT

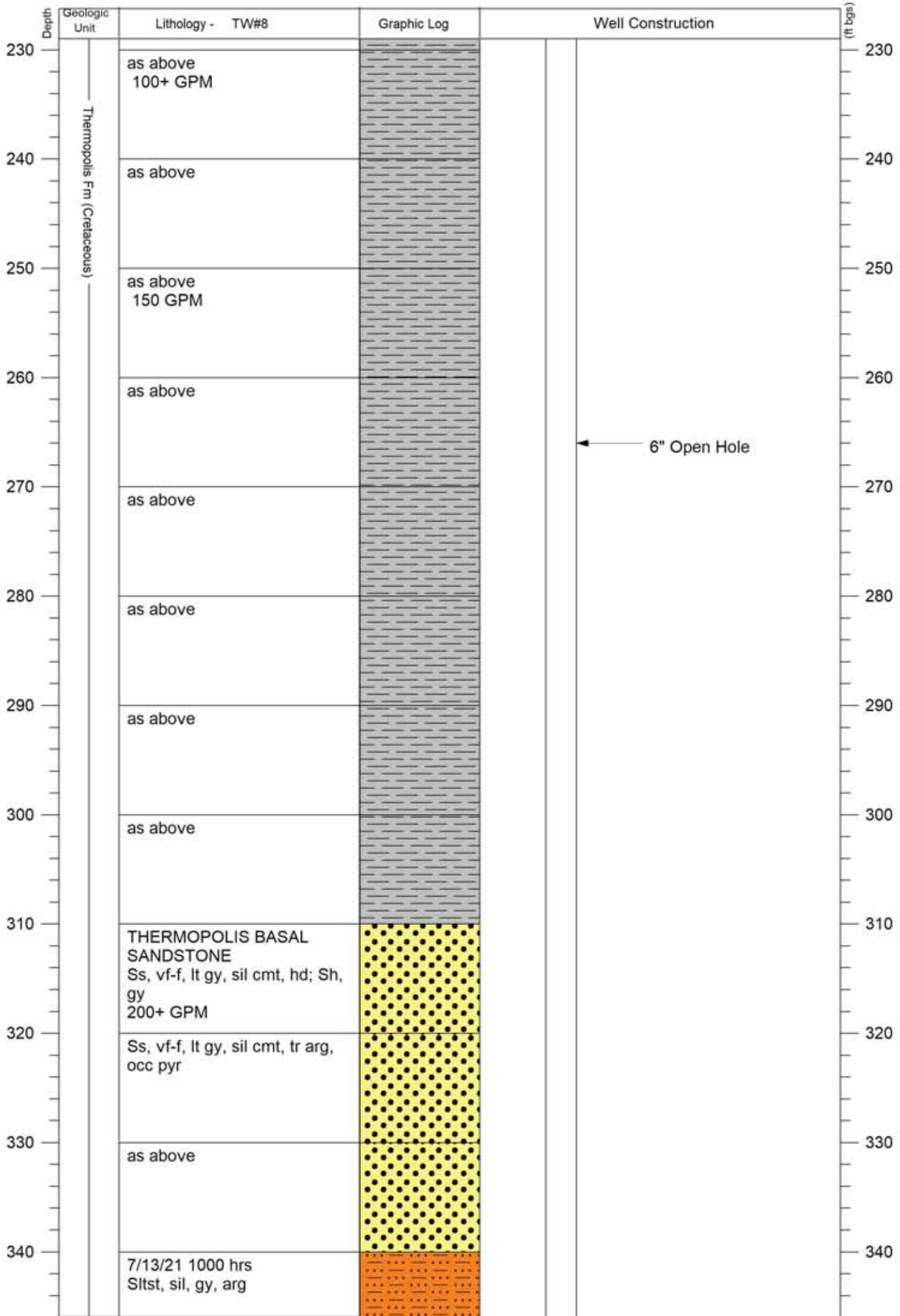
BIG SKY MTN VILLAGE TEST WELLS 2020

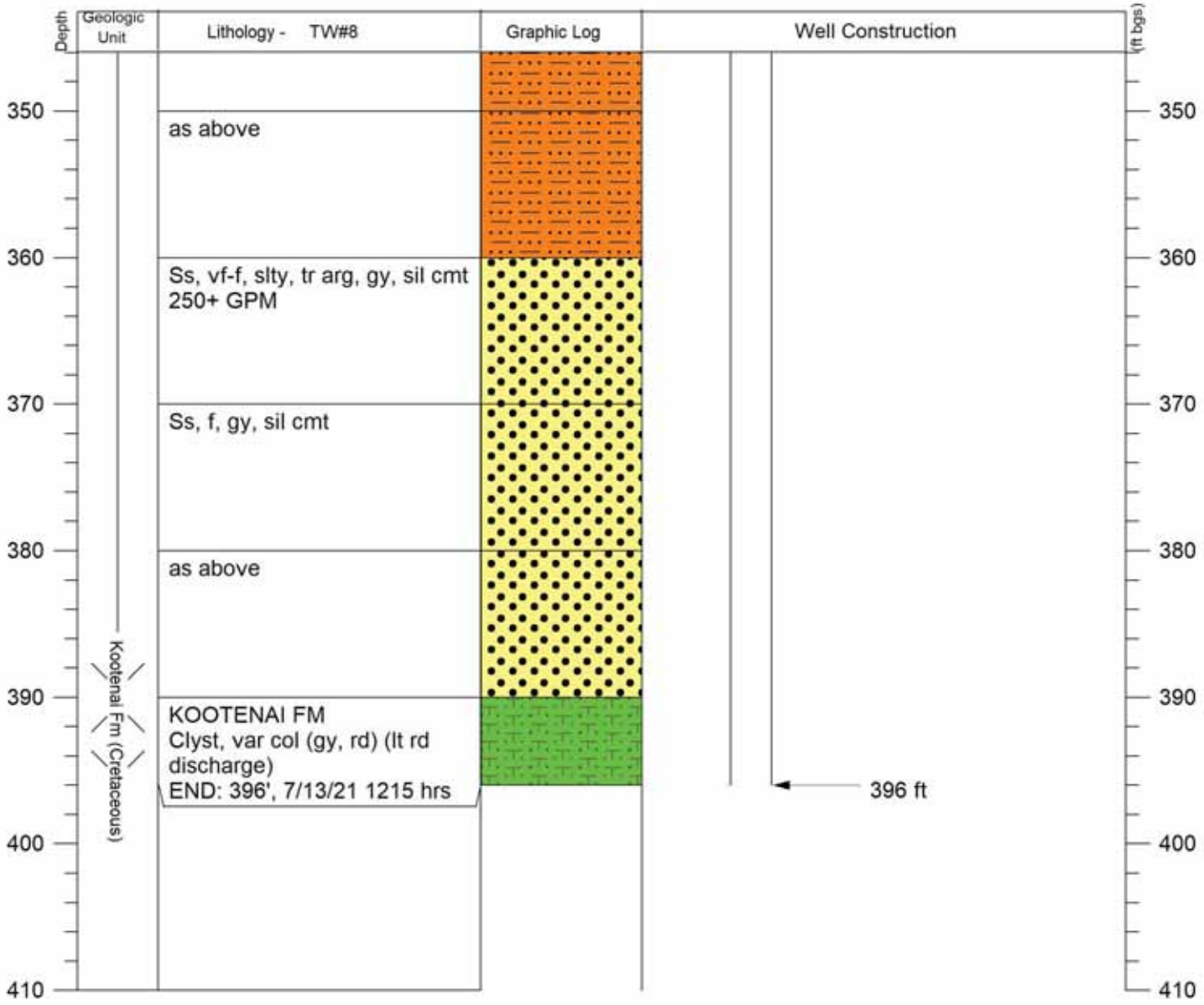
BEDROCK - NON-ARTESIAN				JOB TOTAL---------->			$ 182,509.50	TD (ft)	80	77	738	1040	730	396	662	840
				Bridger Drilling ---------->			$ 168,984.50	BUDGET	$ 5,170.00	$ 5,170.00	$ 24,250.00	$ 24,250.00	$ 28,210.00	$ 28,210.00	$ 28,210.00	$ 24,250.00
				Potts Drilling ---------->			$ 13,525.00	ACTUAL	$ 5,480.00	$ 3,772.00	$ 21,988.00	$ 30,315.00	$ 44,189.00	$ 32,713.50	$ 19,212.00	$ 24,840.00
								B-A	$ (310.00)	$ 1,398.00	$ 2,262.00	$ (6,065.00)	$ (15,979.00)	$ (4,503.50)	$ 8,998.00	$ (590.00)
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total		TW#3	TW#4	TW#5	TW#6	TW#7	TW#8	TW#10	TW#11
B-1.1	Mobilization	3	LS	$ 1,000.00	$ 3,000.00		4	$ 4,000.00				1	1			1	1
B-1.2	6" Drilling with Casing	240	LF	$ 36.00	$ 8,640.00		680	$ 24,480.00				180	200			100	200
B-1.3	6" Drilling Open Hole	2160	LF	$ 26.00	$ 56,160.00		2600	$ 67,600.00				558	840			562	640
B-1.4	Development	18	HR	$ 275.00	$ 4,950.00		1	$ 275.00					1				
				TOTAL	$ 72,750.00			$ 96,355.00									
BEDROCK - ARTESIAN												$ 21,988.00	$ 30,315.00			$ 19,212.00	$ 24,840.00
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
B-2.1	Mobilization	4	LS	$ 1,000.00	$ 4,000.00		2	$ 2,000.00						1	1		
B-2.2	10" Drilling with Casing	320	LF	$ 50.00	$ 16,000.00		262	$ 13,100.00						122	140		
B-2.3	Set and Cement 6" Casing	320	LF	$ 35.50	$ 11,360.00		262	$ 9,301.00						122	140		
B-2.4	6" Drilling Open Hole	2880	LF	$ 26.00	$ 74,880.00		864	$ 22,464.00						608	256		
B-2.5	Development	24	HR	$ 275.00	$ 6,600.00		3.5	$ 962.50						3	0.5		
				TOTAL	$ 112,840.00			$ 47,827.50						$ 28,064.00	$ 19,763.50		
ALLUVIUM																	
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
B-3.1	Mobilization	2	LS	$ 1,000.00	$ 2,000.00		2	$ 2,000.00		1	1						
B-3.2	6" Drilling with Casing	140	LF	$ 36.00	$ 5,040.00		157	$ 5,652.00		80	77						
B-3.3	Development	12	HR	$ 275.00	$ 3,300.00		0	$ -									
				TOTAL	$ 10,340.00			$ 7,652.00									
				TOTAL AS BID	**$ 195,930.00**					$ 3,880.00	$ 3,772.00						
CHANGE ORDERS																	
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total									
C1	Contract time extension	0	NA	$ -	$ -												
C2	TW#3 Well Abandonment	80	LF	$ 20.00	$ 1,600.00		80	$ 1,600.00		80							
C3-1	Wellhead Valve	1	EA	$ 1,100.00	$ 1,100.00		1	$ 1,100.00						1			
C3-2	Downhole casing cutting	1	EA	$ 1,500.00	$ 1,500.00	$ 4,200.00	1	$ 1,500.00						1			
C4-1	Temp Pumping System TW#8	1	EA	$ 3,050.00	$ 3,050.00		1	$ 3,050.00							1		
C4-2	Pumping Test Hourly TW#8	76	HRS	$ 125.00	$ 9,500.00	$ 12,550.00	76	$ 9,500.00							76		
NA	TW#8 Sounding Tube & Seal	1	EA	$ 400.00	$ 400.00		1	$ 400.00							1		
Potts	Temp Pumping System TW#7	1	EA	$ 6,305.00	$ 6,305.00		1	$ 6,305.00						1			
Potts	Pumping Test Hourly TW#7	76	HRS	$ 95.00	$ 7,220.00	$ 13,525.00	76	$ 7,220.00						76			
				TOTAL	$ 30,675.00			$ 30,675.00		$ 1,600.00				$ 16,125.00	$ 12,950.00		
		TOTAL WITH CHANGE ORDERS			**$ 226,605.00**												

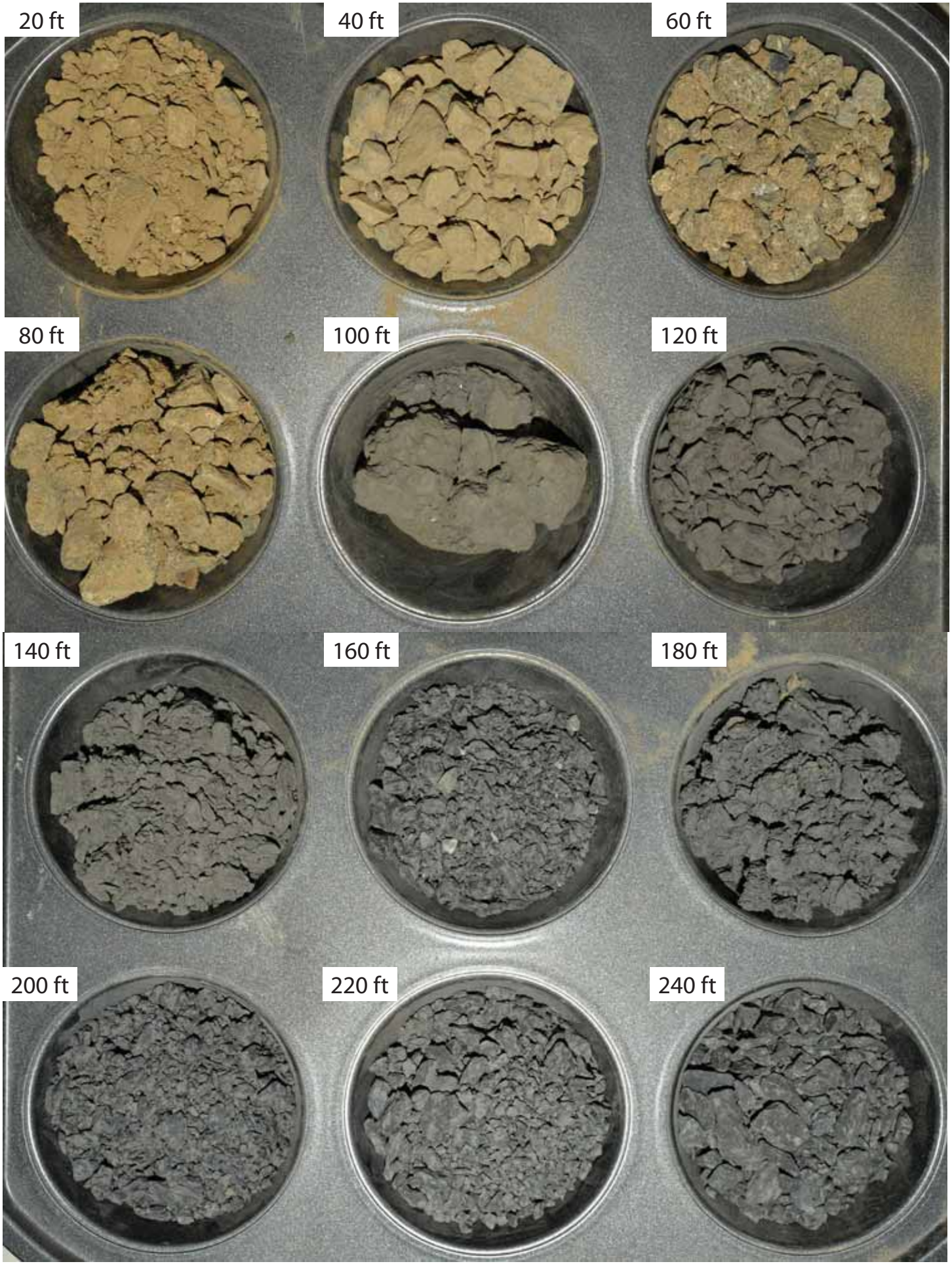
ATTACHMENT B
TEST WELL #8 LOG, SAMPLE PHOTOS, AND WATER QUALITY

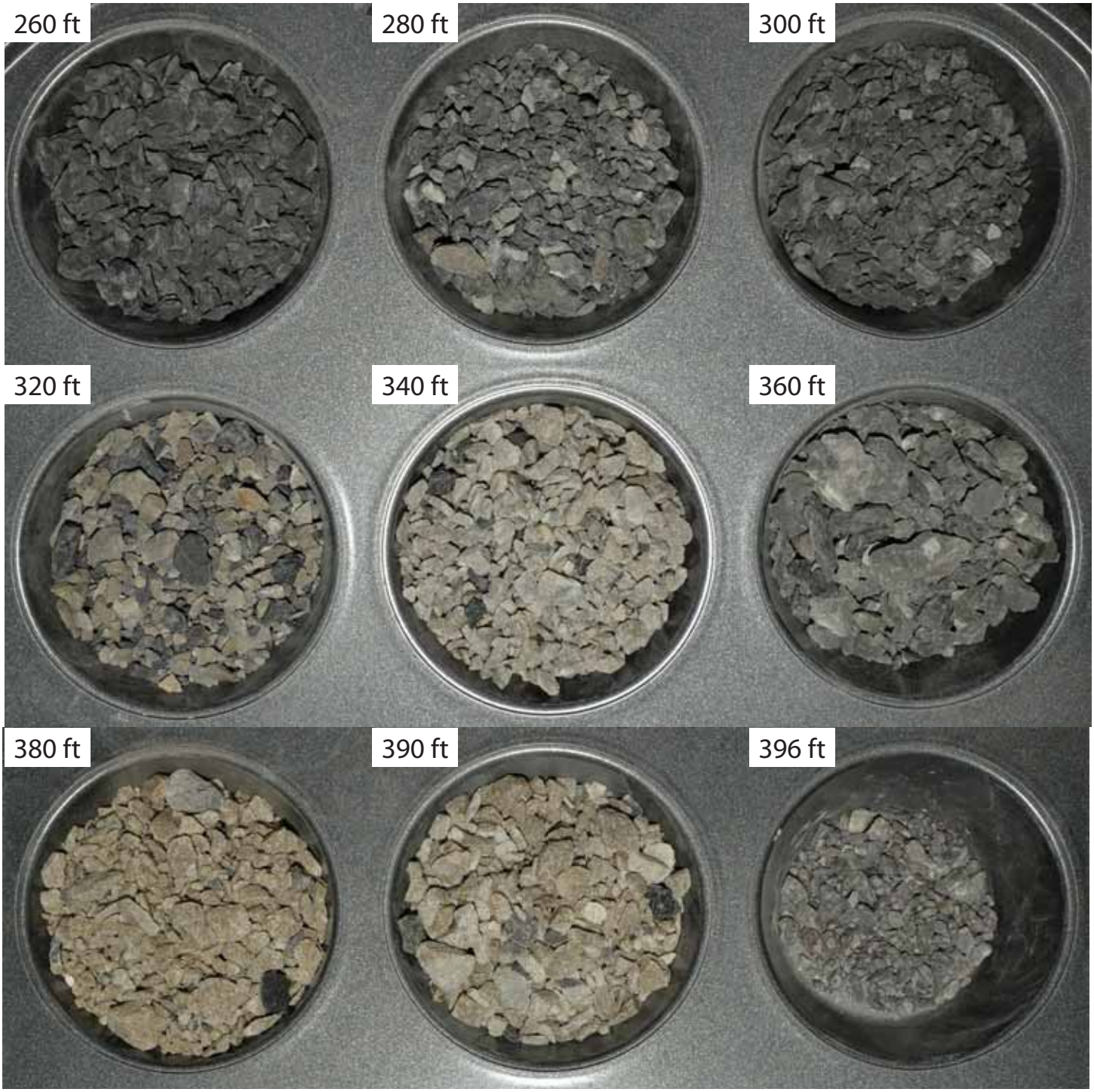

Depth
Geologic Unit
Lithology - TW#8
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at bottom depth of interval. Samples caught in strainer or 5-gal bucket.
START: 7/6/21 1200 hrs
QUATERNARY TILL
Gravel, sndy, slty, clyy, yel-brn
as above
as above
as above
FIRST GW 36 FT, 0 GPM
as above
as above
as above
Clay, grvly, yel (TILL)
THERMOPOLIS FM
Clay, yel - lt gy (weathered shale)
Clay, gy (weathered shale)
as above
Sh, gy
Glacial Till (Quaternary)
2 ft (flange adapter)
SWL 3 ft bgs
7/13/21
Bentonite 3/8" Chips
11 sx @ 50lbs ea.
SWL Till 36 ft
7/6/21
6-5/8" Steel Casing,
17lbs/ft, 0.25" Wall
10-3/4" Borehole
Cement/Bentonite Grout
44 sx, 210lbs, 375 gal
0
10
20
30
40
50
60
70
80
90
100
110


Depth
Geologic Unit
Lithology - TW#8
Graphic Log
Well Construction
(ft bgs)
120
as above
130
as above
STOP TO CEMENT CASING
136 ft
140
7/12/21 1000 hrs
as above
150
as above
160
as above
170
as above
180
as above
190
as above
200
as above
210
Sh, gy; Ss, strgs
50 GPM
220
Sh, gy, occ pyr
50+ GPM


Depth
Geologic Unit
Lithology - TW#8
Graphic Log
Well Construction
(ft bgs)
Thermopolis Fm (Cretaceous)
230
240
250
260
270
280
290
300
310
320
330
340
as above
100+ GPM
as above
as above
150 GPM
as above
as above
as above
as above
as above
THERMOPOLIS BASAL SANDSTONE
Ss, vf-f, lt gy, sil cmt, hd; Sh, gy
200+ GPM
Ss, vf-f, lt gy, sil cmt, tr arg, occ pyr
as above
7/13/21 1000 hrs
Sltst, sil, gy, arg
6" Open Hole


Depth
Geologic Unit
Lithology - TW#8
Graphic Log
Well Construction
(ft bgs)
350
360
370
380
390
400
410
as above
Ss, vf-f, slty, tr arg, gy, sil cmt
250+ GPM
Ss, f, gy, sil cmt
as above
KOOTENAI FM
Clyst, var col (gy, rd) (lt rd discharge)
END: 396', 7/13/21 1215 hrs
Kootenai Fm (Cretaceous)
396 ft


20 ft
40 ft
60 ft
80 ft
100 ft
120 ft
140 ft
160 ft
180 ft
200 ft
220 ft
240 ft


260 ft
280 ft
300 ft
320 ft
340 ft
360 ft
380 ft
390 ft
396 ft

Pace Analytical® Formerly Inter-Mountain Laboratories
1673 Terra Avenue Sheridan, WY 82801 ph: (307) 672-8945

Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 1/5/2022
Report ID: S2110004002
(Replaces S2110004001)
Work Order: S2110004
Collection Date: 9/30/2021 10:00:00 AM
Date Received: 10/1/2021 8:37:00 AM
Sampler: MC
Matrix: Water
COC: 193804

Project:
Lab ID: S2110004-001
Client Sample ID: TW #8 093021 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
General Parameters						
pH	8.1	0.1		s.u.	10/04/2021 17:37 ACE	SM 4500 H B
Electrical Conductivity	545	5		µmhos/cm	10/04/2021 17:37 ACE	SM 2510B
Total Dissolved Solids (180)	300	10		mg/L	10/04/2021 10:17 SMA	SM 2540
Alkalinity, Total (As CaCO3)	249	5		mg/L	10/04/2021 17:37 ACE	SM 2320B
Hardness, Calcium/Magnesium (As CaCO3)	155	1		mg/L	11/08/2021 12:03 JJ	SM 2340B
Silica as SiO2	6	1		mg/L	10/05/2021 12:37 DG	EPA 200.7
Sulfide as H2S	ND	0.01		mg/L	10/01/2021 09:28 KB	HACH 8131
Anions						
Alkalinity, Bicarbonate as HCO3	304	5		mg/L	10/04/2021 17:37 ACE	SM 2320B
Alkalinity, Carbonate as CO3	ND	5		mg/L	10/04/2021 17:37 ACE	SM 2320B
Alkalinity, Hydroxide as OH	ND	5		mg/L	10/04/2021 17:37 ACE	SM 2320B
Chloride	4	1		mg/L	10/04/2021 11:10 AB	EPA 300.0
Fluoride	0.8	0.1		mg/L	10/04/2021 17:37 ACE	SM 4500FC
Nitrogen, Nitrate-Nitrite (as N)	ND	0.1		mg/L	10/14/2021 15:35 AMB	EPA 353.2
Sulfate	37	1		mg/L	10/04/2021 11:10 AB	EPA 300.0
Cations						
Calcium	34	1		mg/L	10/05/2021 12:37 DG	EPA 200.7
Magnesium	17	1		mg/L	10/05/2021 12:37 DG	EPA 200.7
Potassium	6	1		mg/L	10/05/2021 12:37 DG	EPA 200.7
Sodium	47	1		mg/L	10/05/2021 12:37 DG	EPA 200.7
Radiochemistry						
Gross Alpha	ND	3		pCi/L	10/29/2021 11:28 AEF	SM 7110B
Gross Alpha MDC	3.00			pCi/L	10/29/2021 11:28 AEF	SM 7110B
Gross Beta	ND	5		pCi/L	10/29/2021 11:28 AEF	SM 7110B
Radium 226 (Dissolved)	0.7 ± 0.1	0.2		pCi/L	10/25/2021 13:14 WN	SM 7500 Ra-B
Radium 228 (Dissolved)	ND	1		pCi/L	11/05/2021 21:21 WN	Ga-Tech

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
D	Report limit raised due to dilution
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
U	Analyte below method detection limit
C	Calculated Value
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

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Sample Analysis Report

CLIENT: Western Groundwater Services
6595 Bear Claw Lane
Bozeman, MT 59715

Date Reported: 1/5/2022
Report ID: S2110004002
(Replaces S2110004001)
Work Order: S2110004
Collection Date: 9/30/2021 10:00:00 AM
Date Received: 10/1/2021 8:37:00 AM
Sampler: MC
Matrix: Water
COC: 193804

Project:
Lab ID: S2110004-001
Client Sample ID: TW #8 093021 MC

Analyses	Result	RL	Qual	Units	Date Analyzed/Init	Method
Total Recoverable Metals						
Antimony	ND	0.005		mg/L	10/06/2021 15:14 MS	EPA 200.8
Arsenic	ND	0.005		mg/L	10/06/2021 15:14 MS	EPA 200.8
Barium	ND	0.5		mg/L	10/06/2021 15:14 MS	EPA 200.8
Beryllium	ND	0.01		mg/L	10/05/2021 15:20 DG	EPA 200.7
Cadmium	ND	0.002		mg/L	10/06/2021 15:14 MS	EPA 200.8
Chromium	ND	0.01		mg/L	10/05/2021 15:20 DG	EPA 200.7
Iron	0.49	0.05		mg/L	10/05/2021 15:20 DG	EPA 200.7
Manganese	0.06	0.02		mg/L	10/05/2021 15:20 DG	EPA 200.7
Mercury	ND	0.001		mg/L	10/06/2021 16:16 SFK	EPA 245.1
Nickel	ND	0.01		mg/L	10/05/2021 15:20 DG	EPA 200.7
Selenium	ND	0.005		mg/L	10/06/2021 15:14 MS	EPA 200.8
Thallium	0.001	0.001		mg/L	10/06/2021 15:14 MS	EPA 200.8

These results apply only to the samples tested.

RL - Reporting Limit

Qualifiers:

B	Analyte detected in the associated Method Blank
D	Report limit raised due to dilution
G	Analyzed at IML Gillette laboratory
J	Analyte detected below quantitation limits
M	Value exceeds Monthly Ave or MCL or is less than LCL
O	Outside the Range of Dilutions
U	Analyte below method detection limit
C	Calculated Value
E	Value above quantitation range
H	Holding times for preparation or analysis exceeded
L	Analyzed by another laboratory
ND	Not Detected at the Reporting Limit
S	Spike Recovery outside accepted recovery limits
X	Matrix Effect

Reviewed by: John M. Jacobs
John Jacobs, Project Manager

```
   Input file: F:\Project Data\Big Sky Water & Sewer Dist\2020-05 Mtn Village Test Well
Drilling 2020\PHREEQC\TW#8_010522.pqi
  Output file: F:\Project Data\Big Sky Water & Sewer Dist\2020-05 Mtn Village Test Well
Drilling 2020\PHREEQC\TW#8_010522.pqo
Database file: C:\Program Files (x86)\USGS\Phreeqc Interactive 3.4.0-12927\database
\phreeqc.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      PHASES
      EXCHANGE_MASTER_SPECIES
      EXCHANGE_SPECIES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      RATES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      DATABASE C:\Program Files (x86)\USGS\Phreeqc Interactive 3.4.0-12927\database
\phreeqc.dat
      SOLUTION 1 TW#8 9/30/21 11:00 AM
      pH 6.88     # Field measurement
      pe 3.0      # Calculated from field Eh
      Temp 9.3    # Field measurement
      units mg/L
      Si    6
      Cl    4
      F     0.8
      S(6) 37
      Ca   34
      Mg   17
      K     6
      Na   47
      Fe(+2)   0.49
      Mn(+2)   0.06
      Alkalinity 249  # Total as CaCO3
      EQUILIBRIUM_PHASES
      O2(g) -0.68   10.0
      END
-----------------------------------------
Beginning of initial solution calculations.
-----------------------------------------

Initial solution 1.     TW

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Alkalinity        4.977e-03   4.977e-03
      Ca                8.486e-04   8.486e-04
      Cl                1.129e-04   1.129e-04
      F                 4.213e-05   4.213e-05
      Fe(2)             8.777e-06   8.777e-06
      K                 1.535e-04   1.535e-04
      Mg                6.995e-04   6.995e-04
      Mn(2)             1.093e-06   1.093e-06
      Na                2.045e-03   2.045e-03
      S(6)              3.853e-04   3.853e-04
      Si                9.990e-05   9.990e-05
```

----------Description of solution----------

pH	= 6.880
pe	= 3.000
Specific Conductance (µS/cm, 9°C)	= 346
Density (g/cm³)	= 1.00014
Volume (L)	= 1.00039
Activity of water	= 1.000
Ionic strength (mol/kgw)	= 7.273e-03
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 6.729e-03
Total CO2 (mol/kg)	= 6.729e-03
Temperature (°C)	= 9.30
Electrical balance (eq)	= -5.883e-04
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= -5.38
Iterations	= 10
Total H	= 1.110178e+02
Total O	= 5.552659e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	1.425e-07	1.318e-07	-6.846	-6.880	-0.034	0.00
OH-	2.291e-08	2.096e-08	-7.640	-7.679	-0.039	-5.03
H2O	5.551e+01	9.998e-01	1.744	-0.000	0.000	18.02
C(4)	6.729e-03					
HCO3-	4.913e-03	4.513e-03	-2.309	-2.346	-0.037	23.11
CO2	1.754e-03	1.757e-03	-2.756	-2.755	0.001	33.62
MgHCO3+	2.587e-05	2.369e-05	-4.587	-4.625	-0.038	4.90
CaHCO3+	2.546e-05	2.342e-05	-4.594	-4.630	-0.036	8.92
NaHCO3	5.201e-06	5.210e-06	-5.284	-5.283	0.001	1.80
FeHCO3+	2.218e-06	2.032e-06	-5.654	-5.692	-0.038	(0)
CO3-2	1.532e-06	1.091e-06	-5.815	-5.962	-0.148	-7.34
CaCO3	8.442e-07	8.456e-07	-6.074	-6.073	0.001	-14.66
MgCO3	3.823e-07	3.829e-07	-6.418	-6.417	0.001	-17.07
MnHCO3+	2.449e-07	2.248e-07	-6.611	-6.648	-0.037	(0)
FeCO3	1.176e-07	1.178e-07	-6.930	-6.929	0.001	(0)
MnCO3	4.834e-08	4.842e-08	-7.316	-7.315	0.001	(0)
(CO2)2	3.206e-08	3.211e-08	-7.494	-7.493	0.001	67.24
NaCO3-	1.796e-08	1.646e-08	-7.746	-7.784	-0.038	-3.10
Ca	8.486e-04					
Ca+2	8.006e-04	5.697e-04	-3.097	-3.244	-0.148	-18.32
CaHCO3+	2.546e-05	2.342e-05	-4.594	-4.630	-0.036	8.92
CaSO4	2.176e-05	2.180e-05	-4.662	-4.662	0.001	6.74
CaCO3	8.442e-07	8.456e-07	-6.074	-6.073	0.001	-14.66
CaOH+	7.827e-10	7.171e-10	-9.106	-9.144	-0.038	(0)
CaHSO4+	1.697e-11	1.555e-11	-10.770	-10.808	-0.038	(0)
Cl	1.129e-04					
Cl-	1.129e-04	1.033e-04	-3.947	-3.986	-0.038	17.36
FeCl+	7.008e-10	6.421e-10	-9.154	-9.192	-0.038	(0)
MnCl+	2.563e-10	2.353e-10	-9.591	-9.628	-0.037	-8.42
MnCl2	1.059e-14	1.061e-14	-13.975	-13.974	0.001	110.65
MnCl3-	3.290e-19	3.019e-19	-18.483	-18.520	-0.037	43.93
F	4.213e-05					
F-	4.114e-05	3.763e-05	-4.386	-4.424	-0.039	-1.67
MgF+	9.405e-07	8.624e-07	-6.027	-6.064	-0.038	-10.59
NaF	4.041e-08	4.048e-08	-7.393	-7.393	0.001	6.51
HF	5.654e-09	5.663e-09	-8.248	-8.247	0.001	11.58
FeF+	1.849e-09	1.694e-09	-8.733	-8.771	-0.038	(0)
MnF+	1.586e-10	1.455e-10	-9.800	-9.837	-0.037	(0)
HF2-	7.652e-13	7.011e-13	-12.116	-12.154	-0.038	21.07
SiF6-2	8.419e-28	5.974e-28	-27.075	-27.224	-0.149	41.26
Fe(2)	8.777e-06					
Fe+2	6.293e-06	4.502e-06	-5.201	-5.347	-0.145	-23.25
FeHCO3+	2.218e-06	2.032e-06	-5.654	-5.692	-0.038	(0)

FeSO4	1.438e-07	1.441e-07	-6.842	-6.841	0.001	40.12
FeCO3	1.176e-07	1.178e-07	-6.930	-6.929	0.001	(0)
FeOH+	3.410e-09	3.130e-09	-8.467	-8.504	-0.037	(0)
FeF+	1.849e-09	1.694e-09	-8.733	-8.771	-0.038	(0)
FeCl+	7.008e-10	6.421e-10	-9.154	-9.192	-0.038	(0)
FeHSO4+	1.341e-13	1.229e-13	-12.873	-12.911	-0.038	(0)
Fe(OH)2	4.772e-14	4.780e-14	-13.321	-13.321	0.001	(0)
Fe(OH)3-	1.247e-17	1.145e-17	-16.904	-16.941	-0.037	(0)
H(0)	2.897e-23					
H2	1.449e-23	1.451e-23	-22.839	-22.838	0.001	28.63
K	1.535e-04					
K+	1.533e-04	1.403e-04	-3.814	-3.853	-0.039	8.40
KSO4-	1.958e-07	1.799e-07	-6.708	-6.745	-0.037	33.54
Mg	6.995e-04					
Mg+2	6.549e-04	4.683e-04	-3.184	-3.330	-0.146	-21.06
MgHCO3+	2.587e-05	2.369e-05	-4.587	-4.625	-0.038	4.90
MgSO4	1.742e-05	1.745e-05	-4.759	-4.758	0.001	5.07
MgF+	9.405e-07	8.624e-07	-6.027	-6.064	-0.038	-10.59
MgCO3	3.823e-07	3.829e-07	-6.418	-6.417	0.001	-17.07
MgOH+	3.136e-09	2.887e-09	-8.504	-8.540	-0.036	(0)
Mn(2)	1.093e-06					
Mn+2	7.812e-07	5.590e-07	-6.107	-6.253	-0.145	-20.55
MnHCO3+	2.449e-07	2.248e-07	-6.611	-6.648	-0.037	(0)
MnCO3	4.834e-08	4.842e-08	-7.316	-7.315	0.001	(0)
MnSO4	1.762e-08	1.765e-08	-7.754	-7.753	0.001	31.47
MnCl+	2.563e-10	2.353e-10	-9.591	-9.628	-0.037	-8.42
MnF+	1.586e-10	1.455e-10	-9.800	-9.837	-0.037	(0)
MnOH+	3.075e-11	2.822e-11	-10.512	-10.549	-0.037	(0)
MnCl2	1.059e-14	1.061e-14	-13.975	-13.974	0.001	110.65
MnCl3-	3.290e-19	3.019e-19	-18.483	-18.520	-0.037	43.93
Mn(OH)3-	4.211e-21	3.865e-21	-20.376	-20.413	-0.037	(0)
Na	2.045e-03					
Na+	2.038e-03	1.869e-03	-2.691	-2.728	-0.037	-2.47
NaHCO3	5.201e-06	5.210e-06	-5.284	-5.283	0.001	1.80
NaSO4-	2.237e-06	2.055e-06	-5.650	-5.687	-0.037	14.37
NaF	4.041e-08	4.048e-08	-7.393	-7.393	0.001	6.51
NaCO3-	1.796e-08	1.646e-08	-7.746	-7.784	-0.038	-3.10
NaOH	3.911e-21	3.918e-21	-20.408	-20.407	0.001	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-52.053	-52.052	0.001	28.86
S(6)	3.853e-04					
SO4-2	3.435e-04	2.436e-04	-3.464	-3.613	-0.149	11.73
CaSO4	2.176e-05	2.180e-05	-4.662	-4.662	0.001	6.74
MgSO4	1.742e-05	1.745e-05	-4.759	-4.758	0.001	5.07
NaSO4-	2.237e-06	2.055e-06	-5.650	-5.687	-0.037	14.37
KSO4-	1.958e-07	1.799e-07	-6.708	-6.745	-0.037	33.54
FeSO4	1.438e-07	1.441e-07	-6.842	-6.841	0.001	40.12
MnSO4	1.762e-08	1.765e-08	-7.754	-7.753	0.001	31.47
HSO4-	2.477e-09	2.270e-09	-8.606	-8.644	-0.038	38.85
CaHSO4+	1.697e-11	1.555e-11	-10.770	-10.808	-0.038	(0)
FeHSO4+	1.341e-13	1.229e-13	-12.873	-12.911	-0.038	(0)
Si	9.990e-05					
H4SiO4	9.983e-05	1.000e-04	-4.001	-4.000	0.001	53.76
H3SiO4-	6.658e-08	6.098e-08	-7.177	-7.215	-0.038	27.39
H2SiO4-2	1.437e-14	1.023e-14	-13.842	-13.990	-0.148	(0)
SiF6-2	8.419e-28	5.974e-28	-27.075	-27.224	-0.149	41.26

----------Saturation indices----------

Phase	SI**	log IAP	log K(282 K, 1 atm)	
Anhydrite	-2.74	-6.86	-4.12	CaSO4
Aragonite	-0.95	-9.21	-8.25	CaCO3
Calcite	-0.80	-9.21	-8.41	CaCO3
Chalcedony	-0.26	-4.00	-3.74	SiO2
Chrysotile	-10.96	23.29	34.25	Mg3Si2O5(OH)4
CO2(g)	-1.50	-2.76	-1.26	CO2

Dolomite	-1.79	-18.50	-16.71	CaMg(CO3)2
Fluorite	-1.29	-12.09	-10.81	CaF2
Gypsum	-2.26	-6.86	-4.60	CaSO4:2H2O
H2(g)	-19.79	-22.84	-3.05	H2
H2O(g)	-1.93	-0.00	1.93	H2O
Halite	-8.27	-6.71	1.56	NaCl
Hausmannite	-22.85	42.28	65.13	Mn3O4
Manganite	-7.95	17.39	25.34	MnOOH
Melanterite	-6.54	-8.96	-2.42	FeSO4:7H2O
O2(g)	-49.29	-52.05	-2.76	O2
Pyrochroite	-7.69	7.51	15.20	Mn(OH)2
Pyrolusite	-16.77	27.27	44.03	MnO2:H2O
Quartz	0.22	-4.00	-4.22	SiO2
Rhodochrosite	-1.14	-12.21	-11.07	MnCO3
Sepiolite	-7.33	8.86	16.20	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-9.80	8.86	18.66	Mg2Si3O7.5OH:3H2O
Siderite	-0.52	-11.31	-10.79	FeCO3
SiO2(a)	-1.15	-4.00	-2.85	SiO2
Sylvite	-8.66	-7.84	0.82	KCl
Talc	-8.00	15.29	23.29	Mg3Si4O10(OH)2

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Beginning of batch-reaction calculations.

Reaction step 1.

Using solution 1. TW
Using pure phase assemblage 1.

----------Phase assemblage----------

Phase	SI	log IAP	log K(T, P)	Moles in assemblage Initial	Final	Delta
O2(g)	-0.68	-3.44	-2.76	1.000e+01	1.000e+01	-3.655e-04

----------Solution composition----------

Elements	Molality	Moles
C	6.729e-03	6.729e-03
Ca	8.486e-04	8.486e-04
Cl	1.129e-04	1.129e-04
F	4.213e-05	4.213e-05
Fe	8.777e-06	8.777e-06
K	1.535e-04	1.535e-04
Mg	6.995e-04	6.995e-04
Mn	1.093e-06	1.093e-06
Na	2.045e-03	2.045e-03
S	3.853e-04	3.853e-04
Si	9.990e-05	9.990e-05

----------Description of solution----------

pH = 6.876 Charge balance
pe = 15.157 Adjusted to redox equilibrium
Specific Conductance (µS/cm, 9°C) = 345
Density (g/cm³) = 1.00014
Volume (L) = 1.00041
Activity of water = 1.000
Ionic strength (mol/kgw) = 7.258e-03
Mass of water (kg) = 1.000e+00
Total alkalinity (eq/kg) = 4.969e-03

```
                    Total CO2 (mol/kg)  =   6.729e-03
                      Temperature (°C)  =   9.30
                Electrical balance (eq) =  -5.883e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -5.39
                             Iterations  =  14
                                Total H  = 1.110178e+02
                                Total O  = 5.552732e+01
```

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	1.437e-07	1.329e-07	-6.843	-6.876	-0.034	0.00
OH-	2.272e-08	2.079e-08	-7.644	-7.682	-0.039	-5.03
H2O	5.551e+01	9.998e-01	1.744	-0.000	0.000	18.02
C(-4)	0.000e+00					
CH4	0.000e+00	0.000e+00	-152.428	-152.427	0.001	33.90
C(4)	6.729e-03					
HCO3-	4.904e-03	4.505e-03	-2.309	-2.346	-0.037	23.11
CO2	1.765e-03	1.768e-03	-2.753	-2.752	0.001	33.62
MgHCO3+	2.583e-05	2.366e-05	-4.588	-4.626	-0.038	4.90
CaHCO3+	2.542e-05	2.338e-05	-4.595	-4.631	-0.036	8.92
NaHCO3	5.193e-06	5.201e-06	-5.285	-5.284	0.001	1.80
CO3-2	1.516e-06	1.080e-06	-5.819	-5.967	-0.147	-7.34
CaCO3	8.362e-07	8.376e-07	-6.078	-6.077	0.001	-14.66
MgCO3	3.787e-07	3.793e-07	-6.422	-6.421	0.001	-17.07
MnHCO3+	2.448e-07	2.247e-07	-6.611	-6.648	-0.037	(0)
MnCO3	4.792e-08	4.800e-08	-7.319	-7.319	0.001	(0)
(CO2)2	3.247e-08	3.253e-08	-7.488	-7.488	0.001	67.24
NaCO3-	1.778e-08	1.630e-08	-7.750	-7.788	-0.038	-3.10
FeHCO3+	2.057e-15	1.884e-15	-14.687	-14.725	-0.038	(0)
FeCO3	1.082e-16	1.084e-16	-15.966	-15.965	0.001	(0)
Ca	8.486e-04					
Ca+2	8.006e-04	5.699e-04	-3.097	-3.244	-0.148	-18.32
CaHCO3+	2.542e-05	2.338e-05	-4.595	-4.631	-0.036	8.92
CaSO4	2.178e-05	2.182e-05	-4.662	-4.661	0.001	6.74
CaCO3	8.362e-07	8.376e-07	-6.078	-6.077	0.001	-14.66
CaOH+	7.765e-10	7.115e-10	-9.110	-9.148	-0.038	(0)
CaHSO4+	1.712e-11	1.569e-11	-10.766	-10.804	-0.038	(0)
Cl	1.129e-04					
Cl-	1.129e-04	1.033e-04	-3.947	-3.986	-0.038	17.36
MnCl+	2.566e-10	2.355e-10	-9.591	-9.628	-0.037	-8.42
MnCl2	1.061e-14	1.062e-14	-13.974	-13.974	0.001	110.65
FeCl+2	6.008e-16	4.265e-16	-15.221	-15.370	-0.149	(0)
FeCl+	6.511e-19	5.966e-19	-18.186	-18.224	-0.038	(0)
FeCl2+	3.626e-19	3.329e-19	-18.441	-18.478	-0.037	(0)
MnCl3-	3.294e-19	3.023e-19	-18.482	-18.520	-0.037	43.93
FeCl3	3.434e-24	3.439e-24	-23.464	-23.464	0.001	(0)
F	4.213e-05					
F-	4.114e-05	3.764e-05	-4.386	-4.424	-0.039	-1.67
MgF+	9.409e-07	8.627e-07	-6.026	-6.064	-0.038	-10.59
NaF	4.042e-08	4.049e-08	-7.393	-7.393	0.001	6.51
HF	5.700e-09	5.710e-09	-8.244	-8.243	0.001	11.58
MnF+	1.587e-10	1.457e-10	-9.799	-9.837	-0.037	(0)
FeF+2	1.508e-11	1.070e-11	-10.822	-10.971	-0.149	(0)
FeF2+	1.435e-11	1.317e-11	-10.843	-10.880	-0.037	(0)
HF2-	7.716e-13	7.070e-13	-12.113	-12.151	-0.038	21.07
FeF3	7.413e-13	7.425e-13	-12.130	-12.129	0.001	(0)
FeF+	1.718e-18	1.574e-18	-17.765	-17.803	-0.038	(0)
SiF6-2	8.701e-28	6.176e-28	-27.060	-27.209	-0.149	41.26
Fe(2)	8.148e-15					
Fe+2	5.845e-15	4.183e-15	-14.233	-14.379	-0.145	-23.25
FeHCO3+	2.057e-15	1.884e-15	-14.687	-14.725	-0.038	(0)
FeSO4	1.337e-16	1.339e-16	-15.874	-15.873	0.001	40.12
FeCO3	1.082e-16	1.084e-16	-15.966	-15.965	0.001	(0)
FeOH+	3.142e-18	2.884e-18	-17.503	-17.540	-0.037	(0)

FeF+	1.718e-18	1.574e-18	-17.765	-17.803	-0.038	(0)
FeCl+	6.511e-19	5.966e-19	-18.186	-18.224	-0.038	(0)
FeHSO4+	1.257e-22	1.151e-22	-21.901	-21.939	-0.038	(0)
Fe(OH)2	4.362e-23	4.369e-23	-22.360	-22.360	0.001	(0)
Fe(OH)3-	1.131e-26	1.038e-26	-25.947	-25.984	-0.037	(0)
Fe(HS)2	0.000e+00	0.000e+00	-306.738	-306.738	0.001	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-455.317	-455.355	-0.038	(0)
Fe(3)	8.777e-06					
Fe(OH)2+	6.120e-06	5.622e-06	-5.213	-5.250	-0.037	(0)
Fe(OH)3	2.641e-06	2.646e-06	-5.578	-5.577	0.001	(0)
Fe(OH)4-	1.015e-08	9.326e-09	-7.993	-8.030	-0.037	(0)
FeOH+2	5.961e-09	4.231e-09	-8.225	-8.374	-0.149	(0)
FeF+2	1.508e-11	1.070e-11	-10.822	-10.971	-0.149	(0)
FeF2+	1.435e-11	1.317e-11	-10.843	-10.880	-0.037	(0)
FeF3	7.413e-13	7.425e-13	-12.130	-12.129	0.001	(0)
Fe+3	4.666e-13	2.311e-13	-12.331	-12.636	-0.305	(0)
FeSO4+	4.664e-13	4.281e-13	-12.331	-12.368	-0.037	(0)
Fe2(OH)2+4	3.871e-15	9.559e-16	-14.412	-15.020	-0.607	(0)
Fe(SO4)2-	2.335e-15	2.140e-15	-14.632	-14.670	-0.038	(0)
FeCl+2	6.008e-16	4.265e-16	-15.221	-15.370	-0.149	(0)
Fe3(OH)4+5	4.607e-17	5.181e-18	-16.337	-17.286	-0.949	(0)
FeCl2+	3.626e-19	3.329e-19	-18.441	-18.478	-0.037	(0)
FeHSO4+2	2.267e-19	1.598e-19	-18.645	-18.796	-0.152	(0)
FeCl3	3.434e-24	3.439e-24	-23.464	-23.464	0.001	(0)
H(0)	0.000e+00					
H2	0.000e+00	0.000e+00	-47.145	-47.145	0.001	28.63
K	1.535e-04					
K+	1.533e-04	1.403e-04	-3.814	-3.853	-0.039	8.40
KSO4-	1.959e-07	1.800e-07	-6.708	-6.745	-0.037	33.54
Mg	6.995e-04					
Mg+2	6.549e-04	4.684e-04	-3.184	-3.329	-0.146	-21.06
MgHCO3+	2.583e-05	2.366e-05	-4.588	-4.626	-0.038	4.90
MgSO4	1.744e-05	1.747e-05	-4.758	-4.758	0.001	5.07
MgF+	9.409e-07	8.627e-07	-6.026	-6.064	-0.038	-10.59
MgCO3	3.787e-07	3.793e-07	-6.422	-6.421	0.001	-17.07
MgOH+	3.111e-09	2.865e-09	-8.507	-8.543	-0.036	(0)
Mn(2)	1.093e-06					
Mn+2	7.818e-07	5.595e-07	-6.107	-6.252	-0.145	-20.55
MnHCO3+	2.448e-07	2.247e-07	-6.611	-6.648	-0.037	(0)
MnCO3	4.792e-08	4.800e-08	-7.319	-7.319	0.001	(0)
MnSO4	1.765e-08	1.768e-08	-7.753	-7.752	0.001	31.47
MnCl+	2.566e-10	2.355e-10	-9.591	-9.628	-0.037	-8.42
MnF+	1.587e-10	1.457e-10	-9.799	-9.837	-0.037	(0)
MnOH+	3.053e-11	2.802e-11	-10.515	-10.552	-0.037	(0)
MnCl2	1.061e-14	1.062e-14	-13.974	-13.974	0.001	110.65
MnCl3-	3.294e-19	3.023e-19	-18.482	-18.520	-0.037	43.93
Mn(OH)3-	4.113e-21	3.776e-21	-20.386	-20.423	-0.037	(0)
Mn(3)	4.451e-18					
Mn+3	4.451e-18	2.205e-18	-17.352	-17.657	-0.305	(0)
Na	2.045e-03					
Na+	2.038e-03	1.869e-03	-2.691	-2.728	-0.037	-2.47
NaHCO3	5.193e-06	5.201e-06	-5.285	-5.284	0.001	1.80
NaSO4-	2.238e-06	2.056e-06	-5.650	-5.687	-0.037	14.37
NaF	4.042e-08	4.049e-08	-7.393	-7.393	0.001	6.51
NaCO3-	1.778e-08	1.630e-08	-7.750	-7.788	-0.038	-3.10
NaOH	3.880e-21	3.886e-21	-20.411	-20.410	0.001	(0)
O(0)	7.265e-04					
O2	3.633e-04	3.639e-04	-3.440	-3.439	0.001	28.86
S(-2)	0.000e+00					
H2S	0.000e+00	0.000e+00	-150.353	-150.353	0.001	37.09
HS-	0.000e+00	0.000e+00	-150.616	-150.655	-0.039	19.59
S-2	0.000e+00	0.000e+00	-157.040	-157.189	-0.149	(0)
Fe(HS)2	0.000e+00	0.000e+00	-306.738	-306.738	0.001	(0)
Fe(HS)3-	0.000e+00	0.000e+00	-455.317	-455.355	-0.038	(0)
S(6)	3.853e-04					
SO4-2	3.436e-04	2.438e-04	-3.464	-3.613	-0.149	11.73
CaSO4	2.178e-05	2.182e-05	-4.662	-4.661	0.001	6.74

MgSO4	1.744e-05	1.747e-05	-4.758	-4.758	0.001	5.07
NaSO4-	2.238e-06	2.056e-06	-5.650	-5.687	-0.037	14.37
KSO4-	1.959e-07	1.800e-07	-6.708	-6.745	-0.037	33.54
MnSO4	1.765e-08	1.768e-08	-7.753	-7.752	0.001	31.47
HSO4-	2.499e-09	2.290e-09	-8.602	-8.640	-0.038	38.85
CaHSO4+	1.712e-11	1.569e-11	-10.766	-10.804	-0.038	(0)
FeSO4+	4.664e-13	4.281e-13	-12.331	-12.368	-0.037	(0)
Fe(SO4)2-	2.335e-15	2.140e-15	-14.632	-14.670	-0.038	(0)
FeSO4	1.337e-16	1.339e-16	-15.874	-15.873	0.001	40.12
FeHSO4+2	2.267e-19	1.598e-19	-18.645	-18.796	-0.152	(0)
FeHSO4+	1.257e-22	1.151e-22	-21.901	-21.939	-0.038	(0)
Si	9.990e-05					
H4SiO4	9.983e-05	1.000e-04	-4.001	-4.000	0.001	53.76
H3SiO4-	6.604e-08	6.048e-08	-7.180	-7.218	-0.038	27.39
H2SiO4-2	1.414e-14	1.007e-14	-13.850	-13.997	-0.147	(0)
SiF6-2	8.701e-28	6.176e-28	-27.060	-27.209	-0.149	41.26

-------------------------------Saturation indices--------------------------------

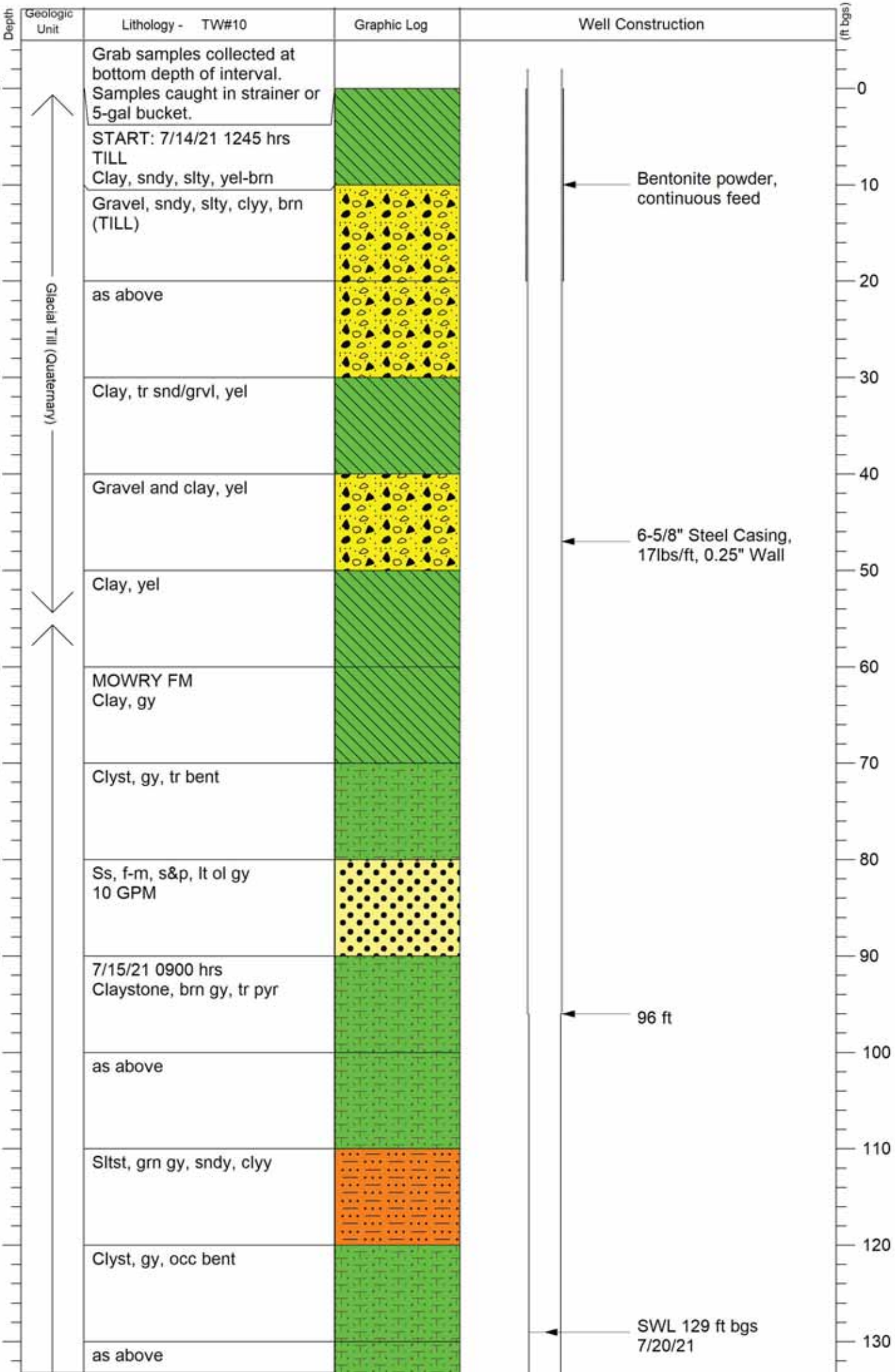
Phase	SI**	log IAP	log K(282 K, 1 atm)	
Anhydrite	-2.74	-6.86	-4.12	CaSO4
Aragonite	-0.96	-9.21	-8.25	CaCO3
Calcite	-0.80	-9.21	-8.41	CaCO3
CH4(g)	-149.81	-152.43	-2.62	CH4
Chalcedony	-0.26	-4.00	-3.74	SiO2
Chrysotile	-10.98	23.27	34.25	Mg3Si2O5(OH)4
CO2(g)	-1.49	-2.75	-1.26	CO2
Dolomite	-1.80	-18.51	-16.71	CaMg(CO3)2
Fe(OH)3(a)	3.10	7.99	4.89	Fe(OH)3
FeS(ppt)	-154.24	-158.16	-3.92	FeS
Fluorite	-1.29	-12.09	-10.81	CaF2
Goethite	8.40	7.99	-0.41	FeOOH
Gypsum	-2.26	-6.86	-4.60	CaSO4:2H2O
H2(g)	-44.09	-47.14	-3.05	H2
H2O(g)	-1.93	-0.00	1.93	H2O
H2S(g)	-149.50	-157.53	-8.04	H2S
Halite	-8.27	-6.71	1.56	NaCl
Hausmannite	1.44	66.57	65.13	Mn3O4
Hematite	18.74	15.99	-2.75	Fe2O3
Jarosite-K	0.21	-7.73	-7.94	KFe3(SO4)2(OH)6
Mackinawite	-153.51	-158.16	-4.65	FeS
Manganite	4.19	29.53	25.34	MnOOH
Melanterite	-15.57	-17.99	-2.42	FeSO4:7H2O
O2(g)	-0.68	-3.44	-2.76	O2 Pressure 0.2 atm, phi 1.000
Pyrite	-252.68	-271.62	-18.94	FeS2
Pyrochroite	-7.70	7.50	15.20	Mn(OH)2
Pyrolusite	7.53	51.57	44.03	MnO2:H2O
Quartz	0.22	-4.00	-4.22	SiO2
Rhodochrosite	-1.15	-12.22	-11.07	MnCO3
Sepiolite	-7.35	8.85	16.20	Mg2Si3O7.5OH:3H2O
Sepiolite(d)	-9.81	8.85	18.66	Mg2Si3O7.5OH:3H2O
Siderite	-9.56	-20.35	-10.79	FeCO3
SiO2(a)	-1.15	-4.00	-2.85	SiO2
Sulfur	-111.56	-106.29	5.27	S
Sylvite	-8.66	-7.84	0.82	KCl
Talc	-8.02	15.27	23.29	Mg3Si4O10(OH)2

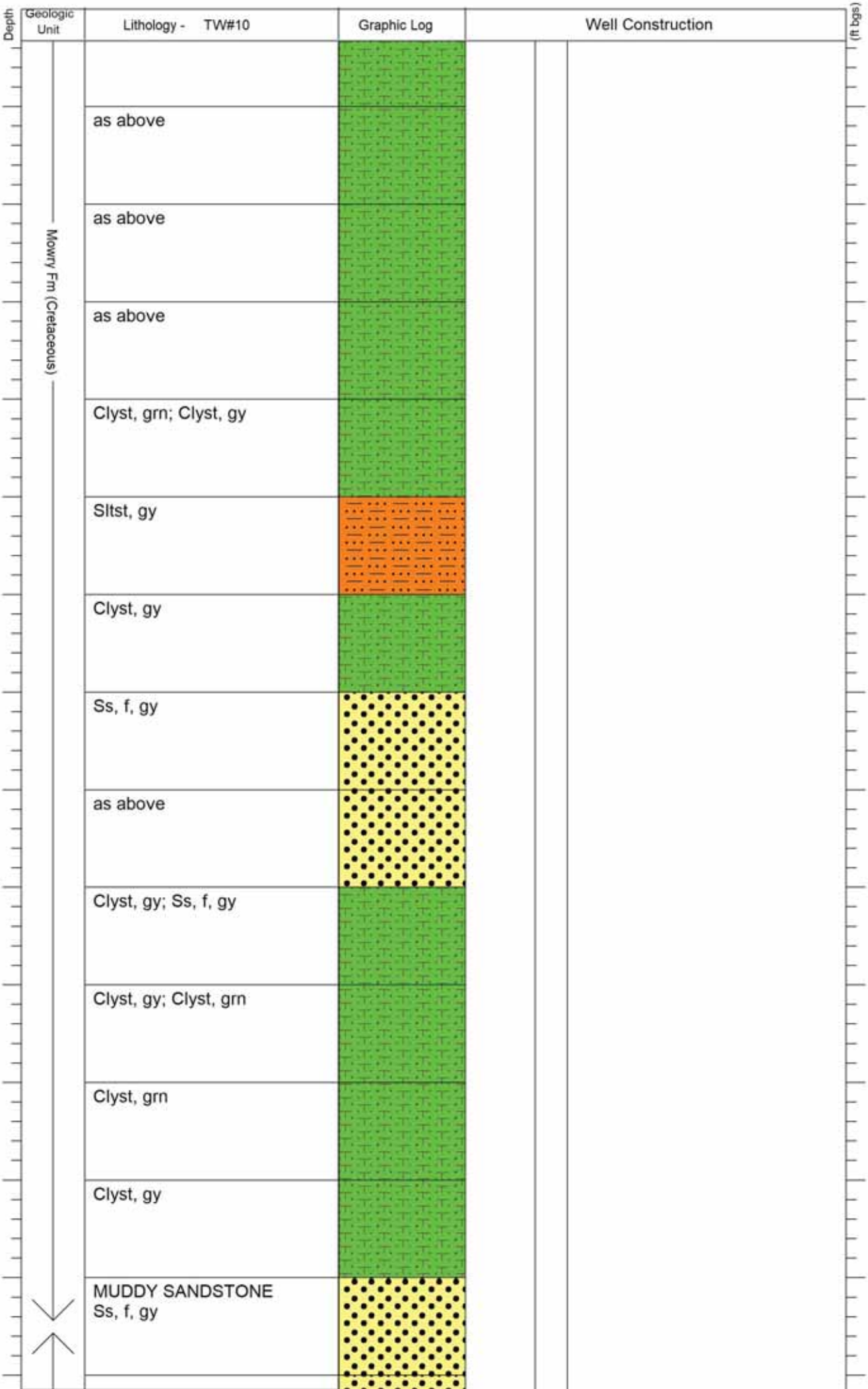
**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

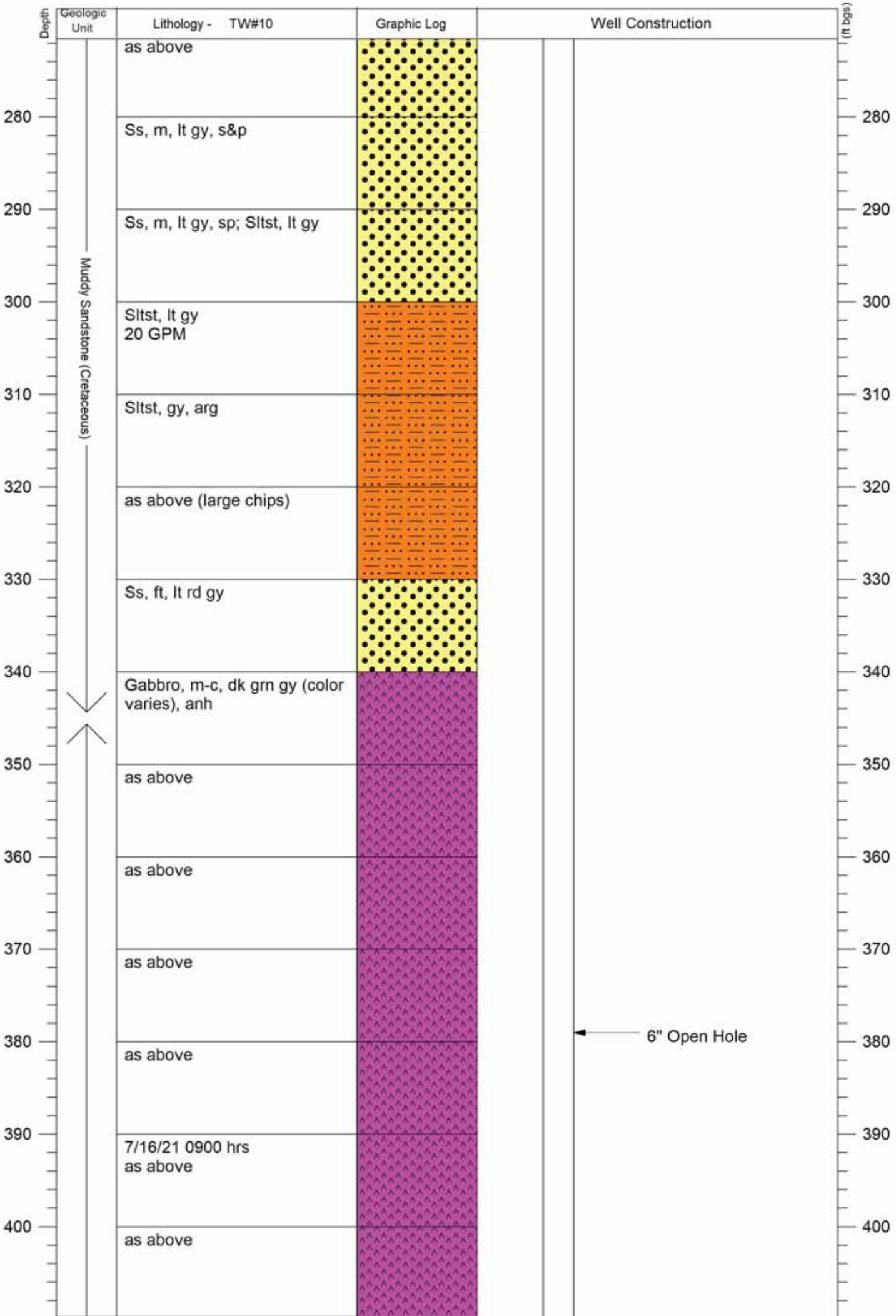
End of simulation.

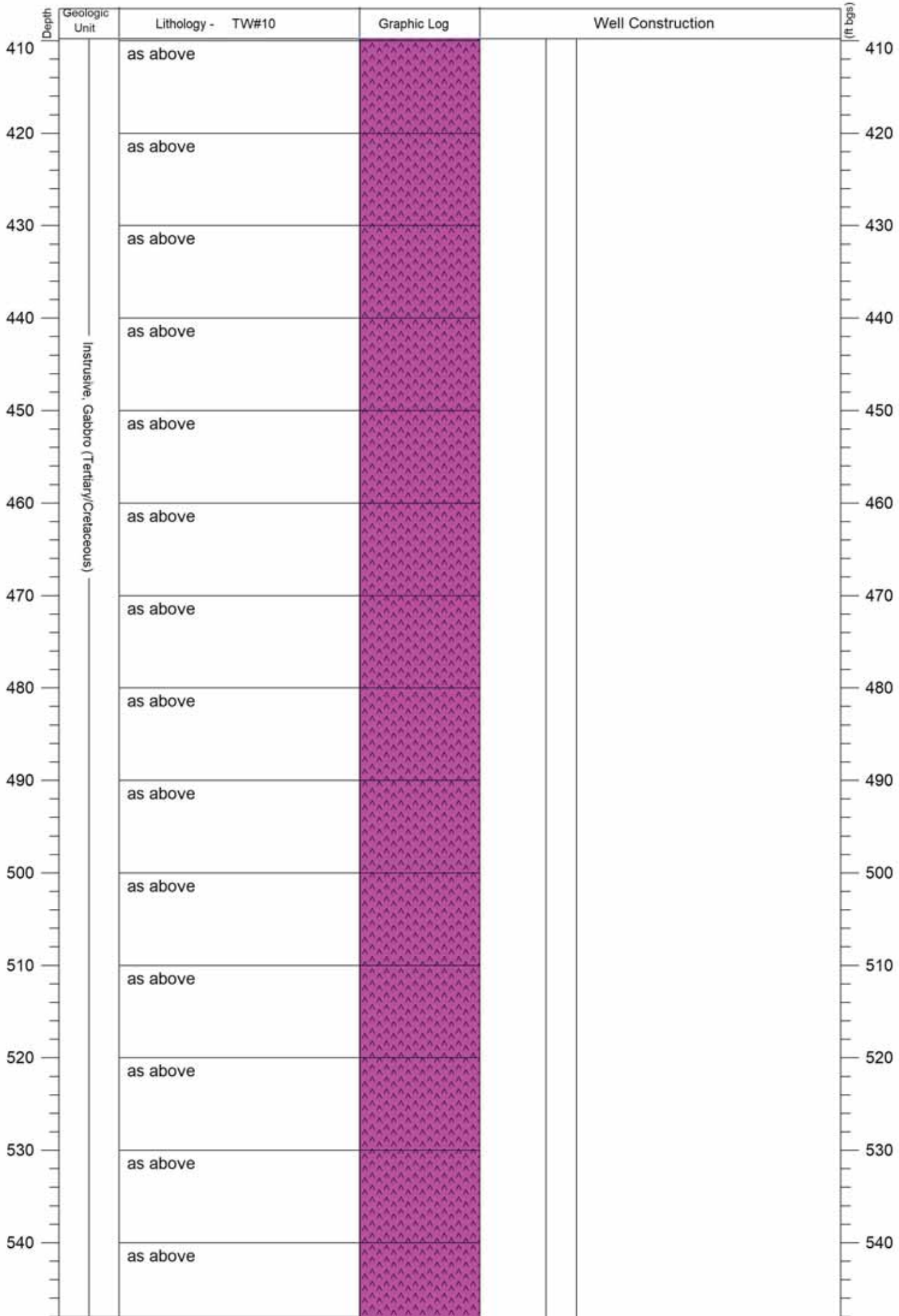
Reading input data for simulation 2.

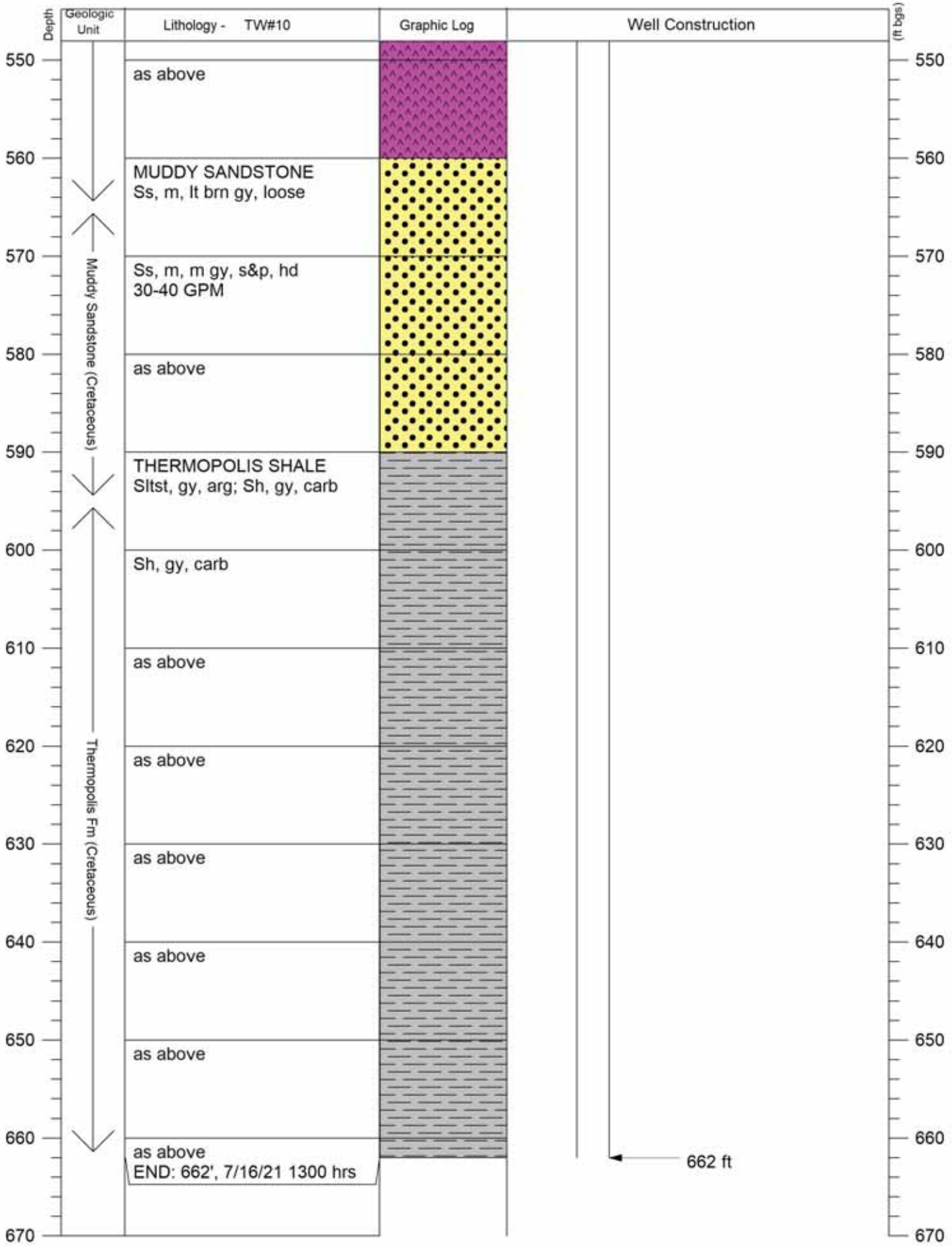
ATTACHMENT C
TEST WELL #10 LOG AND SAMPLE PHOTOS


Depth
Geologic Unit
Lithology - TW#10
Graphic Log
Well Construction
(ft bgs)
Grab samples collected at bottom depth of interval. Samples caught in strainer or 5-gal bucket.
START: 7/14/21 1245 hrs
TILL
Clay, sndy, slty, yel-brn
Gravel, sndy, slty, clyy, brn (TILL)
as above
Clay, tr snd/grvl, yel
Gravel and clay, yel
Clay, yel
MOWRY FM
Clay, gy
Clyst, gy, tr bent
Ss, f-m, s&p, lt ol gy
10 GPM
7/15/21 0900 hrs
Claystone, brn gy, tr pyr
as above
Sltst, grn gy, sndy, clyy
Clyst, gy, occ bent
as above
Glacial Till (Quaternary)
Bentonite powder, continuous feed
6-5/8" Steel Casing, 17lbs/ft, 0.25" Wall
96 ft
SWL 129 ft bgs 7/20/21
0
10
20
30
40
50
60
70
80
90
100
110
120
130

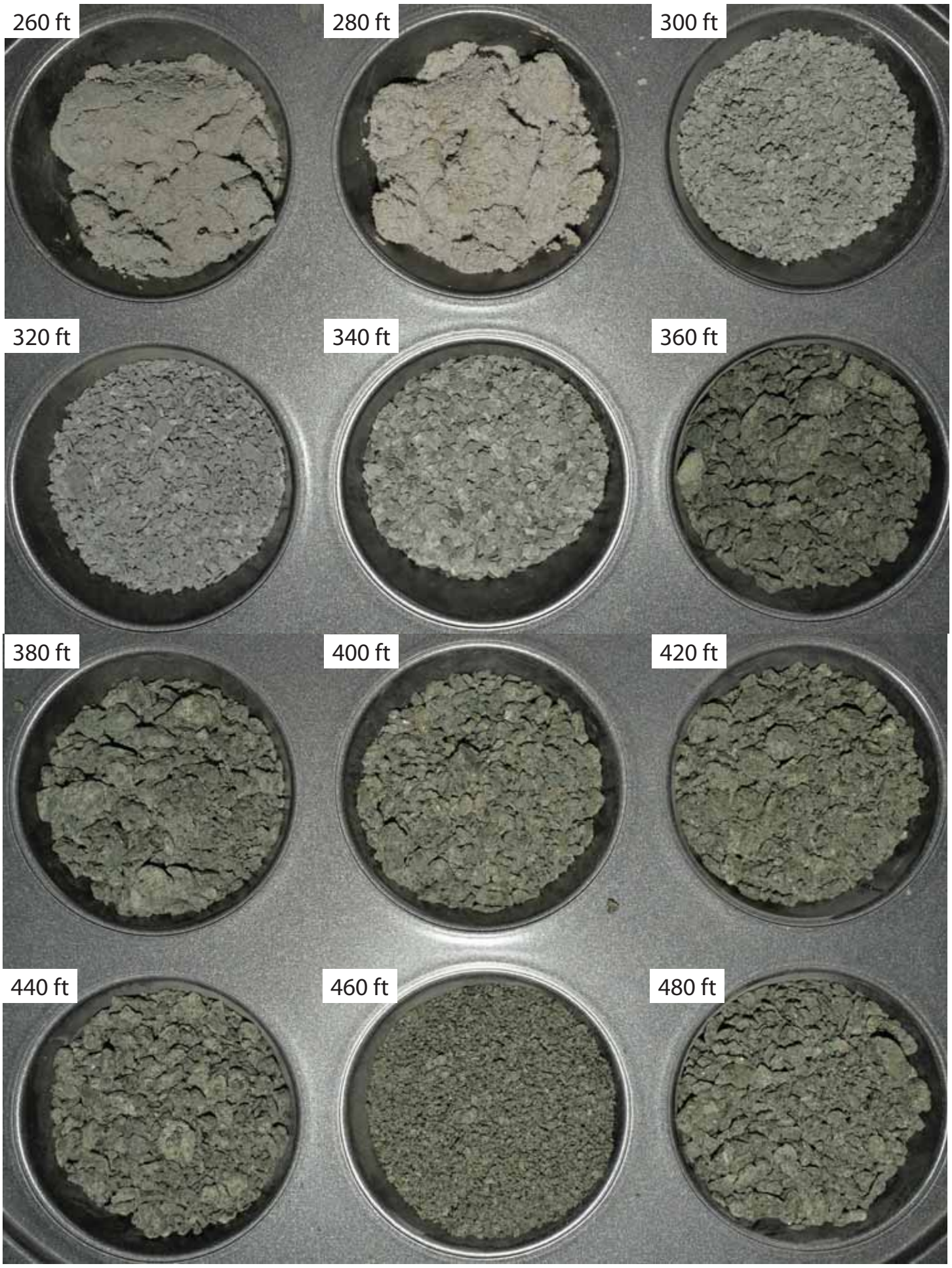

Depth
Geologic Unit
Lithology - TW#10
Graphic Log
Well Construction
(ft bgs)
Mowry Fm (Cretaceous)
as above
as above
as above
Clyst, grn; Clyst, gy
Sltst, gy
Clyst, gy
Ss, f, gy
as above
Clyst, gy; Ss, f, gy
Clyst, gy; Clyst, grn
Clyst, grn
Clyst, gy
MUDDY SANDSTONE
Ss, f, gy
140
150
160
170
180
190
200
210
220
230
240
250
260
270

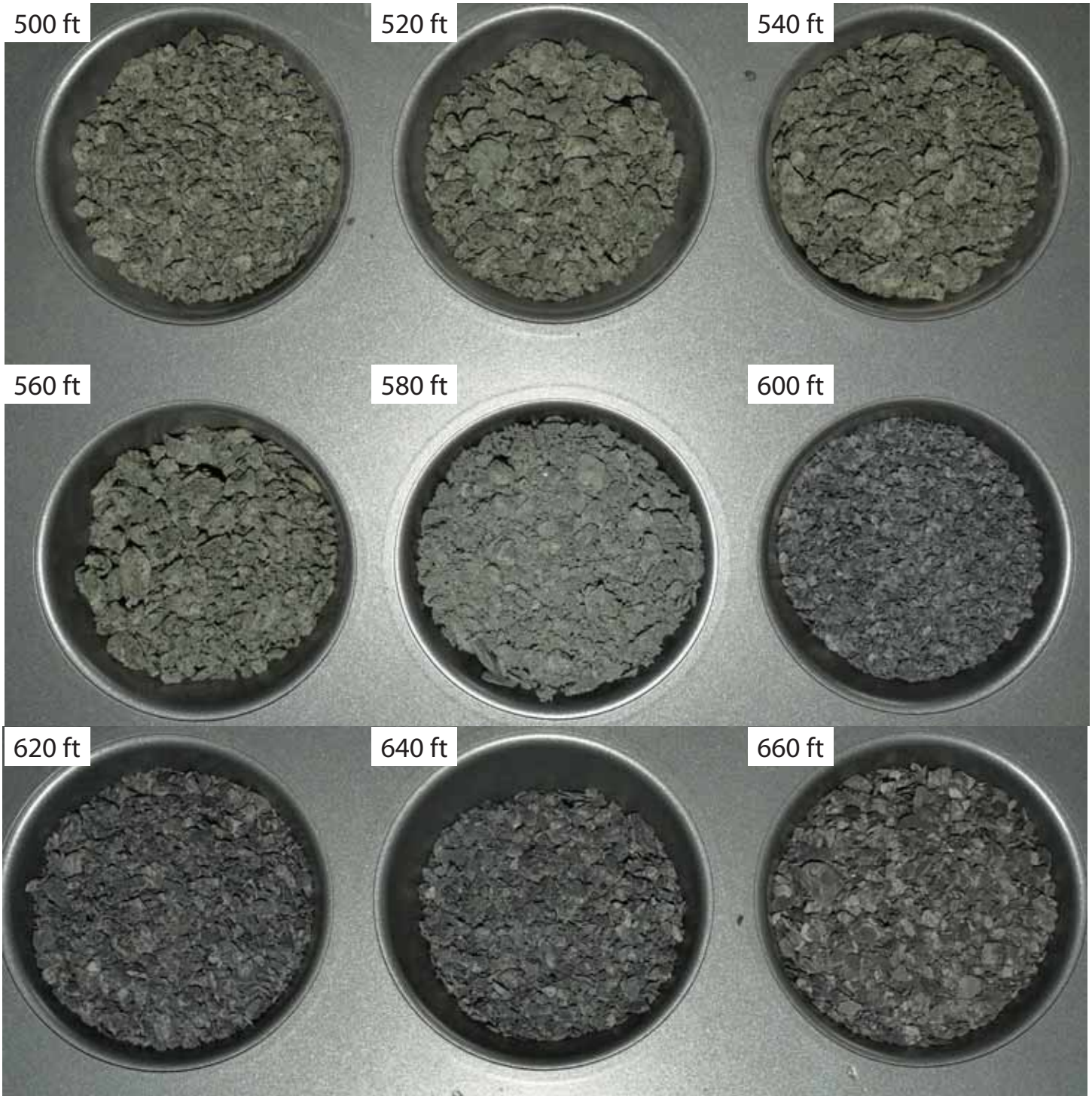

Depth
Geologic Unit
Lithology - TW#10
Graphic Log
Well Construction
(ft bgs)
Muddy Sandstone (Cretaceous)
as above
Ss, m, lt gy, s&p
Ss, m, lt gy, sp; Sltst, lt gy
Sltst, lt gy
20 GPM
Sltst, gy, arg
as above (large chips)
Ss, ft, lt rd gy
Gabbro, m-c, dk grn gy (color varies), anh
as above
as above
as above
as above
7/16/21 0900 hrs
as above
as above
6" Open Hole
280
290
300
310
320
330
340
350
360
370
380
390
400


Depth
Geologic Unit
Lithology - TW#10
Graphic Log
Well Construction
(ft bgs)
Instrusive, Gabbro (Tertiary/Cretaceous)
as above
410
420
430
440
450
460
470
480
490
500
510
520
530
540


Depth
Geologic Unit
Lithology - TW#10
Graphic Log
Well Construction
(ft bgs)
550
560
570
580
590
600
610
620
630
640
650
660
670
as above
MUDDY SANDSTONE
Ss, m, lt brn gy, loose
Ss, m, m gy, s&p, hd
30-40 GPM
as above
THERMOPOLIS SHALE
Sltst, gy, arg; Sh, gy, carb
Sh, gy, carb
as above
as above
as above
as above
as above
as above
END: 662', 7/16/21 1300 hrs
662 ft
Muddy Sandstone (Cretaceous)
Thermopolis Fm (Cretaceous)


20 ft
40 ft
60 ft
80 ft
100 ft
120 ft
140 ft
160 ft
180 ft
200 ft
220 ft
240 ft


260 ft
280 ft
300 ft
320 ft
340 ft
360 ft
380 ft
400 ft
420 ft
440 ft
460 ft
480 ft


500 ft
520 ft
540 ft
560 ft
580 ft
600 ft
620 ft
640 ft
660 ft

ATTACHMENT E – TEST WELL TW#9

MEMORANDUM

To: Ron Edwards, Jim Muscat
Big Sky County Water and Sewer District No. 363

Fr: Mark Cunnane

Re: 2020 Mountain Test Wells – Test Well TW#9

WESTERN GROUNDWATER SERVICES
6595 Bear Claw Lane • Bozeman, MT 59715
(406) 585-5947

1. INTRODUCTION

Test well TW#9 was drilled to 100-ft below ground near to the Thunder Wolf chairlift on property owned by Big Sky Resort LLC (**Figure 1**). Prior to site work, Gaston Engineering completed a property boundary survey to verify the property ownership of the well site. The well was located on the Big Sky Resort LLC parcel approximately 12-feet south of the surveyed property line.

Well drilling was terminated because the owner of the access road to the well site, Middle Fork Properties, LLC (MFP), prohibited use of the road by the driller. This prohibition appears to be intended to block the District from drilling the test well.

Well sites in this area had been identified in 2008 in the District's Source Water Capacity Plan. The target is the lower Kootenai formation in the east limb of the Andesite Mountain anticline. The Kootenai formation underlies glacial till that is partially incised by the Middle Fork West Gallatin River.

Three wells were drilled on the MFP property by a prior land owner in fall 2008 (MFM #1, MFM #2, and MFM#3). These wells appear to develop groundwater from the upper Kootenai formation. They are presently not in use and were acquired by MFP when they purchased the property.

2. WELL CONSTRUCTION

Test well TW#9 was intended to fully penetrate the Kootenai formation to a depth of 400- to 600-ft below ground. The well was drilled to 100-ft and is now completed with 6-inch diameter steel casing cemented into a 10-inch diameter borehole (**Figure 2**). It has been capped with a flange adapter and flange plate. It can be re-entered and drilled open hole to the target depth at a future time.

Based on geological mapping (USGS Ennis quadrangle 1:100,000), the surface material at the drill site is glacial till that overlies the Kootenai formation. The Kootenai formation dips about 30- to 40-degrees to the east. The borehole is projected to enter approximately the lower 50% of the formation.

The upper 45-ft of the borehole penetrated glacial till consisting of clay to boulders and was low permeability. Bedrock was encountered at 45-ft and continued to the bottom of the borehole. Bedrock samples were primarily sandstone with similarity to the basal sandstone of the Thermopolis except for the sample at 100 ft which was much coarser (**Figure 3**). More drill depth and samples are needed to verify the geology. There was good water production from the well at 55- to 60-ft below ground, which declined with depth.

A history report for the well construction work is attached and includes a budget detail. The District has spent $18,280 on driller fees for the project, and $8,382 on consulting services for a total investment of $26,662. Surveying fees are not included in this estimate.

PROPERTY & WELL SURVEY NEAR THUNDERWOLF SKI TERMINAL

GASTON ENGINEERING & SURVEYING, PC
PROFESSIONAL PROGRESSIVE PERSONAL
P.O. BOX 861
BOZEMAN, MT 59771
(406) 586-0588
DRAWN BY: BW
CHECKED BY: JO
DRAWING DATE: 071922
REVISION DATE:

PROPERTY LINE SURVEY
THUNDERWOLF AREA
PLAN VIEW
PROJECT ID# 22-552
BIG SKY, MT

IF THIS LINE DOES NOT MEASURE 1", THE DRAWING IS NOT SCALED CORRECTLY.

PROJECT: 22-552
DRAWING: 22-552_EXHIBIT 071922.dwg
TAB: EXHIBIT

SHEET 1 OF 1

Figure 1. Location Map

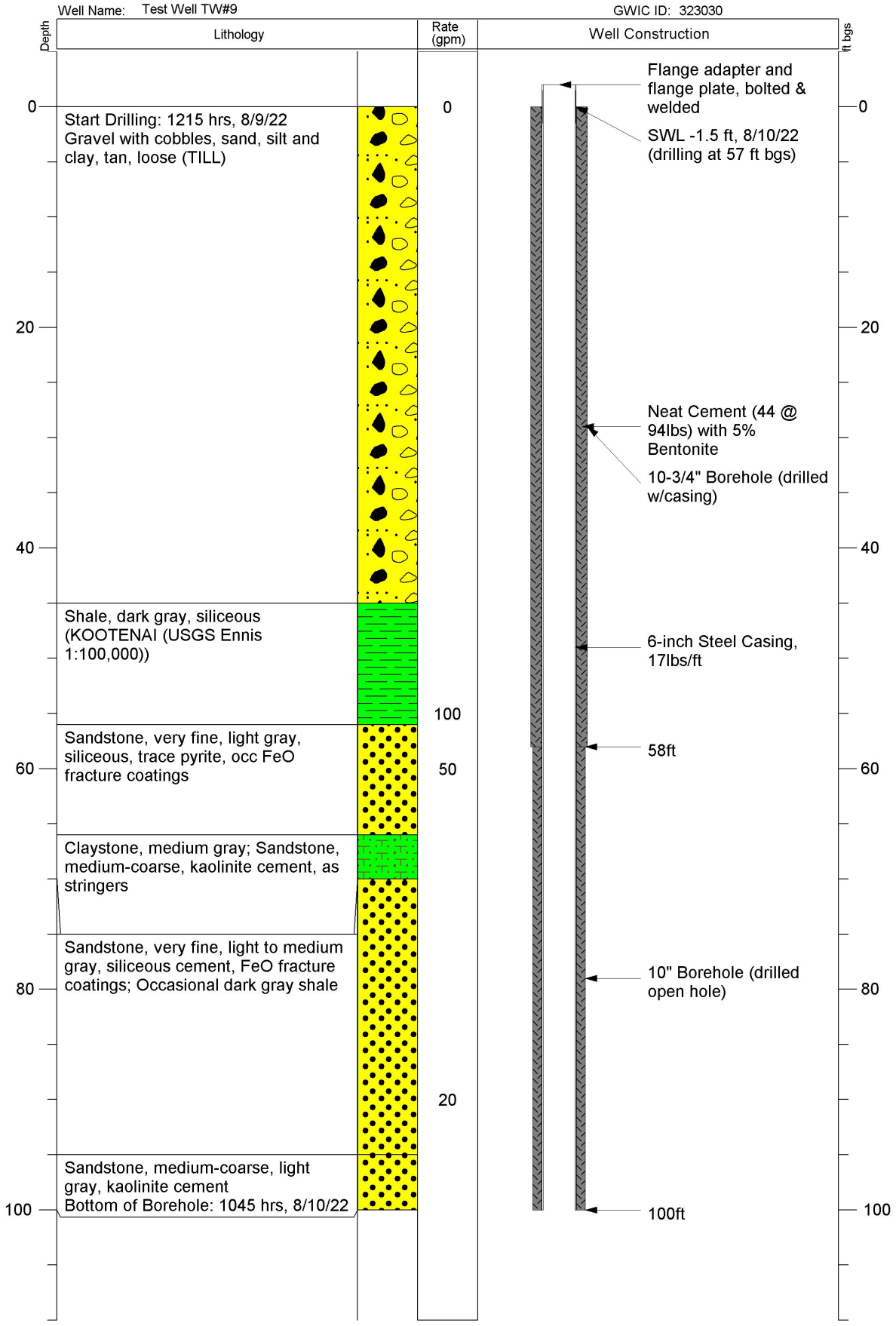


Figure 2. TW#9 As-Built Log

Figure 3. TW#9 Sample Photos

HISTORY OF HOLE
BIG SKY WSD, MTN TEST WELL PROJECT

OWNER:	Big Sky County Water & Sewer District #363		
	Big Sky, MT		
	Jim Muscat (406) 581-6138		
	Ron Edwards (406) 995-2660		
HYDROGEOLOGIST:	Western Groundwater Services, LLC		
	Bozeman, MT (406) 585-5947		
	Mark Cunnane (406) 579-1493		
CONTRACTOR:	Bridger Drilling, Inc.		Potts Drilling Inc. (TW#7 Pumping Test, Nov-Dec, 2020)
	Bozeman, MT (406) 388-7227		
	Tyler Sampson (406) 581-1205		
	Curt Sampson (406) 581-4292		
NOTICE TO PROCEED:	**9/15/2020**		**Bold = payable quantity**
CONTRACT TIME:	**696**		
TOTAL FEES TO-DATE:	**$ 200,789.50**		

DATE	DAY	TIME	ACTIVITY
8/8/2022	Mon	693	TEST WELL TW#9 (Kootenai, west of Thunder Wolf Chairlift) Mobilize drilling equipment to site
8/9/2022	Tue	694	**C5-1 Mobilization 1 EA; C5-2 10" Drilling with Casing 56 LF**
8/10/2022	Wed	695	**C5-2 10" Drilling with Casing 44 LF** (open hole)
8/11/2022	Thu	696	Preparation for cementing 6" Casing
8/12/2022	Fri	697	**C5-3 Set and Cement 6" Casing 104 LF** 44 sacks @ 94lbs + 235lbs bentonite
8/13/2022	Sat	698	No site work completed
8/14/2022	Sun	699	No site work completed
8/15/2022	Mon	700	No site work completed
8/16/2022	Tue	701	No site work completed
8/17/2022	Wed	702	No site work completed
8/18/2022	Thu	703	No site work completed
8/19/2022	Fri	704	No site work completed
8/20/2022	Sat	705	No site work completed
8/21/2022	Sun	706	No site work completed
8/22/2022	Mon	707	Cap well and demobilize equipment from site
	END HISTORY REPORT		

BIG SKY MTN VILLAGE TEST WELLS 2020

BEDROCK - NON-ARTESIAN					JOB TOTAL---------->			$ 200,789.50	TD (ft)	80	77	738	1040	730	396	662	840	100
					Bridger Drilling ---------->			$ 187,264.50	BUDGET	$ 5,170.00	$ 5,170.00	$ 24,250.00	$ 24,250.00	$ 28,210.00	$ 28,210.00	$ 28,210.00	$ 24,250.00	$ 63,500.00
					Potts Drilling ---------->			$ 13,525.00	ACTUAL	$ 5,480.00	$ 3,772.00	$ 21,988.00	$ 30,315.00	$ 44,189.00	$ 32,713.50	$ 19,212.00	$ 24,840.00	$ 18,280.00
									B-A	$ (310.00)	$ 1,398.00	$ 2,262.00	$ (6,065.00)	$ (15,979.00)	$ (4,503.50)	$ 8,998.00	$ (590.00)	$ 45,220.00
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total		TW#3	TW#4	TW#5	TW#6	TW#7	TW#8	TW#10	TW#11	TW#9
B-1.1	Mobilization	3	LS	$ 1,000.00	$ 3,000.00		4	$ 4,000.00				1	1			1	1	
B-1.2	6" Drilling with Casing	240	LF	$ 36.00	$ 8,640.00		680	$ 24,480.00				180	200			100	200	
B-1.3	6" Drilling Open Hole	2160	LF	$ 26.00	$ 56,160.00		2600	$ 67,600.00				558	840			562	640	
B-1.4	Development	18	HR	$ 275.00	$ 4,950.00		1	$ 275.00					1					
				TOTAL	$ 72,750.00			$ 96,355.00										
BEDROCK - ARTESIAN												$ 21,988.00	$ 30,315.00			$ 19,212.00	$ 24,840.00	
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total										
B-2.1	Mobilization	4	LS	$ 1,000.00	$ 4,000.00		2	$ 2,000.00						1	1			
B-2.2	10" Drilling with Casing	320	LF	$ 50.00	$ 16,000.00		262	$ 13,100.00						122	140			
B-2.3	Set and Cement 6" Casing	320	LF	$ 35.50	$ 11,360.00		262	$ 9,301.00						122	140			
B-2.4	6" Drilling Open Hole	2880	LF	$ 26.00	$ 74,880.00		864	$ 22,464.00						608	256			
B-2.5	Development	24	HR	$ 275.00	$ 6,600.00		3.5	$ 962.50						3	0.5			
				TOTAL	$ 112,840.00			$ 47,827.50						$ 28,064.00	$ 19,763.50			
ALLUVIUM																		
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total										
B-3.1	Mobilization	2	LS	$ 1,000.00	$ 2,000.00		2	$ 2,000.00		1	1							
B-3.2	6" Drilling with Casing	140	LF	$ 36.00	$ 5,040.00		157	$ 5,652.00		80	77							
B-3.3	Development	12	HR	$ 275.00	$ 3,300.00		0	$ -										
				TOTAL	$ 10,340.00			$ 7,652.00										
				TOTAL AS BID	**$ 195,930.00**					$ 3,880.00	$ 3,772.00							
CHANGE ORDERS																		
Item No.	Description	Qty	Units	Rate	Total		Act. Qty.	Actual Total										
C1	Contract time extension	0	NA	$ -	$ -													
C2	TW#3 Well Abandonment	80	LF	$ 20.00	$ 1,600.00		80	$ 1,600.00		80								
C3-1	Wellhead Valve	1	EA	$ 1,100.00	$ 1,100.00		1	$ 1,100.00						1				
C3-2	Downhole casing cutting	1	EA	$ 1,500.00	$ 1,500.00	$ 4,200.00	1	$ 1,500.00						1				
C4-1	Temp Pumping System TW#8	1	EA	$ 3,050.00	$ 3,050.00		1	$ 3,050.00							1			
C4-2	Pumping Test Hourly TW#8	76	HRS	$ 125.00	$ 9,500.00	$ 12,550.00	76	$ 9,500.00							76			
NA	TW#8 Sounding Tube & Seal	1	EA	$ 400.00	$ 400.00		1	$ 400.00							1			
Potts	Temp Pumping System TW#7	1	EA	$ 6,305.00	$ 6,305.00		1	$ 6,305.00						1				
Potts	Pumping Test Hourly TW#7	76	HRS	$ 95.00	$ 7,220.00	$ 13,525.00	76	$ 7,220.00						76				
C5-1	TW#9 Mobilization	1	EA	$ 1,000.00	$ 1,000.00		1	$ 1,000.00										1
C5-2	10" Drilling with Casing	120	LF	$ 100.00	$ 12,000.00		100	$ 10,000.00										100
C5-3	Set and Cement 6" Casing	120	LF	$ 70.00	$ 8,400.00		104	$ 7,280.00										104
C5-4	6" Drilling Open Hole	500	LF	$ 52.00	$ 26,000.00													
C5-5	Development	2	HR	$ 275.00	$ 550.00													
C5-6	Wellhead Gate Valve Installed	1	EA	$ 1,500.00	$ 1,500.00													
C5-7	Casing Cutting	1	EA	$ 1,500.00	$ 1,500.00													
C5-8	Temporary Pumping System	1	EA	$ 3,050.00	$ 3,050.00													
C5-9	Pumping Test Hourly	76	HR	$ 125.00	$ 9,500.00	$ 63,500.00												
				TOTAL	$ 94,175.00			$ 48,955.00		$ 1,600.00				$ 16,125.00	$ 12,950.00			$ 18,280.00
		TOTAL WITH CHANGE ORDERS			**$ 290,105.00**	$ 226,605.00												

Western Groundwater Services

8/26/2022