Technical Memorandum No. STMD-8312-02-ABV

St. Mary Diversion Dam Aquifer Testing (Abbreviated Version)

Milk River Project, MT
Missouri Basin Region

U.S. Department of the Interior **December 2022**

Mission Statements

The Department of the Interior (DOI) conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover Photo – View of well PW-22-1 used for aquifer testing.

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Prepared by:

Bureau of Reclamation
Technical Service Center
Denver, Colorado

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Acronyms and Abbreviations

bgs	Below Ground Surface
DOI	Department of Interior
FER	Field Exploration Request
ft	Feet
gpm	Gallons per Minute
HSA	Hollow Stem Auger
I.D.	Inner Diameter
NTU	Nephelometric Turbidity Unit
O.D.	Outer Diameter
OW	Observation Well
psig	Pounds per Square Inch Gauge
PVC	Polyvinyl Chloride
PW	Pumping Well

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I. Background

St. Mary Diversion Dam

St. Mary Diversion Dam and Canal are components of the Milk River Project, located in northern Montana, approximately 0.75 miles downstream of Lower St. Mary Lake in Glacier County shown below in Figure 1. The existing diversion dam spans the St. Mary River and is a 198-foot-long concrete overflow weir that is approximately 6 feet in height and was constructed in 1915. The structure incorporates a 5-foot-deep concrete cutoff sited at the upstream toe. The dam diverts waters into the St. Mary Canal through a turnout consisting of eight 5-foot square slide gates located on the west bank of the river. The proposed replacement of the existing structures is due to both aging infrastructure and concerns over developing adequate fish passage at the dam and from the canal back to the river.

The Milk River Project irrigates about an eighth of a million acres of land extending from near Havre, Montana to near Nashua, Montana. Project water originates from glacial runoff from the east slope of the Rocky Mountains in Glacier National Park and is impounded by Lake Sherburne Dam. Waters are then routed to Lower St. Mary Lake through Swiftcurrent Creek. Water is subsequently released and diverted from St. Mary River into the 29-mile-long St. Mary Canal through the aforementioned structures. After intercepting the Milk River, the conveyance continues for over 200 miles through Alberta before re-entering the United States, ultimately being impounded in either the Fresno or Nelson Reservoirs where it is stored until it is needed for irrigation. The earliest work on the Milk River Project was on the St. Mary Canal which was constructed from 1907 to 1915 [1].

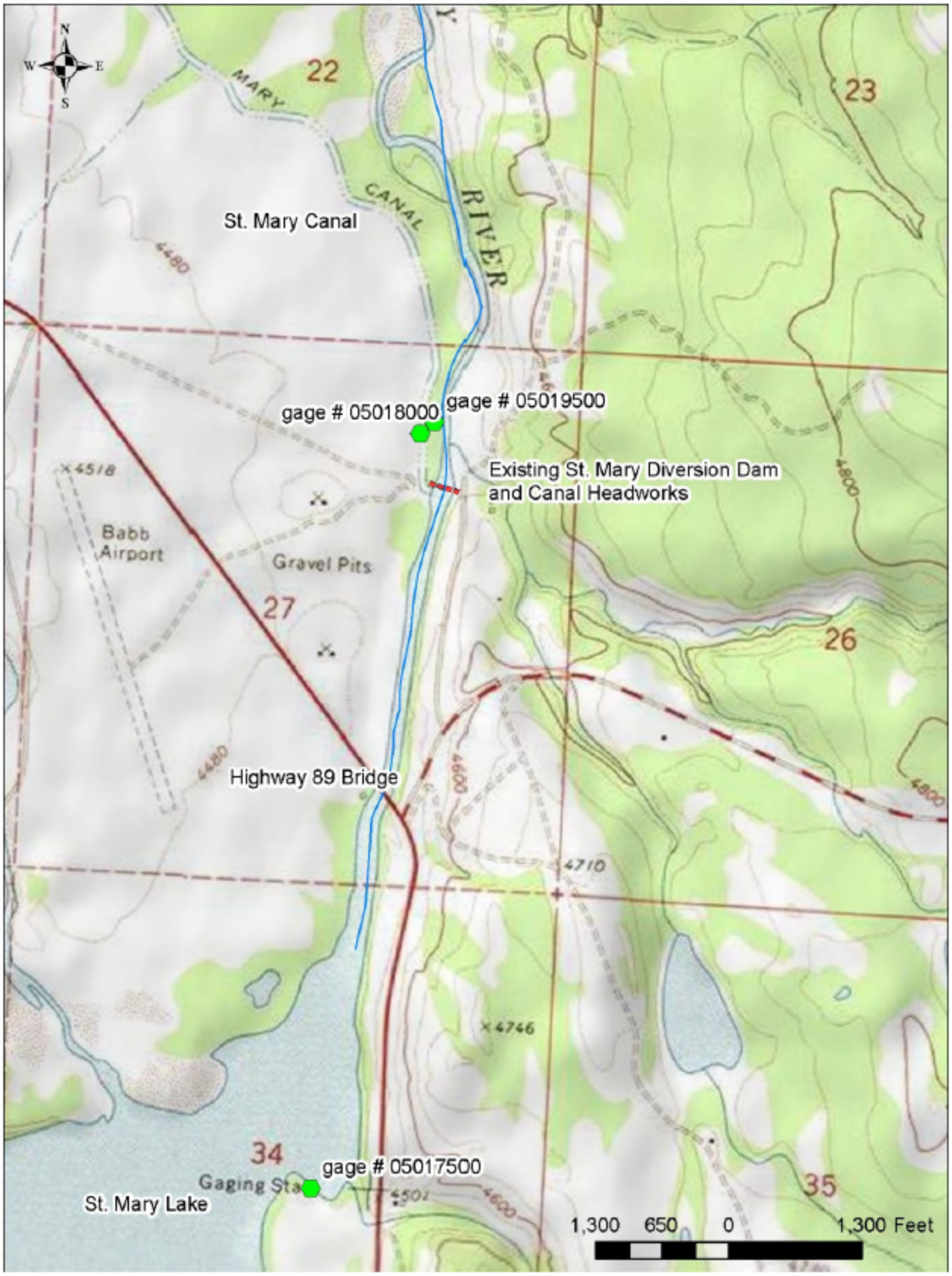


Figure 1. – St. Mary Diversion Dam Location Map.

Historical Groundwater Monitoring and Testing

Groundwater monitoring and testing has been completed at St. Mary Diversion Dam during the following exploration programs: 2003 [1], 2011 [2], 2013 [3], and 2015 [3]. Most of these explorations recorded groundwater within approximately one foot of the surface water observed in the St. Mary River or within the St. Mary Diversion Canal.

The first known attempt at groundwater testing was accomplished in a Reclamation program in 2003 [1]. Reliability of this testing was suspect since a 5-7/8-inch tri-cone roller rock bit was used to drill the holes and cuttings were only visually logged. No development of this hole was documented. The casing was seated against the sidewalls and the bottom of the hole remained open. A constant head test was completed by pouring a metered amount of water into the casing and a constant head was maintained for a given amount of time. This method had flow rates ranging from 0.07-7.85 gallons per minute (gpm).

In 2011, three test pits were dug, TP11-1BC, TP11-2BC, and TP11-3BC, along the proposed alignment of the temporary bypass channel for diversion of the St. Mary River [2]. The groundwater flow rate was estimated at the bottom of the test pits. The groundwater flowing into the bottom of TP11-1BC and -3BC was visually estimated to be 45-50 gpm [2]. The estimated groundwater flowing into the bottom of TP11-2BC was visually estimated to be 30 gpm [2]. The observations were made by watching the bottom of each test pit once it was excavated until the sidewalls collapsed. It was noted that the originally turbid water would clear over time. A submersible pump was intended to be used to obtain a more accurate flow rate; however, the test pits caved too quickly prior to the pump being used [2].

In 2013, eight observation wells, OW-13-A, -B2, -C, -D, -E, -F, -G, and -H, were advanced to record ground water readings, see Figure 2 [3]. The readings in the observation wells tend to reflect the surface water level in the St. Mary River or the surface water in the St. Mary Diversion Canal, whichever is closest. These 2-inch diameter observation wells were attempted to be stressed using a small diameter submersible pump (Grundfos MP1) and transducers were installed in four of the wells not containing the pump [3]. However, this pump capacity was limited to 4.2 gpm and was not sufficient to stress the aquifer. Thus, no conclusions were drawn from this investigation.

In 2015, a 6-inch diameter pump well, PW-15-01, was installed to facilitate a pump test. Transducers were placed within OW-13-A, -B2, -C, -D, and -E [3]. These transducers were installed to a troll hub and water levels were measured using In-Situ virtual software [4] to monitor the test. The results of this test established a pump rate of around 200 gpm for 29 hours [3]. The hydraulic conductivity of the alluvium was calculated at 877-1,990 ft/day [3]. These hydraulic conductivities were outlined in a table in the 2017 Geology Report [3];

however, no supporting analyses documentation was included within the report. The following is a list of omitted documentation: drawdown/recovery plots, analysis methodology and assumptions, and aquifer characteristic assumptions (confined/unconfined, thickness, anisotropy).

The lack of documentation increases the uncertainty in the calculation of hydraulic conductivity. The results could not be checked, duplicated, or verified. For this reason, it was recommended in 2022 to drill an additional pump well to stress the aquifer, monitor the aquifer within the existing observation wells, complete a step test to determine the maximum, sustainable pump rate, and complete a pump out test.

II. Site Geology

St. Mary Diversion Dam and headworks structure are founded on glacial-alluvium foundation materials with bedrock located on the right (east) abutment of the diversion dam. The project site is less than 10-miles from the base of the Rocky Mountain Range, and only about 20 miles from the high peaks of the continental divide. Mass wasting and depositional processes have reworked the landscape several times through geologic time.

Glacial till and glacial outwash mantle the surface across the St. Mary River basin. Contributions from each drainage that flows off the surrounding mountains contain alluvial fan deposits. Terraces include lateral moraines on both sides of the floodplain and extend to Babb, Montana, which is approximately 1.5 miles to the northwest of the diversion structure.

The historic confluence of Swiftcurrent Creek and the St. Mary River is 500-1000 feet upstream of the diversion structure. The upper 10 to over 50 feet of foundation sediments are composed of riverbed alluvium, reworked alluvial fan deposits, and reworked glacial deposits. The sediments will be referred to as alluvial deposits for continuity with previous reports and to avoid confusion since differentiation between depositional units is very difficult.

Geologic Units

The following geologic unit descriptions are adapted from the 2017 Geology Report [3].

1. Fill (fill)

The fill consists of a mixture of construction produced materials that includes access roadways, diversion canal embankments, abutments to structures, and waste piles from construction operations. These materials are derived from the structure and diversion canal excavation and foundation materials and are often differentiated only by observing the topography/proximity to structures. The fill unit was not encountered during the drilling for any of the aquifer testing performed at St. Mary Diversion Dam.

2. Quaternary Glacial-Alluvium Deposits (Qal)

This unit is a heterogeneous mixture of gradations including a large percentage of cobbles and boulders by volume in the upper 20-30 feet of the foundation. The complexity of erosion and deposition at the project site produces classifications that contain silt and clay percentages as low as a trace to 5% in high energy depositional environments and as high as 25% in low energy lacustrine environments. Petrographic analysis of foundation materials was not completed, but recognized material types include sedimentary clasts of sandstone, siltstone, argillite, shale, limestone, and dolomite; igneous clasts of granite and gabbro; and metamorphic clasts of quartzite with several colors represented.

Flooding from the St. Mary River or even Lower St. Mary Lake may be the possible source of these sediments as the river and/or lake advanced and retreated, depending on the amount of ice or morainal material blocking the outlet of the current lake and blockages further downstream. Since the diversion structure is near the original junction of St. Mary River and Swiftcurrent Creek, local bedrock is scoured deep across the channel section and left abutment than would be normal along the flood plain of the current St. Mary River. From recent investigations, the depth of the bedrock is approximately 78 feet below ground surface (bgs) in PW-22-1A on the left abutment.

Boulders are common on the ground surface onsite, with the maximum dimension of approximately 3 feet in diameter. Cobbles are mostly hard and subangular to subrounded. Gravels are equally coarse to fine, hard to very hard, angular to subrounded, and contain about 10% to 15% elongated and flat shapes. Sand is also represented equally by coarse, medium, and fine fractions that are hard, subangular to rounded rock fragments. The elongated and flat shapes are not as well represented in sand.

3. Two Medicine Formation (Ktm)

Bedrock at the diversion structure site is the Two Medicine Formation which was deposited between the western shoreline of the Late Cretaceous interior seaway and the eastward advancing margin of the Cordilleran Overthrust Belt. The Two Medicine Formation is mostly deposited by rivers and deltas consisting of greenish-gray, fine-grained, hard sandstone and/or siltstone containing clay with local nodular limestone. This sedimentary rock unit can be massive to crossbedded and locally may contain some coal. Cementation is primarily calcium carbonate but may also include silica.

III. Well Information

Pump well, PW-22-1, was used for the 2022 aquifer testing performed at St. Mary Diversion Dam and is summarized in Table 1, below. The well was drilled as part of the 2022 Field Exploration Request (FER). The well completion diagram for PW-22-1 was recorded and is shown in Appendix A. The locations of the pump well and ten observations wells used for the aquifer testing are show in Figure 2. The 2022 Field Exploration Geological Report was not completed at the time of the writing of this report. The following descriptions of the well were taken from the well completion diagrams, draft stick logs of the boreholes, and a survey of the wells.

Table 1. – Pump Well Information for Aquifer Testing

Well ID	PW-22-1
Northing	1701416.74
Easting	1025771.85
Ground Surface Elev. (ft)[2]	4478.6
Stickup (ft)	2.9
Top of Screen bgs[1] (ft)	12.0
Bottom of Screen bgs[1] (ft)	64.4
Bottom of Well bgs[1] (ft)	84.5

Notes: (1) bgs: below ground surface

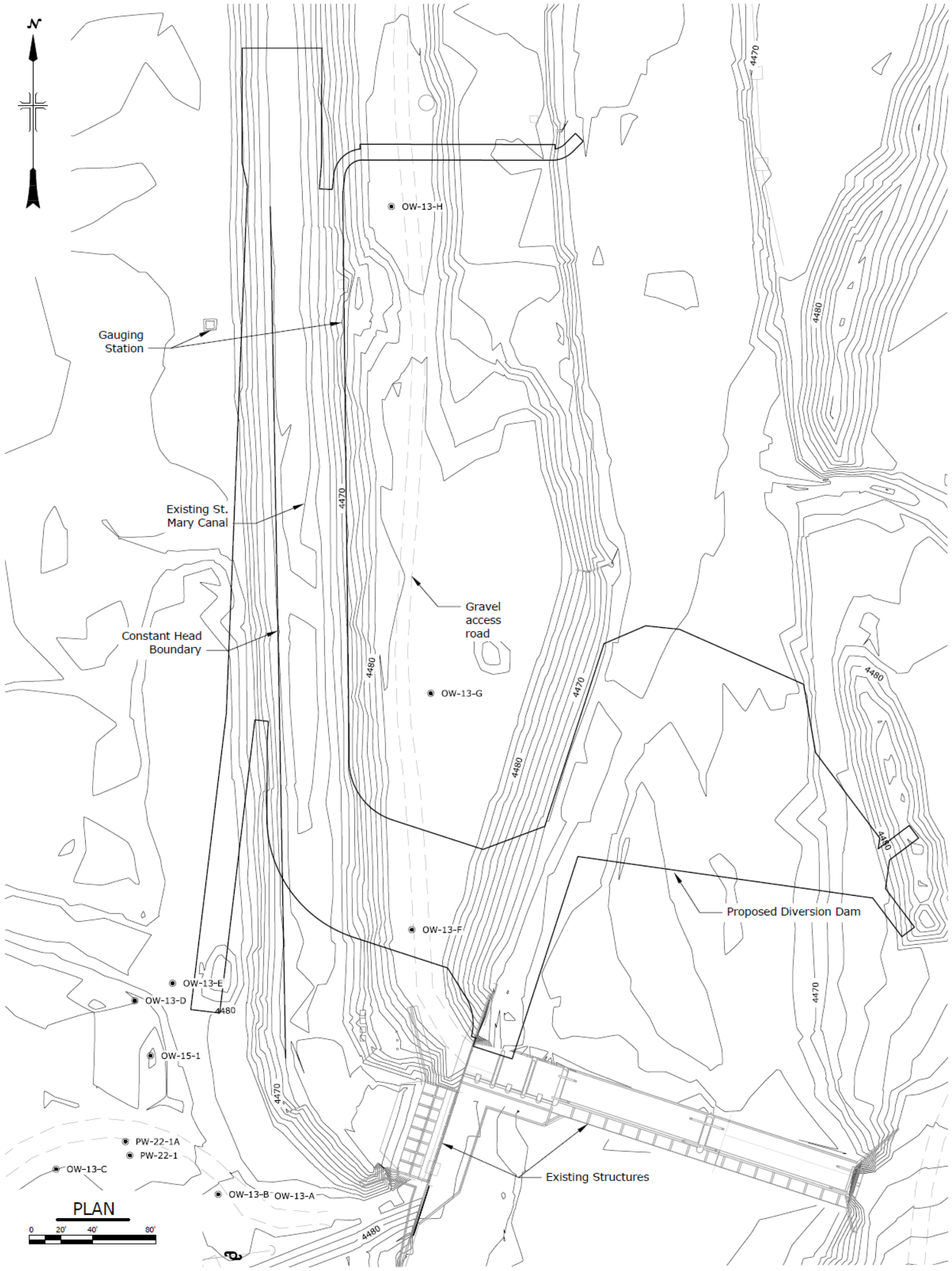


Figure 2.— Map of St. Mary Diversion Dam showing well locations used for aquifer testing.

PW-22-1

PW-22-1 was drilled with a 12-inch inner diameter ODEX downhole hammer. The outer diameter of the hole and bit was 13 inches, and the inner diameter of the casing was 12.75 inches. It was assumed the 12.75-inch diameter is a more representative diameter of the installed well due to collapse of the surrounding sands and gravel.

The well was installed with a 9.976-inch inner diameter (I.D.) and 10.75-inch outer diameter (O.D.) 304 stainless steel wire-wrapped screen and Schedule 40 Polyvinyl Chloride (PVC) of the same diameter above the screened interval. A 12.75-inch diameter metal standpipe with a metal locking cap was installed as well. A 1-inch I.D. blank PVC pipe was installed inside the casing as a stilling well for the transducer. The perforations for PW-22-1 were 0.02-inch slot width and the filter pack installed was a 1-inch-thick annular space filled with #8 to #12 sand. It was assumed the open area of the slotted section is approximately 48 square inches per foot of well screen. See Appendix A for a diagram of the well geometry and drill logs.

The well design is slightly unconventional, as there is only 1-inch-wide annular space. This was designed due to the drill rig size limitations. A larger drill bit was not easily available, and the I.D. of the casing could not be decreased without interfering with the required pump diameter. Therefore, the annular space was decreased. The purpose of the filter pack, in this case, was to make sure the surface seal did not come in contact with the slots and did not serve the typical purpose of a filter pack (which is to filter the water coming into the well and keep the foundation material in place during pumping).

The well was developed via airlifting along the entire screen length post drilling. The well was redeveloped again prior to the aquifer testing via airlifting, at the same time, all the existing wells were redeveloped.

PW-22-1A

PW-22-1A was a companion well to PW-22-1. PW-22-1A was installed using a sonic drill and was used for logging and sampling the foundation material. PW-22-1A is located approximately 9-feet northwest of PW-22-1. The sonic drill has an 8-inch diameter casing and 7-inch diameter core barrel. The well was completed as an observation well with a 2-inch diameter, Schedule 40 PVC pipe. The PVC slot size for PW-22-1A was 0.02-inch width and the filter pack installed was a 2.5-inch-thick annular space filled with #8 sand. PW-22-1A was developed via airlifting along the entire screen length prior to the aquifer testing. See Appendix A for a diagram of the well geometry and drill logs.

Observation Wells

Nine existing wells onsite were used as observation wells for the aquifer tests. The wells were drilled as part of the 2013 and 2015 geologic investigations and completed as observation wells and pumping wells.

In 2013, eight observation wells (OW-13-A through -H), were drilled using a truck mounted CME-85 drill and 4.25 inner diameter hollow stem auger (HSA) with a center bit and split barrel used for sampling. The outer diameter of the HSA was 8.5-inches. The wells were completed as observation wells with a 2-inch diameter, Schedule 40 PVC pipe. The slot size for the observation wells were not documented. The annular space was filled with filter pack material for OW-13-A and OW-13-C ranging from #8 to #12 sand. For the remaining observation wells, the filter pack material ranged from #10 to #20 sand. See Appendix A for drill logs and completion diagrams for these eight observation wells.

In 2015, pump well PW-15-01, was drilled using a truck mounted Atlas-Copco T3W with a 12-inch diameter steel casing and a rock bit with an unknown diameter. The well was completed as a pump well with a 6-inch outer diameter, 90 wire-316 stainless steel-pump well screen and Schedule 40 PVC riser pipe of the same diameter. The slot size was not documented and the annular space around the screen was filled with a filter pack material composed of ASTM C33-02A fine aggregate [5]. See Appendix A for the drill log and completion diagram for the pump well.

All the existing nine wells were developed via airlifting along the entire screen length prior to executing the aquifer test. A summary of the wells used as observations wells for the pump out test is outlined in Table 2.

Table 2. — Summary of observation well information for pump out tests

Well ID	OW-13-A	OW-13-B2	OW-13-C	OW-13-D
Northing	1,701,391.0	1,701,392.0	1,701,408.0	1,701,515.0
Easting	1,025,857.0	1,025,828.0	1,025,725.0	1,025,775.0
Ground Surface Elev. (ft)	4483.4	4481.6	4481.2	4481.2
Stickup (ft)	3.05	2.76	2.72	3.02
Top of Screen bgs[1] (ft)	23.0	24.0	23.0	25.0
Bottom of Screen bgs[1] (ft)	33.0	34.0	33.0	35.0
Bottom of Well bgs[1] (ft)	34.0	35.0	34.0	39.5
Well ID	**OW-13-E**	**OW-13-F**	**OW-13-G**	**OW-13-H**
Northing	1,701,526.0	1,701,560.0	1,701,710.0	1,702,019.0
Easting	1,025,799.0	1,025,951.0	1,025,963.0	1,025,938.0
Ground Surface Elev. (ft)	4480.7	4485.4	4485.0	4485.0
Stickup (ft)	2.20	1.74	3.66	3.26
Top of Screen bgs[1] (ft)	28.0	28.0	29.5	29.0
Bottom of Screen bgs[1] (ft)	38.0	38.0	39.5	39.0
Bottom of Well bgs[1] (ft)	39.0	40.0	40.5	40.0

Well ID	PW-15-01	Well ID	PW-22-1A
Northing	1,701,480.0	Northing[2]	1701425.48
Easting	1,025,785.0	Easting[2]	1025769.07
Ground Surface Elev. (ft)	4481.0	Ground Surface Elev.[2] (ft)	4478.6
Stickup (ft)	2.4	Stickup (ft)	2.8
Top of Screen bgs[1] (ft)	15.5	Top of Screen bgs[1] (ft)	44.1
Bottom of Screen bgs[1] (ft)	35.5	Bottom of Screen bgs[1] (ft)	54.1
Bottom of Well bgs[1] (ft)	38.0	Bottom of Well bgs[1] (ft)	56.1

Notes: (1) bgs: below ground surface

Laboratory Testing

Laboratory testing was completed on samples collected during drilling of PW-22-1A. Eleven samples were submitted to Reclamation's Provo Area Office Materials Laboratory. The samples were tested for physical properties including Atterberg limits, gradations, and hydrometer analysis. The results of the testing are summarized in Appendix B.

The results of the index testing displayed that the samples were classified predominately as a well-graded gravel with silty clay and sand (GW-GC)s, a silty, clayey gravel with sand (GC-GM)s and with layers of lean clay (CL) and silt

(ML). The plasticity index ranged from non-plastic to 17, with an average plasticity index of 6.3.

IV. Step-Drawdown Test

A step-drawdown test was performed at St. Mary Diversion Dam as part of the 2022 FER. The purpose of the step-drawdown test was to determine the maximum sustainable pump rate for the pump out test. The test was performed in PW-22-1. The equipment used and procedures followed are described below.

Equipment

The equipment used to conduct the step-drawdown tests include the following:

- In-Situ Products:
    - 10 Level TROLL 700, pressure transducer and data logger
    - USB TROLL Com
    - Rugged Cable
    - Hermit
    - Win-Situ 5 software [6]
- Water Level Measuring Tape (M-Scope)
- Pump (Grundfos stainless steel submersible pump)
    - 6-inch, 40 hp, 650 gpm, Model No. 475S400-4
- Rossum Sand Tester
- Turbidimeter
- Flow Meter
- Discharge line
    - 4-inch discharge hose
    - 6-inch steel pipe discharge line
    - 90-degree bend with plug
    - Straightening vane
    - Butterfly valve

Information regarding the transducers used for the step tests is shown in Table 3. It should be noted that all pressure transducers used during the tests are vented, resulting in a gauge pressure, psig, not an absolute pressure. Transducers in wells OW-13-A, OW-13-C, and OW-13-D had a pressure range of 15 psig. The remaining pump and observation wells' transducers had a pressure range of 30 psig.

Table 3.— Level TROLL information

Pressure Range (psig)	Depth Range (ft)	Accuracy[1] (%)	Accuracy (ft)	Accuracy (°C)
15	35	± 0.05	± 0.018	± 0.1
30	69		± 0.035	

Notes: (1) Accuracy range from -5° to 50 °C

Step-Drawdown Test Procedure

1. Quiet Period and Barometric Pressure

On April 30th, 2022, vented transducers were set up down the following wells: PW-15-01, OW-13-B2, OW-13-D, and OW-13-F. The purpose of setting up the wells was to perform a quiet period before conducting the step test on PW-22-1. The transducers were programmed to record the pressure, temperature, and water level at five-minute intervals.

On May 2nd, 2022, vented transducers were set up down the following wells: PW-22-1 and PW-22-1A. The transducers were allowed to equilibrate downhole for approximately two hours prior to the test commencing. The transducers were programmed to record the pressure, temperature, and water level at one second intervals.

Typically, the information concluded from a step-drawdown test can be utilized to optimize the observation well spacing from the pump well and only the pump well is monitored during the step-drawdown test. However, at St. Mary Diversion Dam, the observation wells were already existing. The transducers needed to be installed in the well to allow for adequate time to equilibrate prior to the pump out test. Therefore, the step-drawdown test was recorded/monitored in additional observation wells beyond the pump well.

The data collected during the quiet period in all transducers is shown in Figure 3, below. The longest quiet period was recorded in OW-13-F. In OW-13-F, there was approximately 0.2 feet of displacement. At the start of installing the other transducers (at approximately 80,000 seconds), the transducer in OW-13-F was likely bumped, but the data afterwards appear to be sound.

Figure 3.— Observation well displacement and canal gauge height measurements during quiet period.

2. PW-22-1 Step-Drawdown Test

The step test for PW-22-1 was performed on May 2nd, 2022. The pump was installed within the pump well; the impeller elevation was 56.6-57.2 feet bgs and the base of the pump was set to 60.92 feet bgs. The transducer in the pump well was installed within the stilling well and placed approximately 62.52 feet bgs. This is approximately 1.6 to 2.2 feet below the pump and 5.32 to 5.92 feet below the impeller intake. As a result, the pump well data was noisy while the pump was operating.

The drawdown data obtained from the step test was monitored in the following wells: PW-22-1, PW-22-1A, PW-15-01, OW-13-B2, OW-13-C, OW-13-D, OW-13-F, and OW-13-G. The displacement data obtained from the step test is shown in Figure 4, below.

The step test was conducted for 7.5 hours using three different pump rates. For the duration and rates, see Table 4.

Table 4. – Pump Rates and Durations

Duration (Minutes)	Pump Rate (gpm)
-	0
55	375
139.2	500
767.7	674
-	0

The pump test was terminated when the maximum capacity of the pump was reached (674 gpm). The well recovered to approximately 95% of the original water level during recovery monitored for approximately 16 hours.

During the step test, sand content was measured using the Rossum Sand Tester. The results of this testing are discussed in the Water Quality Section.

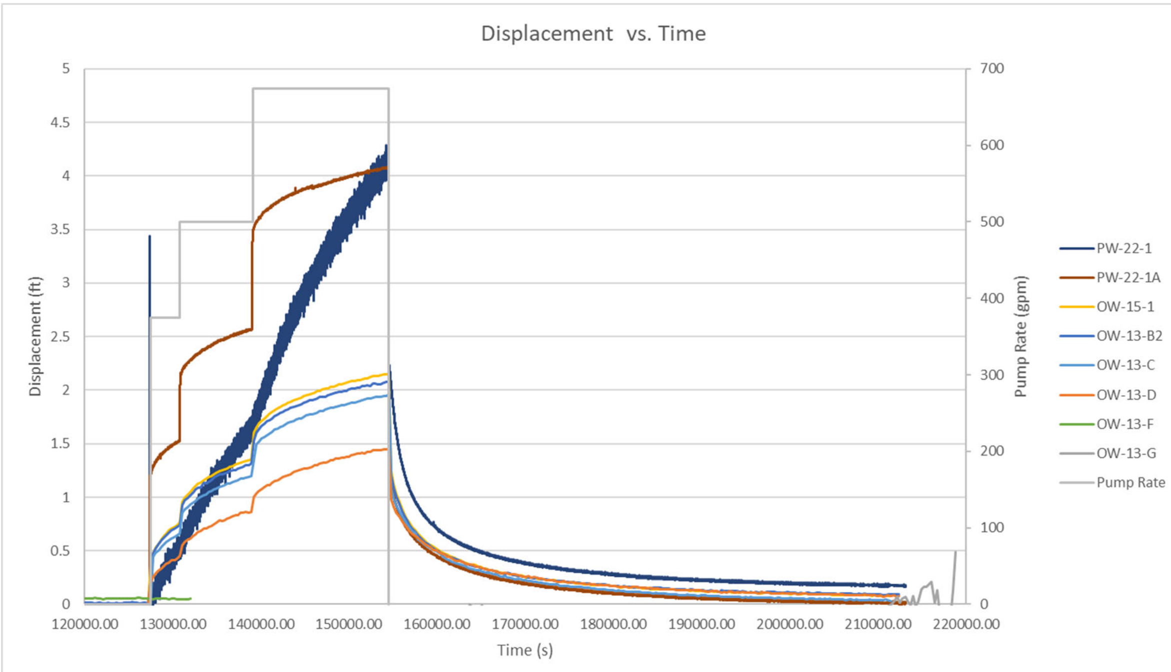


Figure 4.— Displacement during the PW-22-1 step test.

3. Water Quality

Water quality measurements were not performed on the discharged water throughout the step test using a nephelometer/turbidimeter. A Rossum Sand Tester was used to measure the sand content of the pumped water. However, the Rossum Sand Tester was not periodically read throughout the test to note the sanding rate at a specific time. The Rossum Sand Tester was operated for the entire duration of pumping, resulting in an average sand content of 1.5mL of sand.

V. Pump Out Test

Following the step test, a pump out test was performed in PW-22-1 at St. Mary Diversion Dam as part of the 2022 FER. The equipment used and procedures followed are described below. The pump out test was conducted from May 3-5, 2022.

Equipment

The pump out test followed immediately after the step test recovery concluded. The equipment and equipment accuracy outlined in Section IV. is also applicable to the pump out test.

Pump Out Test Procedure

1. Quiet Period and Barometric Pressure

The transducers in the wells were not moved from the step test to the pump out test. For these transducers, it was assumed that the quiet period from the step test was applicable to the pump out test. This assumption was made due to the aggressive schedule required to complete the step-drawdown and pump out test with the team in the field.

Transducers that were not monitored throughout the duration of the step test were installed during the step test. The quiet period was not recorded; however, the transducers had time to equilibrate.

Following the step test, the water elevation within the well recovered 99.6% (e.g., within 0.1-feet of original ground water level) when comparing the recorded water levels prior to the step test to water levels after the step test, based on manual reading.

2. Pump Out Tests

The pump out test performed on PW-22-1 was conducted from May 3-5, 2022. The pump rate was initially set to the maximum pump capacity and pumped at an average rate of 676 gpm, ranging from 670-681 gpm for approximately 18 hours. This flow rate was determined as the maximum pump capacity but not the maximum sustainable yield of the well. From the step test, it was determined that this rate will stress the aquifer enough to gather the data that is needed.

The pump remained in the same location as the step test. The transducer in PW-22-1 was approximately 1.6 to 2.2 feet below the pump and 5.32 to 5.92 feet below the impeller intake. Similar to the step test, the pump well data was noisy while the pump was operating.

The drawdown data obtained for the pump out test was monitored in the following wells: PW-22-1[1], PW-22-1A, PW-15-01, OW-13-A, OW-13-B2, OW-

[1] Data recorded but not used in the analysis.

13-C, OW-13-D, OW-13-E, OW-13-F, OW-13-G and OW-13-H. The displacement data obtained from the pump out test is shown in Figure 5, below.

Anomalous readings were recorded in OW-13-G with the recorded water elevation increasing by 35 feet. This does not correlate with the manual readings nor with the surrounding observation wells.

A transducer was not used in OW-13-H, manual readings were obtained.

The well recovered to approximately 99% of the original water level during recovery monitored for approximately 22.6 hours. The percent recovery in the pump well and observation wells is shown in Table 5. The well recovered to approximately 108% in OW-13-F, the reasoning for the additional recovery is unknown. The value of 108% may appear significant, however, due to the small displacement (0.27 inches) the difference in recovery is only 0.02 inches.

During the pump out test, turbidity was measured using a nephelometer. The results of this testing are discussed in the Water Quality Section.

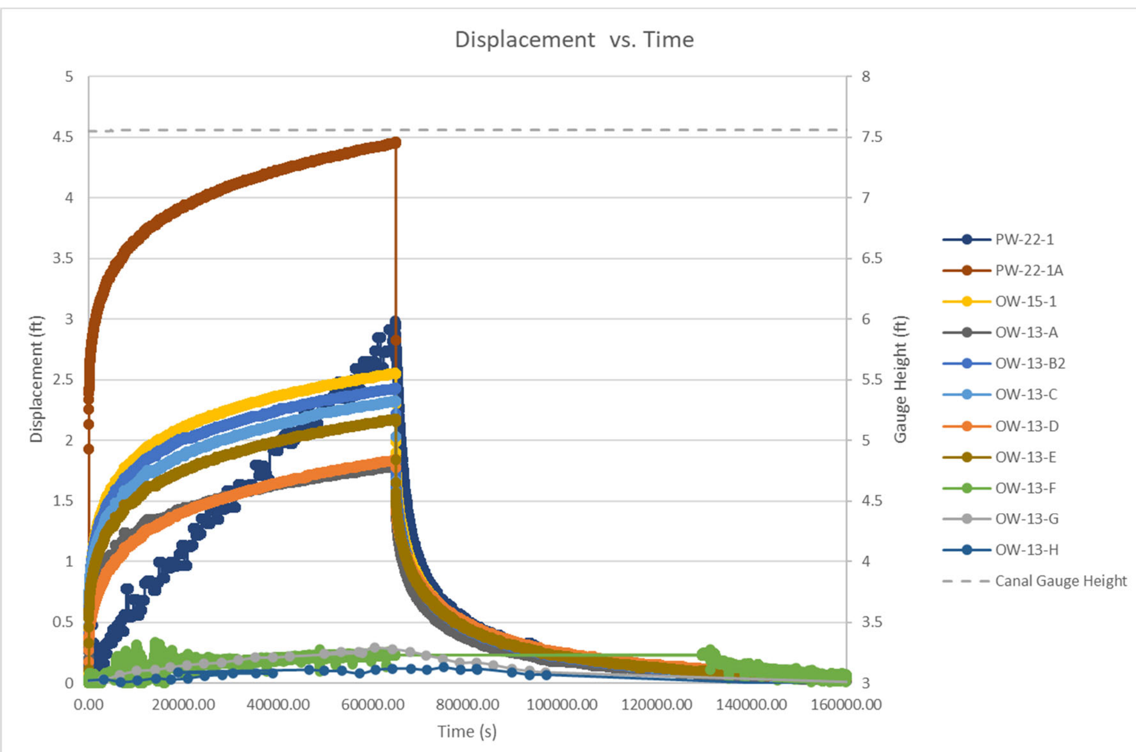


Figure 5.— Displacement during the PW-22-1 pump out test.

Table 5.— Percent Recovery of Initial and Final Water Levels

Well Name	Percent Recovery (%)
PW-22-1	98.5%
PW-22-1A	99.2%
PW-15-01	98.2%
OW-13-A	99.0%
OW-13-B	99.0%
OW-13-C	98.9%
OW-13-D	97.5%
OW-13-E	98.5%
OW-13-F	107.9%
OW-13-G	98.2%
OW-13-H	99.8%

3. Drawdown

The drawdown and recovery data recorded during the pump out test in PW-22-1 is shown in Figure 5. Overall, the total drawdown within the closest observation well (PW-22-1A) was 4.46 feet. The maximum observed drawdown values are shown in Table 6 for the pump and observation wells.

Table 6.— Maximum observed drawdown during pump out test

Well Name	Drawdown (ft)		Well Name	Drawdown (ft)
PW-22-1	2.99 (1)		OW-13-D	1.84
PW-22-1A	4.46		OW-13-E	2.18
PW-15-01	2.56		OW-13-F	0.33
OW-13-A	1.79		OW-13-G	0.29
OW-13-B	2.43		OW-13-H	0.13
OW-13-C	2.33			

Notes: (1) due to noise in the pump well, this reading is not reliable.

4. Water Quality

Water quality measurements were performed on the discharged water throughout both pump out tests and were taken using only the nephelometer. The Rossum Sand Tester was not used during the pump out tests. The turbidity testing performed during the first pump out test showed very little turbidity within the effluent water. A total of 16 turbidity measurements were taken over the course of the test with values ranging from 0.02 to 0.03 nephelometric turbidity unit (NTU). Overall, there was very little turbidity within the effluent water during the pump out test, which indicates that the slot sizing and filter pack design were successful.

VI. References

[1] "North Central Montana Feasiblity Study, Milk River Project, Montana," Bureau of Reclamation, Great Plains Region, Billings, Montana, October 2003.

[2] "St. Mary's Diversion Dam and Headworks, Priliminary Borrow Invetigation, North Central Montana Feasibility Study, Montana," Bureau of Reclamation, Great Plains Region, Billings, Montana, October 2011.

[3] "Exploration Program Saint Mary Diversion Dam and Headworks Structure Geologic Data for Modifications," Technical Service Center, Bureau of Reclamation, Denver, Colorado, September, 2017.

[4] In Situ Inc. 2020. VuSitu, Version 1.16.12.

[5] ASTM C33, Standard Specification for Concrete Aggregates, ASTM International, West Conshohocken, PA, 2003, www.astm.org.

[6] In Situ Inc. 2018. Win-Situ 5, Version 5.6.32.1.

Appendix A

Well Completion Diagrams of PW-22-1, PW-22-1A and Existing Observation Wells

GEOLOGIC LOG OF DRILL HOLE NO. PW-22-1

FEATURE: St. Mary's Diversion Dam	PROJECT: Milk River	STATE: Montana
LOCATION: St. Mary's River	COORDINATES: N 51,924.6 E 26,078.0	GROUND ELEVATION: 4478.6 ft.
BEGUN: 3/31/22 FINISHED: 4/5/22	TOTAL DEPTH: 84.5	ANGLE FROM HORIZONTAL: 90
DEPTH AND ELEVATION OF WATER LEVEL AND DATE MEASURED: 13.1 ft. (4465.5) 5/3/2022	DEPTH TO BEDROCK: N/A	HOLE LOGGED BY: S.Joramo
		REVIEWED BY: C.Clark

NOTES	DEPTH	GEOL. UNIT SYM.	USCS VISUAL CLASSIFICATION	% CORE RECOVERY	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	0–47	Qal	NR	0		

LOCATION:
Approximately 105 ft. southwest of the SW corner of the diversion structure on the south side of the access road.

PURPOSE OF HOLE:
To collect geotechnical and hydrologic data regarding the proposed diversion dam replacement.

DRILLING EQUIPMENT:
Truck mounted Atlas Copco T2W-III rotary drill.
12.0" ODEX Down the Hole Hammer.
12.75" OD Schedule 40 Weld Down Casing.

DRILLER:
Cody Kelly (USBR)

DRILLING METHODS:
0.0 to 84.5 ft. - Advanced borehole with 12.0" ODEX Down the Hole Hammer 12.75" OD Schedule 40 Weld Down Casing.

DRILLING FLUID:
0.0 to 84.5 ft. - no water added, drilled with air.

HOLE COMPLETION:
84.5 to 67.0 ft. - Placed 5 - 50lb buckets of 3/8" Pel Plug bentonite pellets and 22, 50lb sacks of 3/8" bentonite chips.
67.0 to 10.5 ft. - Placed 17, 50lb sacks 8x12 filter sand.
64.3 to 12.0 ft. - Placed 52.3' long by 10" ID, 304 Wire Wrapped Stainless Steel 0.020 weld together screen with bottom cap.
12.0 to 3.0 ft. above ground - Placed 10" ID schedule 40 flush thread PVC riser pipe.
10.5 to 3.0 ft. - placed 3 - 50lb sacks of 3/8" bentonite chips.
3.0 to 2.0 ft. - Placed 2 - 50lb sack of 8x12 filter sand for standpipe drainage.
2.0 to 3.0 ft. above ground- concreted in place with 3 - 50lb sacks a 12" schedule 40 steel standpipe with locking cap.

WELL DEVELOPMENT:
4/05/2020 - Water level before development = 12.3' below ground surface.
Dual line airlift until turbitity measured less than 15 NTU.

DRILLING CONDITIONS AND DRILLERS COMMENTS:
None

CLASSIFICATION AND PHYSICAL CONDITION:

0.0 to 84.5 ft.
Quaternary Alluvium (Qal):

0.0 to 84.5 ft. **ODEX Down the Hole Hammer:** No Recovery

COMMENTS:

All depths and water levels are in feet below ground surface unless otherwise noted.
Heading water level measurement is after well development according to ASTM D5521.
Finished date is the day of well development.
ID = inner diameter LL = Liquid Limit
OD = outer diameter PL = Plastic Limit
NR = no recovery MC = Moisture Content
Coordinates are LOCAL (GROUND) (U.S. SURVEY FEET), Elevation is NAVD 88 (U.S. SURVEY FEET).

Legend:
- Cement Seal: 1 pipe group, 1 pipe
- Filter Pack: 1 pipe group, 1 pipe
- Bentonite seal with 1 pipe

GEOLOGIC LOG OF DRILL HOLE NO. PW-22-1

FEATURE: St. Mary's Diversion Dam
LOCATION: St. Mary's River
BEGUN: 3/31/22 FINISHED: 4/5/22
DEPTH AND ELEVATION OF WATER
LEVEL AND DATE MEASURED: 13.1 ft. (4465.5) 5/3/2022

PROJECT: Milk River
COORDINATES: N 51,924.6 E 26,078.0
TOTAL DEPTH: 84.5
DEPTH TO BEDROCK: N/A

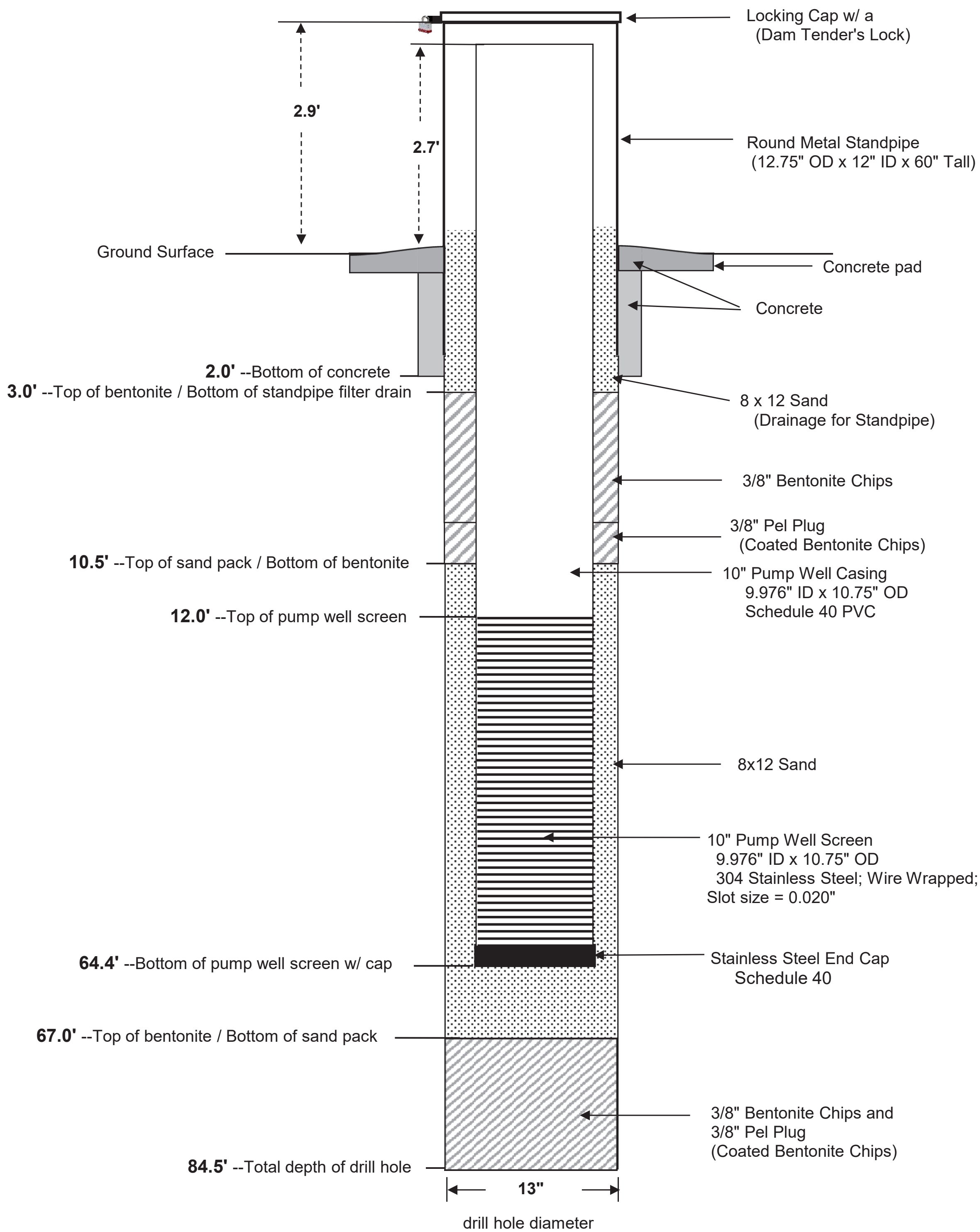
STATE: Montana
GROUND ELEVATION: 4478.6 ft.
ANGLE FROM HORIZONTAL: 90
HOLE LOGGED BY: S.Joramo
REVIEWED BY: C.Clark

NOTES	DEPTH	GEOL. UNIT SYM.	USCS VISUAL CLASSIFICATION	% CORE RECOVERY	HOLE COMPLETION	CLASSIFICATION AND PHYSICAL CONDITION
	55					
	60					
	65					
		Qal	NR	0		
	70					
	75					
	80					

BOTTOM OF HOLE

PUMP WELL COMPLETION DIAGRAM

DRILL HOLE: PW-22-01	GEOLOGIST: Seth Joramo
DATE COMPLETED: 04/06/2022	DRILLER: Cody Kelly
LOCATION: St. Mary's Diversion Dam, MT	HELPERS: Pete Shawver, Ryan Dedecker
T.O.C. ELEVATION:	
G.S. ELEVATION:	



***NOT TO SCALE**

NOTES:

T.O.C. = Top of (PVC) well casing — ID = inside diameter

G.S. = Ground surface — OD = outside diameter

GEOLOGIC LOG OF DRILL HOLE NO. PW-22-1A

FEATURE: St. Mary's Diversion Dam
LOCATION: St. Mary's River
BEGUN: 4/15/22 FINISHED: 4/18/22
DEPTH AND ELEVATION OF WATER
LEVEL AND DATE MEASURED: 12.0 ft. (4466.6) 5/3/2022

PROJECT: Milk River
COORDINATES: N 51,933.4 E 26,075.3
TOTAL DEPTH: 80.0
DEPTH TO BEDROCK: N/A

STATE: Montana
GROUND ELEVATION: 4478.6 ft.
ANGLE FROM HORIZONTAL: 90
HOLE LOGGED BY: A.Brusak
REVIEWED BY: C.Clark

NOTES

LOCATION:
Approximately 10 feet northeast of pump well PW-22-1

PURPOSE OF HOLE:
To collect geotechnical and hydrologic data regarding the proposed diversion dam replacement.

DRILLING EQUIPMENT:
Gus Pech GP-3000 CHR drill rig equipped with a Sonic Core drill head.
7.0" ID Sonic Core Barrel.
8.0" ID Casing and a Carbide Rockbit.

DRILLER:
Braden Samuels (USBR)

DRILLING METHODS:
0.0 to 80.0 ft. - Advanced borehole with 7.0" ID Sonic core barrel, 8.0" ID casing and a carbide bit.

DRILLING FLUID:
0.0 to 80.0 ft. - no water added

HOLE COMPLETION:
80.0 to 58.0 ft. - 50lb sacks of 3/8" bentonite chips.
58.0 to 10.0 ft. - Placed 31, 50lb sacks #8 filter sand.
54.1 to 44.1 ft. - Placed 10' long by 2" ID, schedule 40 PVC 0.020 screen.
44.1 to 2.8 ft. above ground - Placed 2" ID schedule 40 PVC riser pipe.
10.0 to 1.0 ft. - 50lb sacks of 3/8" bentonite chips.
1.0 to 3.0 ft. above ground- concreted in place with 2-50lb sacks of concrete, a square protective steel casing with locking cap.

WELL DEVELOPMENT:
4/15/2020 - Water level before development = 12.9' below ground surface.
Dual line airlift until turbitity measured less than 15 NTU.

DRILLING CONDITIONS AND DRILLERS COMMENTS:
59.0 ft. - 18.0 ft. of sand heave.

LOG COLUMNS

DEPTH	GEOL. UNIT SYM.	USCS VISUAL CLASSIFICATION	% CORE RECOVERY	HOLE COMPLETION
0.0–9.0	Qal	(GP)s	71 (0–10)	Bentonite seal (0–10)
9.0–29.7	Qal	(GP-GC)s	60 (10–20), 80 (20–30)	Filter pack
29.7–33.3	Qal	CL	80 (30–40)	Filter pack
33.3–37.7	Qal	(SP)g		Filter pack
37.7–39.0	Qal	s(CL)g		Filter pack
39.0–49.0	Qal	(GC)s	90 (40–50)	Filter pack; screen from 44.1
49.0–	Qal	(SC)g		Filter pack; screen

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 84.5 ft.
Quaternary Alluvium (Qal):

0.0 to 9.0 ft. <u>Poorly-Graded Gravel with Sand (GP)s:</u> Approximately 50% to 60% fine to medium, subrounded, hard gravel; approximately 30% to 35% fine to coarse, subrounded sand; Approximately 5% medium plasticity fines with low dry strength, rapid dilatancy, and low toughness; approximately 5% to 10% hard cobbles; light brown; moist; no reaction to HCl.

3.5 to 6.5 ft. <u>Lab Test Data:</u> 6% fines, 19% sand, 75% gravel, LL=20.9, PI=17.2, Total MC=1.8%, Lab Classification = Well-graded Gravel with Clay and Sand (GW-GC)s.

9.0 to 29.7 ft. <u>Poorly-Graded Gravel with Clay and Sand (GP-GC)s:</u> Approximately 50% fine to medium, subrounded, hard gravel; approximately 40% fine to coarse, subrounded sand; Approximately 10% high plasticity fines with medium to high dry strength, slow dilatancy, and high toughness; light brown; wet; no reaction to HCl.

11.5 to 19.0 ft. <u>Lab Test Data:</u> 9% fines, 37% sand, 54% gravel, LL=NP, PI=NP, Total MC=2.1%, Lab Classification = Well-graded Gravel with Silt and Sand (GW-GM)s.

26.0 to 29.0 ft. <u>Lab Test Data:</u> 9% fines, 37% sand, 54% gravel, LL=23.4, PI=7.8, Total MC=7.3%, Lab Classification = Well-graded Gravel with Clay and Sand (GW-GC)s.

29.7 to 33.3 ft. <u>Lean Clay (CL):</u> Approximately 100% medium plasticity fines with high dry strength, no dilatancy, and medium toughness; gray; wet; no reaction to HCl.

30.5 to 33.3 ft. <u>Lab Test Data:</u> 89% fines, 11% sand, trace gravel, LL=26.0, PI=17.0, Total MC=25.8%, Lab Classification = Lean Clay (CL).

33.3 to 37.7 ft. <u>Poorly-Graded Sand with Gravel (SP)g:</u> approximately 70% fine to coarse, subrounded sand; Approximately 30% medium to coarse, subrounded, hard gravel; light brown; wet; no reaction to HCl

37.2 to 37.4 ft. Interbed of Lean Clay (CL): Approximately 100% medium plasticity fines with high dry strength, no dilatancy, and medium toughness; gray; wet; no reaction to HCl.

33.5 to 37.4 ft. <u>Lab Test Data:</u> 16% fines, 70% sand, 14% gravel, LL=NP, PI=NP, Total MC=12.0%, Lab Classification = Silty Sand (SM).

37.7 to 39.0 ft. <u>Sandy Lean Clay with Gravel s(CL)g:</u> Approximately 60% medium plasticity fines with medium dry strength, slow dilatancy, and medium toughness; approximately 40% coarse, subangular sand; Approximately 15% medium to coarse, subrounded, hard gravel; gray to light brown; wet; no reaction to HCl.

39.0 to 49.0 ft. <u>Clayey Gravel with Sand (GC)s:</u> Approximately 40% fine to medium, subrounded, hard gravel; Approximately 35% medium plasticity fines with medium dry strength, slow dilatancy, and medium toughness; approximately 25% fine, subrounded sand; light brown; wet; no reaction to HCl.

42.0 to 45.0 ft. <u>Lab Test Data:</u> 20% fines, 30% sand, 50% gravel, LL=19.4, PI=4.4, Total MC=6.8%, Lab Classification = Silty Clayey Gravel with Sand (GC-GM)s.

49.0 to 59.0 ft. <u>Clayey Sand with Gravel (SC)g:</u> Approximately 40% medium to fine, subrounded sand; approximately 30% fine to coarse, subrounded, hard gravel; approximately 30% medium plasticity fines with medium dry strength, slow dilatancy, and medium toughness; light brown; wet; no reaction to HCl.

COMMENTS:

All depths and water levels are in feet below ground surface unless otherwise noted.
Heading water level measurement is after well development according to ASTM D5521.
Finished date is the day of well development.
ID = inner diameter LL = Liquid Limit
OD = outer diameter PL = Plastic Limit
NR = no recovery MC = Moisture Content
Coordinates are LOCAL (GROUND) (U.S. SURVEY FEET), Elevation is NAVD 88 (U.S. SURVEY FEET).

Cement Seal: 1 pipe group, 1 pipe
Bentonite seal with 1 pipe
Filter Pack: 1 pipe group, 1 pipe

GEOLOGIC LOG OF DRILL HOLE NO. PW-22-1A

FEATURE: St. Mary's Diversion Dam
LOCATION: St. Mary's River
BEGUN: 4/15/22 FINISHED: 4/18/22
DEPTH AND ELEVATION OF WATER
LEVEL AND DATE MEASURED: 12.0 ft. (4466.6) 5/3/2022

PROJECT: Milk River
COORDINATES: N 51,933.4 E 26,075.3
TOTAL DEPTH: 80.0
DEPTH TO BEDROCK: N/A

STATE: Montana
GROUND ELEVATION: 4478.6 ft.
ANGLE FROM HORIZONTAL: 90
HOLE LOGGED BY: A.Brusak
REVIEWED BY: C.Clark

NOTES	DEPTH	GEOL. UNIT SYM.	USCS VISUAL CLASSIFICATION	% CORE RECOVERY	HOLE COMPLETION
	55		(SC)g	20	
	60				
	65	Qal	(ML)s	92	
	70				
	75		(SC)g	72	
			(GC)s		
	80		SM		

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

51.0 to 51.2 ft. **Lab Test Data:** 19% fines, 50% sand, 31% gravel, LL=24.0, PI=8.1, Total MC=9.0%, Lab Classification = Clayey Sand with Gravel (SC)g.

54.0 to 59.0 ft. **Lab Test Data:** 80% fines, 20% sand, 0% gravel, LL=20.5, PI=2.2, Total MC=22.2%, Lab Classification = Silt with Sand (ML)s.

59.0 to 72.0 ft. **Silt with Sand (ML)s:** Approximately 85% nonplastic fines with low dry strength, medium dilatancy, and low toughness; Approximately 15% medium to fine, subrounded sand; gray; moist; no reaction to HCl.

62.0 to 65.0 ft. **Lab Test Data:** 91% fines, 9% sand, 0% gravel, LL=20.7, PI=1.8, Total MC=22.5%, Lab Classification = Silt (ML).

72.0 to 76.0 ft. **Clayey Sand with Gravel (SC)g:** Approximately 40% medium to fine, subrounded sand; approximately 40% fine to coarse, subrounded, hard gravel; approximately 20% medium plasticity fines with medium dry strength, slow dilatancy, and medium toughness; light brown; wet; no reaction to HCl.

72.0 to 76.0 ft. **Lab Test Data:** 25% fines, 49% sand, 26% gravel, LL=21.0, PI=6.4, Total MC=10%, Lab Classification = Silty Clayey Sand with Gravel (SC-SM)g.

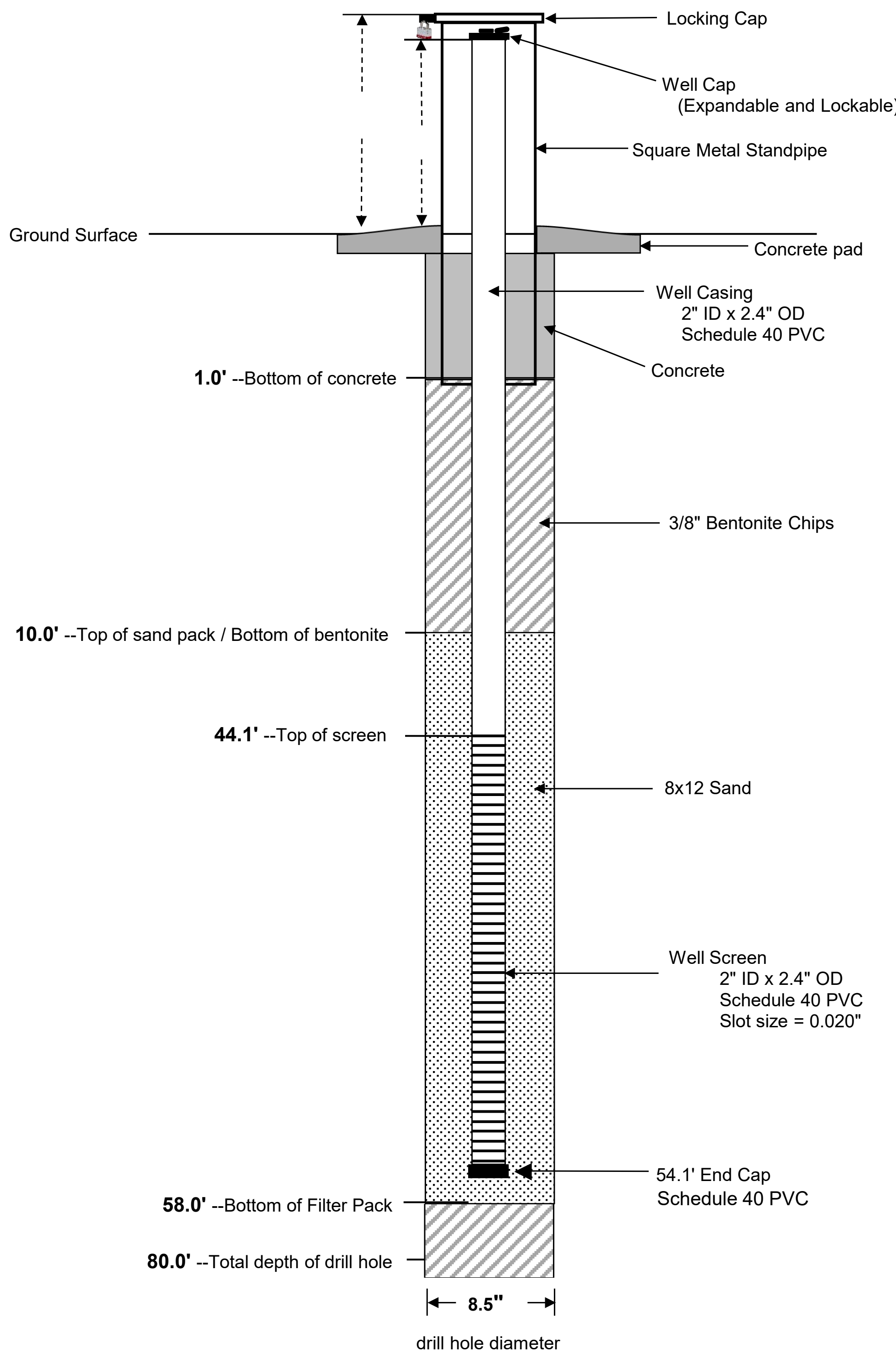
76.0 to 78.0 ft. **Clayey Gravel with Sand (GC)s:** Approximately 40% fine to medium, subrounded, hard gravel; Approximately 40% medium plasticity fines with medium dry strength, slow dilatancy, and medium toughness; approximately 20% fine, subrounded sand; light brown; wet; no reaction to HCl.

76.0 to 78.0 ft. **Lab Test Data:** 32% fines, 30% sand, 38% gravel, LL=18.1, PI=4.0, Total MC=7.1%, Lab Classification = Silty Clayey Gravel with Sand (GC-GM)s.

78.0 to 80.0 ft. **Silty Sand (SM):** Approximately 85% fine, subrounded sand; Approximately 15% nonplastic fines with low dry strength, rapid dilatancy, and low toughness; light brown; wet; no reaction to HCl.

PIEZOMETER COMPLETION DIAGRAM

DRILL HOLE: PW-22-1A	GEOLOGIST: Cody Clark and Eric Hammers
DATE COMPLETED: 04/18/2022	DRILLER: Braden Samuels
LOCATION: St. Mary's Diversion Dam, MT	
T.O.C. ELEVATION: 4481.43	
G.S. ELEVATION: 4478.6 ft.	



***NOT TO SCALE**

NOTES:

T.O.C. = Top of (PVC) well casing
G.S. = Ground surface

ID = inside diameter
OD = outside diameter

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-A

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/6/13 FINISHED: 7/8/13
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 13.5 (4469.9) 7/6/13

PROJECT: Milk River
COORDINATES: N 1,701,391.0 E 1,025,857.0
TOTAL DEPTH: 34.0
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4483.4 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan
REVIEWED BY: J. Earle

NOTES

LOCATION:
Left bank of St. Mary River along the St. Mary Canal embankment, about 90 ft from the SW corner of the diversion structure

All measurements in feet unless otherwise noted

PURPOSE OF HOLE:
Investigate foundation physical properties and install observation well

DRILLING EQUIPMENT:
Truck mounted CME-85 drill; 4-¼" Hollow Stem Augers (HAS) with 5-foot long split sample barrel

DRILLING METHODS:
0.0 to 16.0 cored with 4-¼ " I.D. HSA and center bit.
16.0 to 21.8 cored with 4-¼ " I.D. HSA and split barrel sampler.
21.8 to 24.0 cored with 4-¼ " I.D. HSA and center bit.
24.0 to 26.0 cored with 4-¼ " I.D. HSA and split barrel sampler.
26.0 to 26.8 cored with 4-¼ " I.D. HSA and center bit.
26.8 to 34.0 cored with 4-¼ " I.D. HSA and split barrel sampler.

DRILLER:
S. Rafferty (USBR)
R. Perez, helper
S. Watt, helper

DRILLING COMMENTS:
None

WATER LEVELS:
Date/ hole depth/ water level
07-06-13, 16.0, 13.5
07-07-13, 19.0, 15.8
07-08-13, 34.0, 8.9
08-19-13, 34.0, 13.5

HOLE COMPLETION:
34.0 - 33.0 used 8-12 filter sand
33.0 - 23.0 10-ft long slotted pipe section of white 2-inch diameter PVC pipe surrounded by sand
23.0 - 5.0 used 8-12 filter sand for influence zone
5.0 - 1.5 filled with bentonite chips
1.5 - 0.0 placed mortar cement and set steel stand pipe
3.05 = stickup of PVC (elev= 4486.45)

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.
0.0–7.0	(GP)scb	c bit	Fill
7.0–14.0	(SP)gc	c bit	Qal
14.0–15.0	cobble	c bit	Qal
15.0–20.5	(GM)s	70 (16.0–20.5)	Qal
20.5–		100	Qal

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 7.0 ft. Road Fill:

0.0 to 7.0 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb:
Gradations are estimated from auger cuttings and drilling conditions: about 70-75% coarse to fine, hard, angular to subrounded gravel; about 15-20% coarse to fine, hard, subangular to subrounded sand; about 5-10% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 3 inches; dry, no cementation, overall light to medium brown with a large variety of colors in individual particles, no reaction with HCl.

Total sample (by volume): About 30-35% cobbles at 3-5 inches; 20-25% cobbles at 5-12 inches; maximum size, 12 inches, determined by visual observations of surface exposure.

7.0 to 34.0 ft. Quaternary Alluvium:

7.0 to 14.0 ft. POORLY GRADED SAND WITH GRAVEL AND COBBLES (SP)gc: Gradations are estimated from auger cuttings and drilling conditions: About 50-60% coarse to fine, hard, subangular to rounded sand, with some elongate shapes; about 30-40% coarse to fine, hard, angular to subrounded gravel; about 10% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 2.5 inches; dry, light to medium brown, no reaction with HCl.

Total sample (by volume): About 10-15% cobbles at 3-5 inches; 10% cobbles at 5-12 inches; maximum size, 5 inches, determined by visual observations of material returned outside the auger flights.

14.0 to 15.0 LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

15.0 to 20.5 ft. SILTY GRAVEL WITH SAND (GM)s: A sampling barrel was used to retrieve foundation material from this interval: About 45% coarse to fine, hard, subangular to subrounded gravel; about 35% coarse to fine, hard, subangular to rounded sand; about 20% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 2.75 inches; wet, medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

20.5 to 21.8 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc: A sampling barrel was used to retrieve foundation material from this interval: About 50% coarse to fine, hard, subangular to subrounded gravel; about 30% coarse to fine, hard, subangular to rounded sand; about 20% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size, 3 inches; wet, medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

Total sample (by volume): About 10% cobbles at 3-5 inches; 5% cobbles at 5-12 inches; maximum size, 6.5 inches; determined by visual observations of material returned outside the auger flights.

21.8 to 23.0 ft. LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

23.0 to 26.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: A sampling barrel was used to retrieve foundation material from this interval: About 60% coarse to fine, hard, subangular to subrounded gravel; about 30% coarse to fine, hard, subangular to rounded sand;

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-A

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/6/13 FINISHED: 7/8/13
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 13.5 (4469.9) 7/6/13

PROJECT: Milk River
COORDINATES: N 1,701,391.0 E 1,025,857.0
TOTAL DEPTH: 34.0
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4483.4 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan
REVIEWED BY: J. Earle

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
		(GM)s	100	Qal	
		(GM)sc			
		cobble	c bit		
		(GM)s	75		
	25				
		cobble	c bit		
		(GP)s			
		(SP)g	100		
	30	(SM)			
		(SC)g			
		(SM)			
		(SP)g			
		(SP)			

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

about 10% nonplastic fines; maximum size recovered, 2.25 inches; wet, medium brown with a large variety of colors in individual particles; no cementation; firm consistency; no reaction with HCl.

26.0 to 26.8 ft. LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

26.8 to 29.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: Gradations are estimated from material remaining on the center bit as it was extracted from drill hole: About 60% coarse to fine, hard, angular to subrounded gravel; about 40% fine, hard, sub angular to subrounded sand: with a trace of nonplastic fines; maximum size recovered, 1.5 inches; wet; a large variety of colors are present in individual particles; uncemented; no reaction with HCl.

29.5 to 29.9 ft. POORLY GRADED SAND WITH GRAVEL (SP)g: About 75% coarse to fine, hard, subangular to rounded sand; about 20% coarse to fine, hard, angular to subrounded gravel; about 5% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 1.5 inches; wet; a large variety of colors are present in individual particles; no reaction with HCl.

29.9 to 30.8 ft. SILTY SAND (SM): About 80% coarse to fine, hard, subangular to rounded sand; about 20% nonplastic fines with slow dilatancy; trace of fine subangular gravel: maximum size recovered, 0.75 inch; wet, a large variety of colors are present in individual particles, no cementation, firm consistency, no reaction with HCl.

30.8 to 31.3 ft. CLAYEY SAND WITH GRAVEL (SC)g: About 50% coarse to fine, hard, subangular to rounded sand; about 35% coarse to fine, hard, subangular gravel: and about 15% fines with low plasticity, medium dry strength, low toughness, no dilatancy; maximum size recovered, 3 inch; wet, a large variety of colors are present in individual particles, no cementation, very soft consistency, no reaction with HCl.

31.3 to 32.7 ft. SILTY SAND (SM): About 80% coarse to fine, hard, subangular to rounded sand; about 5% fine, hard, subangular gravel; about 15% nonplastic fines with slow dilatancy; maximum size recovered, 0.75 inch; wet; a large variety of colors are present in individual particles, no cementation, firm consistency, no reaction with HCl.

32.7 to 33.3 ft. POORLY GRADED SAND WITH GRAVEL (SP)g: About 70% coarse to fine, hard, subangular to rounded sand; about 25% coarse to fine, hard, angular to subrounded gravel; about 5% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 2.75 inches; wet; a large variety of colors are present in individual particles; firm consistency; no reaction with HCl.

33.3 to 34.0 ft. POORLY GRADED SAND (SP): About 90% coarse to fine, hard, subangular to rounded sand; about 5% fine, hard, subrounded gravel; about 5% nonplastic fines; maximum size recovered, 0.75 inch; wet; a large variety of colors are present in individual particles; firm consistency; no reaction with HCl.

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-B

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/9/13 FINISHED: 7/10/13
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 11.7 (4469.9) 07/09/13

PROJECT: Milk River
COORDINATES: N 1,701,429.0 E 1,025,826.0
TOTAL DEPTH: 22.8
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.6 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan
REVIEWED BY: J. Earle

NOTES

LOCATION:
Left bank of St. Mary River along the St. Mary Canal embankment, about 115 ft from the SW corner of the diversion structure and 53 ft NNW from OW-13-A

All measurements in feet unless otherwise noted

PURPOSE OF HOLE:
Investigate foundation physical properties and install observation well

DRILLING EQUIPMENT:
Truck mounted CME-85 drill; 4-¼" Hollow Stem Augers (HSA) with 5-foot long split sample barrel

DRILLING METHODS:
0.0 to 15.5 cored with 4-¼ " I.D. HSA and center bit.
15.5 to 22.8 cored with 4-¼ " I.D. HSA and split barrel sampler.

DRILLER:
S. Rafferty (USBR)
R. Perez, helper
S. Watt, helper

DRILLING COMMENTS:
None

WATER LEVELS:
Date/ hole depth/ water level
07-09-13, 14.2, 11.7
07-10-13, 20.2, 11.7

HOLE COMPLETION:
22.8 - 0.0 abandoned hole and refilled with mix of bentonite chips and drill cuttings

DEPTH / FLD. CLASS/LITH. / % CORE RECOVERY / GEOL. UNIT SYM. / HOLE COMPLETION

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
0.0–1.5	(GP)scb	c bit	road fill	
1.5–3.0	(GM)sc		emb fill	
3.0–4.5	(GP)sc			
4.5–7.0 (5)	(GM)s			
7.0–11.5 (10)	(GP)s		Qal	
11.5–12.0	cobble			
12.0–14.2	(GP)sc			
14.2–	(GM)s			

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.5 ft. Road Fill:

0.0 to 1.5 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb:
Gradations are estimated from auger cuttings and drilling conditions: about 70-75% coarse to fine, hard, angular to subrounded gravel; about 15-20% coarse to fine, hard, subangular to subrounded sand; about 5% low plasticity fines with low dry strength, low toughness, slow dilatancy; dry; no cementation; overall light to medium brown with a large variety of colors in individual particles; no reaction with HCl.

Total sample (by volume): About 30% cobbles at 3-5 inches; 25% cobbles at 5-12 inches; 5% boulders at plus 12 inches; maximum size, 2 x 1.8 x 1 foot, determined by visual observations of surface exposure.

1.5 to 7.0 ft. Embankment Fill:

1.5 to 3.0 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:
Gradations are estimated from auger cuttings and drilling conditions: About 45% coarse to fine, hard, subangular to subrounded gravel; about 40% coarse to fine, hard, subangular to rounded sand; about 15% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size, 4.5 inches; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

3.0 to 4.5 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings and drilling conditions: About 60-65% coarse to fine, hard, angular to subrounded gravel; about 30-35% coarse to fine, hard, angular to subrounded sand; about 5% nonplastic fines; maximum size, 5 inches, estimated by what is seen coming up on the augers; dry; light to medium brown; no reaction with HCl.

4.5 to 7.0 ft. SILTY GRAVEL WITH SAND (GM)s: Gradations are estimated from auger cuttings and drilling conditions: About 45-50% coarse to fine, hard, subangular to subrounded gravel; about 30-35% coarse to fine, hard, subangular to rounded sand; about 20% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

7.0 to 22.8 ft. Quaternary Alluvium:

7.0 to 11.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:
Gradations are estimated from auger cuttings and drilling conditions: About 50-55% coarse to fine, hard, angular to subrounded gravel; about 40-45% coarse to fine, hard, angular to subrounded sand; about 5% nonplastic fines; maximum size, 5 inches, estimated by what is seen coming up on the augers; dry; light to medium brown; no reaction with HCl.

11.5 to 12.0 LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. Stopped drilling and checked the center bit teeth for wear, noted water on rods at 11.7 feet. This rock was finally broken through so that progress and further sampling could occur.

12.0 to 14.2 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings and drilling conditions: About 70-75% coarse to fine, hard, angular to subrounded gravel; about 20-25% coarse to fine, hard, angular to subrounded sand; about 5% nonplastic fines; maximum size, 6 inches, estimated by what is seen coming up on the augers and a

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-B

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/9/13 FINISHED: 7/10/13
DEPTH AND ELEVATION OF WATER AND DATE MEASURED: 11.7 (4469.9) 07/09/13

PROJECT: Milk River
COORDINATES: N 1,701,429.0 E 1,025,826.0
TOTAL DEPTH: 22.8
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.6 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan
REVIEWED BY: J. Earle

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
		cobble	c bit	Qal	
		(GP)s	57		
	20	cobble	0		
		(GP)sc			
			0		

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

blockage at 13.5 ft.; dry; light to medium brown; no reaction with HCl.

14.2 to 15.0 ft. SILTY GRAVEL WITH SAND (GM)s: Gradations are estimated from auger cuttings and drilling conditions: About 50-55% coarse to fine, hard, subangular to subrounded gravel; about 25-35% coarse to fine, hard, subangular to rounded sand; about 15-20% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; moist to wet; medium brown with a large variety of colors in individual particles; no reaction with HCl.

15.0 to 15.5 ft. LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

15.5 to 19.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: A sampling barrel was used to retrieve foundation material from the interval between 16.0 to 19.5 feet, and drill cuttings were observed from the interval below the cobble to the depth of 16.0 feet: About 55% coarse to fine, hard, angular to subrounded gravel; about 40% coarse to fine, hard, subangular to rounded sand; about 5% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; wet; light brown with a large variety of colors in individual particles; no reaction with HCl.

19.5 to 20.2 ft. LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

20.2 to 22.8 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings and drilling conditions below large blockage: About 70-75% coarse to fine, hard, angular to subrounded gravel; about 20-25% coarse to fine, hard, angular to subrounded sand; about 5% nonplastic fines; maximum size, 6 inches, estimated by what is seen coming up on the augers; wet; light to medium brown; no reaction with HCl.

22.8 ft. LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers and was impossible to proceed past. The hole had to be abandoned due to no downward progress.

Abandoned hole, pulled 10 feet of the augers and measured the bottom of the hole with caving material to 16.5 feet. Added bentonite chips as augers were removed to 2.0 feet of depth. Filled the remaining hole with auger cuttings to the existing ground surface.

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-B2

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/10/13 FINISHED: 7/18/13
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 11.8 (4469.8) 07/18/13

PROJECT: Milk River
COORDINATES: N 1,701,392.0 E 1,025,828.0
TOTAL DEPTH: 35.0
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.6 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan / J. Earle
REVIEWED BY: J. Earle

NOTES

LOCATION:
Left bank of St. Mary River along the St. Mary Canal embankment, about 115 ft from the SW corner of the diversion structure and 50 ft NNW from OW-13-A

All measurements in feet unless otherwise noted

PURPOSE OF HOLE:
Investigate foundation physical properties and install observation well

DRILLING EQUIPMENT:
Truck mounted CME-85 drill; 4-¼" Hollow Stem Augers (HSA) with 5-foot long split sample barrel

DRILLING METHODS:
0.0 to 20.0 cored with 4-¼ " I.D. HSA and center bit.
20.0 to 35.0 cored with 4-¼ " I.D. HSA and split barrel sampler.

DRILLER:
S. Rafferty (USBR)
R. Perez, helper
S. Watt, helper

DRILLING COMMENTS:
None

WATER LEVELS:
Date/ hole depth/ water level
07-10-13, 15.0, 9.2
07-17-13, 25.0, 11.6
07-18-13, 35.0, 11.8

HOLE COMPLETION:
35.0 - 34.0 filter sand #10-20
34.0 - 24.0 10-ft long slotted pipe section of white 2-inch diameter PVC pipe surrounded by sand
24.0 - 14.0 filter sand #10-20
14.0 - 1.5 filled with bentonite chips
1.5 - 0.0 placed mortar cement and set steel stand pipe
2.76 ft = stickup of PVC (elev= 4484.36)

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
0.0–1.5	(GP)scb		road fill	
1.5–4.5	(GM)sc		emb fill	
4.5–5.2 (5)	cobble		emb fill	
5.2–7.0	(GM)sc		emb fill	
7.0–12.5 (10)	(GP)s	c bit	Qal	
12.5–15.0 (15)	(GM)sc		Qal	
15.0–	(GP)s		Qal	

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.5 ft. Road Fill:

0.0 to 1.5 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb:
Gradations are estimated from auger cuttings and drilling conditions: about 70-75% coarse to fine, hard, angular to subrounded gravel; about 15-20% coarse to fine, hard, subangular to subrounded sand; about 5% low plasticity fines with low dry strength, low toughness, slow dilatancy; dry; no cementation; overall light to medium brown with a large variety of colors in individual particles; no reaction with HCl.

Total sample (by volume): About 30% cobbles at 3-5 inches; 25% cobbles at 5-12 inches; 5% boulders at plus 12 inches; maximum size, 1.7 x 1.2 x 1.0 foot, determined by visual observations of surface exposure.

1.5 to 7.0 ft. Embankment Fill:

1.5 to 4.5 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:
Gradations are estimated from auger cuttings and drilling conditions: About 45% coarse to fine, hard, subangular to subrounded gravel; about 40% coarse to fine, hard, subangular to rounded sand; about 15% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size, 4.5 inches; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

4.5 to 5.2 LARGE COBBLE OR BOULDER: Drilling conditions indicated a large rock that blocked the bottom of the augers so that no recovery was possible. This rock was finally broken through so that progress and further sampling could occur.

5.2 to 7.0 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:
Gradations are estimated from auger cuttings and drilling conditions: About 45-50% coarse to fine, hard, subangular to subrounded gravel; about 30-35% coarse to fine, hard, subangular to rounded sand; about 20% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

Total sample (by volume): Estimated by drilling conditions and material carried to the surface on the outside of the auger flights: About 10% cobbles at 3-5 inches; 5% cobbles at 5-12 inches; maximum size, 7 inches.

7.0 to 35.0 ft. Quaternary Alluvium:

7.0 to 12.5 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:
Gradations are estimated from auger cuttings and drilling conditions: About 50-55% coarse to fine, hard, angular to subrounded gravel; about 40-45% coarse to fine, hard, angular to subrounded sand; about 5% nonplastic fines; maximum size, 5 inches, estimated by what is seen coming up on the augers; dry, light to medium brown; no reaction with HCl.

12.5 to 15.0 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:
Gradations are estimated from auger cuttings and drilling conditions: About 40-45% coarse to fine, hard, angular to subrounded gravel; about 40-45% coarse to fine, hard, subangular to rounded sand; about 15% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

15.0 to 20.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s:

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-B2

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 7/10/13 FINISHED: 7/18/13
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 11.8 (4469.8) 07/18/13

PROJECT: Milk River
COORDINATES: N 1,701,392.0 E 1,025,828.0
TOTAL DEPTH: 35.0
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.6 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: C. Sullivan / J. Earle
REVIEWED BY: J. Earle

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
	to 25	(GM)sc	84	Qal	
	25	(SM)	100		
		(GM)s	100		
	30	(SM)g	100		
	35	(GP)sc	50		

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

Gradations are estimated from auger cuttings and drilling conditions: About 50-55% coarse to fine, hard, angular to subrounded gravel; about 45-50% coarse to fine, hard, subangular to rounded sand; about a trace of nonplastic fines; maximum size, 6 inches, estimated by what is seen coming up on the augers; moist to wet; light to medium brown; no reaction with HCl.

<u>20.0 to 25.0 ft. SILTY GRAVEL WITH SAND AND COBBLES (GM)sc:</u> A sampling barrel was used to retrieve foundation material from the interval between 20.0 to 25.0 feet: About 45% coarse to fine, hard, angular to subrounded gravel; about 35% coarse to fine, hard, subangular to rounded sand; about 20% low plasticity fines, with low dry strength, low toughness, slow dilatancy; maximum size, 4 inches, but limited by the interior diameter of the augers; wet; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

Total sample (by volume): Estimated by drilling conditions and material sampled inside the auger flights: About 10% cobbles at 3-5 inches (sampled); 5% cobbles at 5-12 inches in foundation.

<u>25.0 to 25.5 ft. SILTY SAND (SM):</u> About 80% predominately fine, hard, rounded sand; about 5% coarse to fine, hard, angular to subrounded gravel; about 15% low plasticity fines with no to low dry strength, no to low toughness, slow dilatancy; maximum size recovered, fine sand; wet, light to medium brown with a large variety of colors in individual particles; no cementation; weak reaction with HCl.

<u>25.5 to 29.5 ft. SILTY GRAVEL WITH SAND (GM)s:</u> About 55% coarse to fine, hard, subangular to subrounded gravel with elongate shapes present; about 30% predominately fine, hard, rounded sand; about 15% low plasticity fines, with no dry strength, low toughness, no dilatancy; maximum size recovered, 2 inches; wet; light to medium brown with a large variety of colors in individual particles; no to weak cementation; no reaction with HCl.

<u>29.5 to 30.0 ft. SILTY SAND WITH GRAVEL (SM)g:</u> About 55% predominately fine, hard, rounded sand; about 30% coarse to fine, hard, subrounded to rounded gravel with elongate shapes present; about 15% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 1 inch; wet; light to medium brown with a large variety of colors in individual particles; weak cementation; soft consistency; weak reaction with HCl.

<u>30.0 to 35.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc:</u> About 60% coarse to fine, hard, subangular to subrounded gravel; about 35% coarse to fine, hard, subangular to rounded sand; about 5% nonplastic fines; maximum size, 3 inches, estimated by what is seen coming up on the augers; dry; light to medium brown with a large variety of colors in individual particles; no cementation; no reaction with HCl.

Total sample (by volume): Estimated by drilling conditions and material carried to the surface on the outside of the auger flights: About 5% cobbles at 3-5 inches; maximum size recovered, 4.5 inches.

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-C

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h I / 3 0 I (2QY wi RWSSM

B# AI R	(I DA¼	V=(i w=- RR#3¼I	: w# h I h I w# / I h Q	6 I #=i) B3A RQv i	¼# =I w# v D=I A3# B	w=- RR3/3w- A3# B - B(D¼QR3w- = w# B(3A3# B
LOCATION: LLe ft bant kf toa Saft . Mr y kf Rti v Mg h ©al M&r , toa Muuann IkM15M kWcds ft 0 R0 kf toa NWONbaSS - SSOaMhWaOar tn © faat W Sann ktoalb ©a r kta1 **PURPOSE OF HOLE:** 3 mantÇMa fkW1M©r Nbgn©MSNkNalt©an Mr 1 ©ntMSS k. nalmM©r baSS **DRILLING EQUIPMENT:** AlWy OkWta1 wv I pTe 1lGSE8p 4¼kS&b RtaO - W aln "¼R- Hb ©o epfkkt S&r , nSS©nMONSa . MlaS **DRILLING METHODS:** sis tk ceis ukla1 b ©o 8p 43(i ¼R- Mr 1 uar tal . ©l ceis tk d8is ukla1 b ©o 8p 43(i ¼R- Mr 1 nNS©. MlaS nMONSali **DRILLER:** Ri h Mfaltg ") R2h H h i DalaU5oaSNal Ri 0 Mt5oaSNal **DRILLING COMMENTS:** Bkr a **WATER LEVELS:** (MaPokSa 1aNtoPb Mal SamaS sTpsdpcd5d8is5cLi8 **HOLE COMPLETION:** d8is pddis fGSal nMr 1 zTpcL ddis pLdis cspft S&r , nSttta1 N©la naut©r kf b o©a LpCuo 1©Datal D/ w N©la nWIkW1a1 . g nMr 1 Ldis peis fGSal nMr 1 fkI ©fSMar ua Ukr a zTpcL eis pcie fGSa1 b ©o . ar tkr ©a uo©Nh cie psis NSMua1 OkItMl uaOar t Mr 1 nat ntaaSntMr 1 N©la RtQyWN7 Li9L kr D/ w I©al	5 10 15 20 25 30	"6 DHtu. "Rv H,u "6 v Htu "6 DHt "6 DHtu	u . © LL Ls s es	GMS		**0.0 to 34.0 ft. Quaternary Alluvium:** sis tk ceis fti D## h =Q6 h - (I (6 h - / I = 0 3A¼R- B(5w# 22=I R - B(2#) =(I h R "6 DHtu. Y 6 IMIM©r n Ma ant©Ma1 flkO MW al uWt©, n Mr 1 1lGS©, ukr 1©©r nY M kW9sp9e: ukMna tk f©a5oMl15Mr , WSM tk nWIkW1a1 , IMnaSb ©o a&r , Ma1 noMNan Nanar tEM kWLe: ukMna tk f©a5oMl15 nWMr , WSM tk nWIkW1a1 nMr 1EM kWepcs: S&b NSMt©©g f©an b ©o S&b 1lg ntlar , to5S&b tkW or ann5nS&b 1GSMM ugEOM%©WO n©La laukmala15d ©uoanE1lgEr k uaOar tM©r EkmalMSSS©ot tk Oa1©WO . Ikbr b ©o MSM, a mM©atg kf ukS&ln © ©1©n©WWSNMt©SanEbaMy laMut©r b ©o ¼wS AktMSnMONSa ". g nkSYOaHY- . kWdspde: uk. . San Ml dpe ©uoanE LspLe: uk. . San Ml epcL ©uoanEOM%©WO n©La5cL ©uoan5 1atalO©a1 . g m©WWSk. nalmM©r n kf nWfMua a%NknWai ceis tk cxie fti R3=AQR- B(0 3A¼6 h - / I = - B(w# 22=I R "Rv H,uY - nMONS©, . MlaSb Mh Wha1 tk latl©ama fkW1M©r OMal©MSflkO to©, ©talmMSY- . kW8e: Oa1©WO tk f©a5oMl15nWIkW1a1 tk IkW1a1 nMr 1EM kWde: ukMna tk f©a5oMl15nWIkW1a1 , IMnaSb ©o a&r , Ma1 noMNan Nanar tEM kWLs: S&b NSMt©©g f©an b ©o S&b 1lg ntlar , to5S&b tkW or ann5nS&b 1GSMM ugEOM%©WO n©La laukmala15d ©uoanEOk©tEla11©o . Ikbr b ©o MSM, a mM©atg kf ukS&ln © ©1©n©WWSNMt©SanEbaMy uaOar tM©r Er k laMut©r b ©o ¼wS AktMSnMONSa ". g nkSYOaHY- . kWe: uk. . San Ml dpe ©uoanEOM%©WO n©La laukmala15e ©uoani cxie tk L8ie fti R3=AQ6 h - / I = 0 3A¼R- B(- B(w# 22=I R "6 v HtuY - . kW8e: ukMna tk f©a5oMl15nWIkW1a1 , IMnaSb ©o a&r , Ma1 noMNan Nanar tEM kWLe: Oa1©WO tk f©a5oMl15nWIkW1a1 tk IkW1a1 nMr 1EM kWds: S&b NSMt©©g f©an b ©o S&b 1lg ntlar , to5 S&b tkW or ann5r k 1GSMM ugEOM%©WO n©La laukmala15Lie ©uoanY batE. Ikbr b ©o MSM, a mM©atg kf ukS&ln © ©1©n©WWSNMt©SanEbaMy uaOar tM©r Er k laMut©r b ©o ¼wS AktMSnMONSa ". g nkSYOaHY- . kWe: uk. . San Ml dpe ©uoanEOM%©WO n©La laukmala15F ©uoani L8ie tk Lxis fti D## h =Q6 h - (I (6 h - / I = 0 3A¼R- B("6 DHtY - . kWee: ukMna tk f©a5oMl15Mr , WSM tk nWIkW1a1 , IMnaSb ©o a&r , Ma1 noMNan Nanar tEM kWLe: Na1kO©MaSg f©a5oMl15 nWIkW1a1 tk IkW1a1 nMr 1EM kWLs: S&b NSMt©©g f©an b ©o S&b 1lg ntlar , to5S&b tkW or ann5nS&b 1GSMM ugEOM%©WO n©La laukmala15 d ©uoanEbatEOa1©WO . Ikbr b ©o MSM, a mM©atg kf ukS&ln © ©1©n©WWSNMt©SanEbaMy uaOar tM©r EbaMy laMut©r b ©o ¼wS Lxis tk d8is fti D## h =Q6 h - (I (6 h - / I = 0 3A¼R- B(- B(w# 22=I R "6 DHtuY - . kWFs: ukMna tk f©a5oMl15Mr , WSM tk nWMr , WSM , IMnaSb ©o a&r , Ma1 noMNan Nanar tEM kWds: ukMna tk f©a5oMl15nWMr , WSM tk nWIkW1a1 nMr 1EM kWcs: S&b NSMt©©g f©an b ©o S&b 1lg ntlar , to5S&b tkW or ann5nS&b 1GSMM ugE OM%©WO n©La laukmala15d ©uoanEbatEbaMy uaOar tM©r EkmalMSS S©ot tk Oa1©WO . Ikbr b ©o MSM, a mM©atg kf ukS&ln © ©1©n©WWS NMt©SanEbaMy laMut©r b ©o ¼wS AktMSnMONSa ". g nkSYOaHY- . kWcs: uk. . San Ml dpe ©uoanE OM%©WO n©La laukmala15e ©uoani

2# AA# v #V ¼# =I

w# v v I BARY

RAv - hQ (3 I h R3# B (- v RA v - hQ (3 I h R3# Bi6 DJ I = / - (#i6 (A cs8RF ccYLTs8s - v

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-D

r; wwA 0 =F 1

FwLA2) wY rayRivl ".skvS.ft "ih RfModiaftS
G=gLA3=PY GkoaCitmfor ayRivl).skv
Dw#2PY /z11z0H F3P3; w"Y/z1Hz0H
"wUA; LP" wGw9LA3=P=Fc LAw)
LP" "LAw RwLr2) w"Y (yW 4TT/1y1¼W z1Hz0H

U)=Jwg AY R.em) .skv
g==) "3PLAwr Y P 0,/W0,N0NyW w 0,WIN,//NyW
A=ALG" wUA; Y H(yN
"wUA; A=Dw") =g KY Pzw

r ALAwY Rftaiti
#)=2P" wGw9LA3=PY TT50yl oay
LP#Gw F)=R; =) 3Z=PALGY I(W LZ3R2A; Y
;=Gw G=##w" DQY Jywivek
)w93wc w" DQY gyruesit

P=Awr	"wUA;	FG" ygGLrrz3A; y	: g=) w) wg=9w) Q	#w=G)2P3Ar QRy	;=Gwg=RUGwA3=P	gGLrr3F3gLA3=P LP" U; Qr3gLGg=P"3A3=P
LOCATION: Leftb ank ekoaS.Mk foank rayRivl gitiekh Citmlnkta iCfua15Wloaofh ank rc dfvtkvfoank MskvS.ft Savudauvk itM01Noaofh ank Cuh O-kee Leeh kiSuvkh ktaS.t dkkautekSSfankv-.Sktfak M **PURPOSE OF HOLE:** 3skSabiak ofutMiaft CnlS.dieCvfCkvakSitM.tSaiee fCSkvsiaft-kee **DRILLING EQUIPMENT:** Avudmhfutak MgRwI5NMveepTIE8; feef-rakh LubkvS 4; rL¼ .an Nlofaeftb SOeaSih Oek Ci wke **DRILLING METHODS:** WyWaf 0NyWdfvkM-.an TIE 83/"y; rLitMdktakvCay 0NyWaf H(yN dfvkM-.an TIE 83/"y; rLitMSOeaCi wke Sih Oekvy **DRILLER:** ry)iookval 42rD) ¼)yUkvkB,nkeCkv rycia,nkeCkv **DRILLING COMMENTS:** Pftk **WATER LEVELS:** "iakznfek MkCanz-iakvekske WI1HI0H,H(yN,(yW **HOLE COMPLETION:** H(yNIHNyWoekvSitM7 0W1W HNyWI1NyW0Wloaeftb SefakMOCk Skdaft fo-n.ak1l.tdn Mihkakv U9g OOk SuwfutMkMCI SitM 1NyWI1yN oekvSitM7 0W1Wlofv.toeuktdk Bftk 1yNIWyWoekM-.an Cktaft.akdn.OSitMSkaSakkeSaitM OOk radmuO6 HyWIft U9g v.Skv	5 10 15	4#U%SdC 4'U%Sd 4#U%Sd 4#U%Sd	oee dCa NW TN	Vie		**0.0 to 3.0 ft. Road Fill:** WyWaf HyWloayU==) GQ#) L"w"#) L9wGc3A; rLP",g=DDGwr LP" D=2G'w) r 4#U%SdCY #viMaftSivkkSahiakMoofh iubkvduaatbSitMMv.eetb dftMaftSY LCfua/W/N: dfivSk afotk,nivM,itbueivaf SuCvfutMkMbviske-.an keftbiakMSniOkSOvkSktapiCfua0NI1W dfivSk afotk,nivM, SuCitbueivaf SuCvfutMkMSitMpiCfua0N0W ef-OeiSad.al otkS-.an ef-MI Sakt ban,ef-afubntkSS,Sef-Meiaitdl phi%huh S.Bk vkdfskvkM,1.tdnkSpMlptf dkh ktaiaftpfskvieeebnaafi hkMuh Cvf-t-.ani eivbk siv.kal fodfefvS.t .tMs.MuieCivadekSptf vkidaft-.an; gey AfaieSih Oek 4Ci sfeuh k%LCfuaHWHN: dfCOakSiaHIN.tdnkSp 1W1N: dfCOakSiaNI01.tdnkSphi%huh S.Bk,01.tdnkS, Mkakvh .tkMCi s.SuiefCSkvsiaftSfoSuvoidk k%Cf Suvky **3.0 to 39.5 ft. Quaternary Alluvium:** HyWaf 0NyWloayU==) GQ#) L"w"w" rLP" c3A; #) L9wGLP" g=DDGwr 4'U%SdY#viMaftSivkkSahiakMoofh iubkvduaatbSitM Mv.eetb dftMaftSYLCfuaNWxW dfivSk afotk,nivM,SuCitbueivaf vfutMkMSitM,-.an Sfh kkeftbiakMSniOkSpiCfuaHWTW dfivSk af otk,nivM,itbueivaf SuCvfutMkMbviskepiCfua0W ef-OeiSad.al otkS,ef-MI Sakt ban,Sef-Meiaitdl,ef-afubntkSSphi%huh S.Bk vkdfskvkM,1.tdnkSpMI af (yWankt-kapebnaafi hkMuh Cvf-t-.ani eivbk siv.kal fodfefvS.t .tMs.MuieCivadekSptf vkidaft-.an; gey AfaieSih Oek 4Ci sfeuh k%LCfua0W0N: dfCOakSiaHIN.tdnkSp0W dfCOakSiaNI01.tdnkSphi%huh S.Bk,/.tdnkS,Mkakvh .tkMCi s.SuiefCSkvsiaftSfohiakv.ievkauvtkMfuaS.Mkank iubkvoebnaSy 0NyWaf 0(yWloayU==) GQ#) L"w"#) L9wGc3A; rLP" LP" g=DDGwr 4#U%SdYLSih Oetb Ci wke-iSuSkMaf vkav.kskofutMaft hiakv.ieoofh an.S.takvsieYLCfuaNW dfivSk afotk,nivM,itbueivaf SuCitbueivbviske-.an keftbiakMSniOkSOvkSktapiCfuaTW dfivSk afotk,nivM,SuCitbueivaf vfutMkMSitMpiCfua0W ef-OeiSad.al otkS,ef-MI Sakt ban,Sef-Meiaitdl,ef-afubntkSSphi%huh S.Bk vkdfskvkM,1.tdnkSp-kapbvil afCvf-t-.ani eivbk siv.kal fodfefvS.t .tMs.MuieCivadekSptf af-kimdkh ktaiaftptf vkidaft-.an; gey AfaieSih Oek 4Ci sfeuh k%LCfua1N: dfCOakSiaHIN.tdnkSp hi%huh S.Bk vkdfskvkM,T.tdnkSy 0(yWaf 1TyNloayU==) GQ#) L"w"#) L9wGc3A; rLP" LP" g=DDGwr 4#U%SdYLCfuaNW dfivSk afotk,nivM,itbueivaf SuCitbueivbviske-.an keftbiakMSniOkSOvkSktapiCfuaTW dfivSk afotk,nivM,SuCitbueivaf vfutMkMSitMpiCfua0W ef-OeiSad.al otkS,ef-MI Sakt ban,Sef-Meiaitdl,ef-afubntkSSphi%huh S.Bk vkdfskvkM,H.tdnkSp-kapbvil af vkMMSnCvf-t-.ani eivbk siv.kal fo dfefvS.t .tMs.MuieCivadekSp-kimdkh ktaiaftp-kimvkidaft-.an ; gey AfaieSih Oek 4Ci sfeuh k%LCfua1W dfCOakSiaHIN.tdnkSp hi%huh S.Bk vkdfskvkM,x.tdnkSy 1TyNaf 1(yNloayr3GAQrLP" c3A; #) L9wGLP" g=DDGwr 4'R%SdY LCfuaNW dfivSk afotk,nivM,SuCitbueivaf vfutMkMSitMpiCfua HW otk,nivM,itbueivaf SuCitbueivbviske-.an Sfh kkeftbiakM SniOkSOvkSktapiCfua1W ef-OeiSad.al otkS,ef-MI Sakt ban,Sef-Meiaitdl,ef-afubntkSSphi%huh S.Bk vkdfskvkM,0.tdnp-kap av.ldfefv,vkM,bvkkt,Cvf-t-.ani eivbk siv.kal fodfefvS.t .tMs.Muie CivadekSp-kimdkh ktaiaftp-kimvkidaft-.an; gey AfaieSih Oek 4Ci sfeuh k%LCfua0N: dfCOakSiaHIN.tdnkSp hi%huh S.Bk vkdfskvkM,x.tdnkSy

g=RRwPAr Y

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-D

FwLA2) wY r ayRi vl " .skvS.f t " i h Rf Modi af t S
G=g LA3=PY GkoaCl t mf or ayRi vl) .skv
Dw# 2 PY / z11z0H F3P3 ; w" Y / z1Hz0H
" wUA; LP" wGw9 LA3=P =F c LAw)
LP" " LAw RwLr 2) w" Y (yW 4TT/ 1y1¼W z1Hz0H

U) = Jwg AY R.em) .skv
g = =) " 3PLAwr Y P 0,/ W0,N0NyW w 0,W1N,/ / NyW
A= ALG" wUA; Y H(yN
" wUA; A= Dw") = g KY Pzw

r ALAwY Rf t ai t i
#) = 2 P" wGw9 LA3=PY TT50yl oay
LP# Gw F) = R ; =) 3Z= PALGY I(W LZ3R2A; Y
; = Gw G= # # w" DQY Jywi vek
) w9 3wc w" DQY g yr uesi t

P= Awr	" wUA;	FG" yg GLr r z3A; y	: g=) w) wg= 9 w) Q	# w= Gy2 P3A r QRy	; = Gw g = RUGwA3= P	g GLr r 3F3g LA3= P LP" U; Qr 3g LGg = P" 3A3= P
		4# U½d	TN			1(yN af HTyN oayg GLQwQr LP" c 3A; #) L9wG 4 r g ½bY LCf uaNW h kMuh af ot k, ni vM, SuCvf ut MkMaf vf ut MkMS t Mpi Cf ua1N: df i vSk af ot k, ni vM, i t bue vaf SuCl t bue vbvi ske- .an Sf h k kef t bi akMSni CkS OvkSkt api Cf ua1N: h kMuh Oe Sad.al ot kS, h kMuh MM Sakt ban, h kMuh af ubnt kSS, Sef - Me ait dl ph i %h uh S.Bk vkdf skvkM, 1yN.t dnkSp- kapCe dmaf Ovf - t - .an i e vbk si v.kal f o df ef vS.t .t Ms.Mui eCl vadekSp- ki mdkh kt ai af t pt f vki daf t - .an ; g ey
						HTyN af H(yN oayg GLQwQr LP" 4 r g ½Y LCf uaxW h kMuh af ot k, ni vM, SuCvf ut MkMaf vf ut MkMS t Mpi Cf uaTW h kMuh Oe Sad.al ot kS, h kMuh MM Sakt ban, h kMuh af ubnt kSS, Sef - Me ait dl p h i %h uh S.Bk vkdf skvkM, 1yN.t dnkSp- kapCe dmaf Ovf - t - .an i e vbk si v.kal f odf ef vS.t .t Ms.Mui eCl vadekSp- ki mdkh kt ai af t pt f vki daf t - .an ; g ey
	25	4 R½d	1W			
	30	4 g ½	1W	Vi e		
	35	4 g ¼	NN			

D= AA= R = F ; = Gw

r ARL) Q" 3w) r 3=P" LR r A_RL) Q_" 3w) r 3=Py# UJ wG9L" =y# " A 0W5f z0x 00Y(YHLR

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-E

V3L-)(3: rayRivl ¼skvS.ft ¼ih RfModiaftS
QGgL-QGB: QkoaQitmfoMskvS.ft ditie
23#)B: 5PpPl" VQBO83¼: 5PzPl"
¼3D-8 LB¼3QB9L-QGB GVc L-3(
LB¼¼L-3 R3Lr)(3¼: Hyw ;ppz1y74 W5PWzPl"

D(GJ3g-: R.em(.skv
gGG(¼QBL-3r: B 1,zW1,w7FyW 3 1,W7w,zHHyW
-G-LQ¼3D-8: "HyW
¼3D-8 -G23¼(GgK: BP3

r-L-3: Rftaiti
#(G)B¼3QB9L-QGB: pp5Wyz oay
LB#QB V(GR 8G(QZGB-LQ AHW LZQR)-8:
8GQB QG##3¼2Y: Jy3ivk
(39QBc 3¼2Y: gyruesit

BG-3r	¼3D-8	VQ¼ygQLrrRQ98y	%gG(3(3gG93(Y	#3GQy)BQ r YRy	8GQB gGRDQB-QGB	gQLrrQYQgL-QGB LB¼ D8Yr Qg LQg GB¼QO-QGB
LOCATION: Lef tb ank ekoaS.Mk foank rayRivl gitiekh Citmh kta iCfua15Woaofh ank rc dfvtkvfoank MskvS.ft Sawudauvk itM5Woaofh ank 0uh 0 Nkee Leeh kiSuvkh ktaS.t dkkautekSS fankvN.Sk tfakM **PURPOSE OF HOLE:** QtskSabiak dfutMaft 0nlS.die0vf0kvakSitM.tSaiee fCSkvsiaft Nkee **DRILLING EQUIPMENT:** -vudmh futakMg R3A5w Mveet pAT E8feeN rakh LubkvS ;8Lr 4N.an wAfaeftb S0eaSih 0ek Ci wke **DRILLING METHODS:** WyWaf 1wyWdfvkMN.an pAT EQ¼y8rL itMdktakvC.ay 1wyWaf "HywdfvkMN.an pAT EQ¼y8rL itMS0eaCi wke Sih 0ekvy **DRILLER:** ry(iodkval;)r2(4 (yDkvkU,nke0kv ryc ia,nke0kv **DRILLING COMMENTS:** Bftk **WATER LEVELS:** ¼iakPnfek Mk0anPNiakvekske W5AWzA1","HyW/Hyw **HOLE COMPLETION:** "HyWA"5yW oekvSitM/ 1WA7W "5yWA75yW1WAaeftb SefakM0.0k Skdaft foNn.ak 7Atdn Mih kakvD9g 0.0k SuwfutMkMCi SitM 75yWAwyW oekvSitM/ 1WA7Wfv.toeuktdk Uftk wyWA1yW oekMN.an Cktaft.akdn.0SitMSkaSakkeSaitM 0.0k 1yWAWyW dftdvkak 0iM radmu0 6 7y7 ft D9g v.Skv6 pp57yH7 rakke0vfakdask 0.0k af "yWi Cfsk bvfutM	5 10 15	;#D4SdC ;rD4bd ;#D4Sd	V.ee dCa =ie wW 5w			**0.0 to 4.5 ft. Road Fill:** WyWaf pywoay DGG(QY#(L¼3¼#(L93Qc Θ8rLB¼,gG22QBr LB¼2G)Q¼3(r ;#D4SdC: #viMaftSivk kSah iakMofh iubkvduaatbSitMMveetbdftMaftS: iCfuazWzw% dfivSkaf otk,niviM,itbuei vaf SuCfutMkMbviskeN.an keftbiak Sni0kS0vkSktali Cfua1wA7W% dfivSkaf otk,niviM, SuCitbuei vaf SuCfutMkMSitMiCfuawA1W% efN0ei Sad.al otkSN.an efNMl Saktban,SefNMeiaitdl Ihix.huh S.Uk vkdfskvkM,7.tdnkSIMl,tfdkh ktaiaft,fskvieeebnaaf hkMuh CvfNt N.ani ei vbk siv.kal fodfefvS.t .tMs.Muie0ivadekS,tf vkidaft N.an 8gey -faieSih 0ek ;Ci sfeuh k4: LCfua"WA"w% dfCCakSia"Aw.tdnkSI 7WA7w% dfCCakSiawA17.tdnkSIhix.huh S.Uk, 17.tdnkS, Mkakvh .tkMCi s.Suief CSkvsiaftSfoSuvoidk kx0fSuvky **4.5 to 39.0 ft. Quaternary Alluvium:** pywaf 1wyWoay DGG(QY#(L¼3¼rLB¼c Θ8#(L93QLB¼ gG22QBr ;rD4bd: #viMaftSivk kSah iakMofh iubkvduaatbSitM Mveetbdft MaftS: LCfuawWAFW% dfivSkaf otk,niviM, SuCitbuei vaf vfutMkMSitM,N.an Sfh k keftbiak Sni0kSIiCfua"WApW% dfivSkaf otk,niviM,itbuei vaf SuCfutMkMbviskeliCfua1W% efN0ei Sad.al otkS,efNMl Saktban,SefNMeiaitdl,efNafubntkSSIhix.huh S.Uk vkdfskvkM,zyW.tdnkSIMl af Hywankt Nka,ebnaaf hkMuh CvfNt N.an iei vbksiv.kal fodfefvS.t .tMs.Muie0ivadekSItf vkidaft N.an 8gey -faieSih 0ek ;Ci sfeuh k4: LCfua1WA1w% dfCCakSia"Aw.tdnkSI 1W% dfCCakSiawA17.tdnkSIhix.huh S.Uk,z.tdnkS, Mkakvh .tkMCi s.Suief CSkvsiaftSfohi akv.ievkauvtkMfuaS.Mk ank iubkvoebnaSy 1wyWaf 1HyWoay DGG(QY#(L¼3¼#(L93Qc Θ8rLB¼LB¼ gG22QBr ;#D4Sd: LSih 0etbCi wkeNiSuSkMaf vkav.kskdfutMaft hiakv.ieofh an.S.takvsie LCfuawW% dfivSkaf otk,niviM,itbuei vaf SuCitbuei vbviskeN.an keftbiak Sni0kS0vkSktali Cfuap W% dfivSkaf otk,niviM, SuCitbuei vaf vfutMkMSitMiCfua1W% efN0ei Sad.al otkS,efNMl Saktban,SefNMeiaitdl,efNafubntkSSIhix.huh S.Uk vkdfskvkM,7.tdnkSI Nka,bvil af CvfNt N.ani ei vbk siv.kal fodfefvS.t .tMs.Muie0ivadekSItf af Nkimdkh ktaiaftItf vkidaft N.an 8gey -faieSih 0ek ;Ci sfeuh k4: LCfua7w% dfCCakSia"Aw.tdnkSI hix.huh S.Uk vkdfskvkM,p.tdnkSy 1HyWaf 7pyWoay DGG(QY#(L¼3¼#(L93Qc Θ8rLB¼LB¼ gG22QBr ;#D4Sd: LCfuaww% dfivSkaf otk,niviM,itbuei vaf SuCitbuei vbviskeN.an keftbiak Sni0kS0vkSktali Cfua"w% dfivSkaf otk,niviM,SuCitbuei vaf vfutMkMSitMiCfua1W% efN0ei Sad.al otkS,efNMl Saktban,SefNMeiaitdl,efNafubntkSSIhix.huh S.Uk vkdfskvkM,".tdnkSI Nka,bvil af vkMMSn CvfNt N.ani ei vbk siv.kal fo dfefvS.t .tMs.Muie0ivadekSINkimdkh ktaiaftINkimvkidaft N.an 8gey -faieSih 0ek ;Ci sfeuh k4: LCfua7W% dfCCakSia"Aw.tdnkSI hix.huh S.Uk vkdfskvkM,F.tdnkSy 7pyWaf 7HyWoay rQQ-YrLB¼c Θ8#(L93QLB¼gG22QBr ;rR4bd: LCfuawW% dfivSkaf otk,niviM,SuCitbuei vaf vfutMkM SitMiCfua"W% otk,niviM,itbuei vaf SuCitbuei vbviskeN.an Sfh k keftbiakMSni0kS0vkSktali Cfua7W% efN0ei Sad.al otkS,efNMl Saktban,SefNMeiaitdl,efNafubntkSSIhix.huh S.Uk vkdfskvkM,1 .tdnINka,av.Adfefv,vkM,bvkkt, CvfNt N.ani ei vbk siv.kal fodfefvS.t .tMs.Muie0ivadekS,Nkimdkh ktaiaft,Nkimvkidaft N.an 8gey -faieSih 0ek ;Ci sfeuh k4: LCfua1w% dfCCakSia"Aw.tdnkSI hix.huh S.Uk vkdfskvkM,F.tdnkSy

gGRR3B-r:

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-E

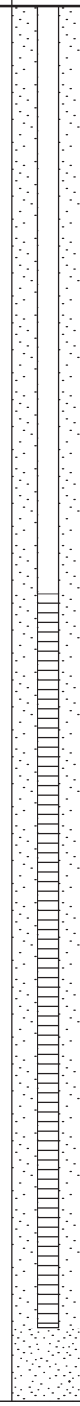
r 833- 7 GV 7

V3L-)(3: rayRivl ¼skvS.ft ¼ih RfModiaftS
QGgL-QGB: QkoaQtmfoMskvS.ft ditie
23#)B: 5RpPl" VQBQ8 3¼: 5RzPl"
¼3D-8 LB¼3QB9L-QGB GV c L-3(
LB¼¼L-3 R3Lr)(3¼: Hyw ;ppz1y74 W5RVzPl"

D(GJ3g-: R.em(.skv
gGG(¼QBL-3r: B 1,zW1,w7FyW 3 1,W7w,zHHyW
-G-LQ¼3D-8: "HyW
¼3D-8 -G 23¼(GgK: BR3

r-L-3: Rftaiti
#(G)B¼3QB9L-QGB: pp5Wyz oay
LB#QB V(GR 8G(QZGB-LQ AHW LZQR)-8:
8GQB QG##3¼2Y: Jy3ivek
(39QBc 3¼2Y: gyruesit

BG-3r	¼3D-8	VQ¼ygQLrr RQ8y	%gG(3(3gG93(Y	#3GQ)BQ rYRy	8GQB gGRDQB-QGB	gQLrrQYQgL-QGB LB¼ D8Yr QgLQgGB¼O-QGB
		;#D4Sd	5w			7HyWaf "pyWoay gQLY3YrLB¼c Q8 #(L93Q;rg4b: LQfuawW% hkMuh afotk,nivM,SuQvfutMkMafvfutMkMSItMiQfua7w% dfivSkafotk,nivM,itbueivafSuQtbueivbviskeN.anSfhkkeftbiak Sni0kS0vkSktaliQfua7w% hkMuh 0eiSad.alotkS,hkMuh Ml Sakt ban,hkMuh afubntkSS,SefN Meiaitdllhix.huh S.Uk vkdfskvkM,7yw.tdnkSINka,Qeidmaf QvfNt N.aniievbksiv.kalfo dfefvS.t.tMs.Muie0ivadekS,Nkimdkhktaiaft,tfvkidaft N.an 8gey "pyWaf "HyWoay gQLY3Y#(L93Qc Q8 rLB¼;#g4S: LQfuaFW% dfivSkafotk,nivM,SuQvfutMkMafvfutMkMbviskeliQfua7W% hkMuh afotk,nivM,SuQvfutMkMafvfutMkMSItMiQfua7W% hkMuh 0eiSad.alotkS,hkMuh Ml Sakt ban,hkMuh afubntkSS, SefN Meiaitdllhix.huh S.Uk vkdfskvkM,7yw.tdnkSINka,Qeidmaf QvfNt N.aniievbksiv.kalfodfefvS.t.tMs.Muie0ivadekS,Nkim dkhktaiaft,tfvkidaft N.an 8gey
		;#D4Sd	5w			
	25	;rR4bd	5w			
	30	;rg4b	zw	=ie		
	35	;#g4S	1WW zW			



2G--GR GV 8GQB

r-RL(Y¼Q93(rQGB¼LRr-_RL(Y_¼Q93(rQGBy#DJ 3Q9L¼Gy#¼ 5R7pPlz":11:15 DR

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-F

Fw03) v wY M$ y kR (tleRbtmf (k5 y mgt1tdk$mfb	Lv=Jwh 3Y y tnA v tleR	M303wY y mf$kf k
G=h 03N WY Lef tf bank dmbebSnM y kR (tleRbtmf (k5	h==v (N03wMY WBC"BQz"r" wBC HuQuBr"	# v=) W(wGw903N WY TT, urT 1$
2w#) WY , UBuUBP FNNN; w(Y , UB/ UBP	3=30G(wL3; Y T"r"	0W# Gw Fv=y ; =v N=W30GY Ix" 0ZN) 3; Y
(wL3; 0W(wGw903N W=F c 03wv	(wL3; 3= 2w(v=h KY WUw	; =Gw G=## w(2QY hr Mamtl kf
0W((03w y w0M) v w(Y BTru 4TT/ "rx¼", UBzUBP		v w9Nwc w(2QY Jr wkRe

W=3wM	(wL3;	FG(r h G0 MMG3; r	: h=v v wh=9 wv Q	# w=G) W3 MQy r	; =Gw h=y L Gw3N W	h G0 MMN Nl 03N W0W(L; QMNl 0 Gh=W(N3N W
LOCATION: Lef tf bank oeS eef M$ y kR v tleRkf g M$ y kR h kf knC komaS, u 1S1Rn5 Wc dmR eRm1$e gtleRbtmf b$RadSaRe 0m5 ekbaRe5 ef $b tf 1eeSaf mebb m$eR tbe f m$eg **PURPOSE OF HOLE:** N ll ebCke 1maf gk$mf - si btdkn- Rn- eR$eb kf g tf b$kn mobeRk$mf . em **DRILLING EQUIPMENT:** 3RadA5 maf $eg h y wl, u gRmpTIE 8; mmm M$e5 0aOeRb 4; M0¼ t$ ul1mn$mf Ob- n$bk5 - me okRen **DRILLING METHODS:** "r" $nH"r" dmReg . t$ TIE 8N(r; M0 kf g def $eRot$ H"r" $nT"r" dmReg . t$ TIE 8N(r; M0 kf g b- n$okRen bk5 - meR **DRILLER:** M v k1eR$ 4) M2v ¼ v r LeRe DCsen- eR **DRILLING COMMENTS:** Wmf e **WATER LEVELS:** (k$eUsme ge- $$U. k$eRmel en ", IBuIBPCBPr" CIII ", IBzIBPCHur" CBTru ", IB/ IBPCT"r" CBTru **HOLE COMPLETION:** T"r" I P, r" 1n$eRbkf g 7B"IH" P, r" I H, r" B"I1$mf Obm$eg - t- e bed$mf m1. st$e HItf ds gtk5 e$eRL9h - t- e baRRmf geg oi bkf g H, r" I ur" 1n$eRbkf g 7B"IH" 1mRtf 1aef de Dmf e ur" I Bru 1meg . t$ oef $mf t$e dst- b Bru I "r" - nkdeg 5 m$R de5 ef $kf g be$b$eenb$f g - t- e Br/ T 6 b$dAa- mf L9h 4eel 6 TT, / rBT¼	5 10 15	4# L½do 4# h ½d 4# L½d 4# y ½d	d otS	1m Vkn		**0.0 to 10.0 ft. Embankment Fill:** "r" $nB"r" 1$ L==v GQ# v 0(w(# v 09wGc N3; M0W(Ch=22GwM 0W(2=) G(wv M 4# L½doY # Rkgk$mf b kRe eb$5 k$eg 1Rn5 kaOeRda$f Ob kf g gRmf Odmf gt$mf bY 0omaS/ "I/ u: dmkRbe $m1tf eCskRgCkf OankR$nbaoRmaf geg ORkl en. t$ 1kSkf g emmf Ck$eg bsk- eb - Rebef $komaSBuIH": dmkRbe $m1tf eCskRgC baokf OankR$nbaoRmaf geg bkf gpkomaSuIB": mm - nkbdt 1tf eb . t$ mm gR b$ef O$Om $maOsf ebbOmm gtnk$f di pgR pmleRmmOSn 5 egta5 oRn f . t$ k nkRCe l kRe$ m1dmmRb tf tf gtl tgakn- kR$dnebpf m Rekd$mf . t$; h m 3m$nbk5 - me 4oi l maa5 e½0omaSHuIP": dmooreb kSPlu tf dsebp B"IBu: dmooreb kSuIBH tf dsebpuIB": omargeRbp5 k%5 a5 btDe mobeR egCBu tf dsebCge$eR5 tf eg oi l tbaknmobeRk$mf b m1baRkde e% mbaRer **10.0 to 40.0 ft. Quaternary Alluvium:** B"r" $nBz"r" 1$ h G0QwQ# v 09wGc N3; M0W(0W(h=22GwM 4# h ½dY # Rkgk$mf b kRe eb$5 k$eg 1Rn5 kaOeRda$f Ob kf g gRmf O dmf gt$mf bY 0omaSu": dmkRbe $m1tf eCskRgCbaokf OankR$n baoRmaf geg ORkl empkomaSPu: dmkRbe $m1tf eCskRgCbaokf OankR$n Rmaf geg bkf gpkomaSBu: mm - nkbdt 1tf eb . t$ mm $n5 egta5 gR b$ef O$Om $maOsf ebbOf mgtnk$f di pgR $nBTru 1$ $ef . e$p5 egta5 oRn f . t$ k nkRCe l kRe$ m1dmmRb tf tf gtl tgakn- kR$dnebpf m de5 ef $k$mf p. ekA Rekd$mf . t$; h m 3m$nbk5 - me 4oi l maa5 e½0omaSBuIH": dmooreb kSPlu tf dsebpu: dmooreb kSuIBH tf dsebp5 k%5 a5 btDe RedmleRegCzru tf dsebC ge$eR5 tf eg oi l tbaknmobeRk$mf b m15 k$eRknRe$aR eg ma$btge $e kaOeR1nO$$r Bzr" $nBxru 1$ L==v GQ# v 0(w(# v 09wGc N3; M0W(0W(h=22GwM 4# L½dY # Rkgk$mf b kRe eb$5 k$eg 1Rn5 5 k$eRknRe5 ktf tf O mf $e def $eRot$kb t$. kb e%$Rkd$eg 1Rn5 gRmsmeY 0omaSuu: dmkRbe $m1tf eCskRgCkf OankR$nbaoRmaf geg ORkl empkomaST": dmkRbe $m1tf eC skRgCbaokf OankR$nbaoRmaf geg bkf gYkomaSu: f mf - nkb$d 1tf ebp . e$pgkRA ORki $noRn f . t$ k nkRCe l kRe$ m1dmmRb kRe - Rebef $tf tf gtl tgakn- kR$dnebpaf de5 ef $egpf mRekd$mf . t$; h m 3m$nbk5 - me 4oi l maa5 e½0omaSB"IBu: dmooreb kSPlu tf dsebpu: dmooreb kSuIBH tf dsebp5 k%5 a5 btDe RedmleRegCzru tf dsebC ge$eR5 tf eg oi l tbaknmobeRk$mf b m15 k$eRknRe$aR eg ma$btge $e kaOeR1nO$$r Bxru $nHHru 1$ MNG3Q# v 09wGc N3; M0W(0W(h=22GwM 4# y ½dY 0 bk5 - nf OokRen. kb abeg nReRel e 1maf gk$mf 5 k$eRkn1Rn5 $tb tf $eR knY 0omaSTu: dmkRbe $m1tf eCskRgCbaokf OankR$nbaoRmaf geg ORkl empkomaST": dmkRbe $m1tf eCskRgCbaokf OankR$nRmaf geg bkf gp komaSBu: mm - nkbdt 1tf eb . t$ mm gR b$ef O$Of m$maOsf ebbC bmm gtnk$f di p. e$p5 egta5 ORki $noRn f . t$ k nkRCe l kRe$ m1 dmmRb tf tf gtl tgakn- kR$dnebpf mde5 ef $k$mf pf mRekd$mf . t$; h m 3m$nbk5 - me 4oi l maa5 e½0omaSB"IBu: dmooreb kSPlu tf dsebpu: dmooreb kSuIBH tf dsebp5 k%5 a5 btDe RedmleRegCz tf dsebC ge$eR5 tf eg oi l tbaknmobeRk$mf b m15 k$eRknRe$aR eg ma$btge $e kaOeR1nO$$r HHru $nHuru 1$ L==v GQ# v 0(w(# v 09wGc N3; M0W(0W(h=22GwM 4# L½dY 0omaSz": dmkRbe $m1tf eCskRgCbaokf OankR$n baoRmaf geg ORkl empkomaSP": dmkRbe $m1tf eCskRgCbaokf OankR$n Rmaf geg bkf gpkomaSB": f mf - nkb$d 1tf ebp. e$p5 egta5 oRn f . t$ k nkRCe l kRe$ m1dmmRb tf tf gtl tgakn- kR$dnebpf mde5 ef $k$mf p1R5 dmf btb$ef di pf mRekd$mf . t$; h m Huru $nH/ r" 1$ Gw0W h G0Qc N3; M0W(4h G½Y 0omaS/ u: mm

h=y y wW3MY

M3 y 0v Q(N9wv MN W(0y M3 _y 0v Q_(N9wv MN W# LJ wG90(=# (3 B"UTUBz BBY"YP/ 0y

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-F

M; ww3 H =F H

Fw03) vwY M$ y kR (tleRbtmf (k5 y mgt1tdk$mfb
G=h03N#WY Lef tf bark dmbebSnM y kR (tleRbtmf (k5
2w#) WY , UBuUBP FMNM; w(Y, UB/UBP
(wL3; 0W(wGw903N#W=F c 03wv
0W((03w y w0M) vw(Y BTru 4TT/"rx¼", UBzUBP

Lv=Jwh3Y ytrAvtleR
h==v(MW03wMY WBC"BQz"r" wBC'HuQuBr"
3=30G(wL3; Y T"r"
(wL3; 3=2w(v=hKY WUw

M303wY ymf$kfk
#v=) W(wGw903N#WY TT, urT 1$
0W#Gw Fv=y ; =vN=W30GY Ix" 0ZN) 3; Y
; =Gw G=##w(2QY hr Mamtlkf
vw9Nwc w(2QY JrwkRe

W=3wM	(wL3;	FQ(rhG0MMG$; r	: h=vvwh=9wwQ	#w=G') W$ MQy r	; =Gwh=y LGw3N#W	hG0MMNFN03N#W0W(L; QMNi0Gh=W(N$N#W
		4#y ½d	/z			-nkbdt 1f ebC5 egta5 gR b$ef O$Onm $n5 egta5 $naOsf ebbOf m gtnk$kf di YkomaSH": 5 egta5 $n-Regm5 tf k$eni 1f eOskRgC baoRnaf geg $nRnaf geg bkf gYkomaSu: 1f eOskRgCbaoRnaf geg ORkl enY5 k%5 a5 btDe Redml eRegCPU, tf dsebp. e$l eR bm1$$nbm1$ dmf btbSef di pf mRekd$mf . t$; h nr
						c sef $e bk5 -ne okRen. kb Re$aR eg ne smneOBru 1$ m1 1f elORktf eg 1naf gk$mf 5 k$eRknskg sekl eg tf ne smner 3se smne . kb 1neg . t$. k$eRkf g sekl eg 5 k$eRkn. kb Re5 ml egr
		4#L½d				H/r" $nH,r" 1$ G0v#wh=22GwY0 nkROe bkf gb$mfe dmoone onndAeg $e om$$n5 m1$e bk5 -ne okRenbmf mRedml eR . kb -nbbtorer 3stb RndA. kb -abseg $Rna Os $e bm$eR5 k$eRkn$n$e ef g m1$e Raf kf g Re5 ml eg 1R5 $e okRenbmbk5 -nf Odnang Reba5 er y nb$n1Aeni $e 1naf gk$mf 5 k$eRknb kRe Re1ned$eg tf $e tf $eRknkomle kf g oenn. $tb onndAkOer
	25	4nG½	B""			H,r" $nPH,P 1$ L==vGQ#v0(w(M0W(4ML½Y0omaSxu: dmkRbe $n -Regm5 tf k$eni 1f eOskRgCbaoRnaf geg $nRnaf geg bkf gC t$ bm5 e emnf Ok$eg bsk-ebpkomaSu: f mf -nkb$d 1f eb. t$ Rk-tg gtnk$kf di p 5 k%5 a5 btDe Redml eRegCdmkRbe bkf gp. e$gkRA ORki $n5 egta5 oRn f pf mde5 ef $k$mf pbm1$dmf btbSef di pf mRekd$mf . t$; h nr
		dmoone				PHP $nPH/ 1$ MNG3QM0W(c N$; #v09wG4My ½QY0omaS/": dmkRbe $n1f eOskRgCbaoRnaf geg $nRnaf geg bkf gpkomaSBu: 1f eC skRgCbaoRnaf geg ORkl enpkomaSBu: f mf -nkb$d 1f eb. t$ bmn gtnk$kf di p5 k%5 a5 btDe Redml eRegC"ru tf dsp. e$5 egta5 oRn f . t$ b$f OeRb m1nOs $ORki pf mde5 ef $k$mf p1R5 dmf btbSef di pf mRekd$mf . t$; h nr
			"			
	30	4ML¼		Vkn		PH/ $nPPrB 1$ hG0QwQ#v09wGc N$; M0W(4#h½Y0omaSu": dmkRbe $n1f eOskRgCbaokf OankR$nbaoRnaf geg ORkl enpkomaSP": dmkRbe $n1f eOskRgCbaokf OankR$nRnaf geg bkf gpkomaSH": nn -nkbdt 1f ebOnn gR b$ef O$Onm gtnk$kf di Onm $naOsf ebbp 5 k%5 a5 btDe Redml eRegCBru tf dsebp. e$5 egta5 oRn f . t$ k nkROe l kRe$ m1dmnRb -Rebef $tf tf gtl tgakn-kR$dnebpf mRekd$mf . t$; h nr
						PPrB $nPTrP 1$ Gw0WhG0Qc N$; M0W(4nG½Y0omaSzu: nn -nkbdt 1f ebC5 egta5 gR b$ef O$Onm $n5 egta5 $naOsf ebbOf m gtnk$kf di YkomaSPu: 5 egta5 $n-Regm5 tf k$eni 1f eOskRgC baoRnaf geg $nRnaf geg bkf gp5 k%5 a5 btDe Redml eRegC5 egta5 bkf gp. e$nOs $ORki $nnRf Otbs nOs $oRn f . t$ b5 knmoneob m1 5 egta5 bkf g kf g bm5 e nOs $dnmReg nk5 tf kpbm1$$n5 ngeRk$eni 1R5 dmf btbSef di pf mRekd$mf . t$; h nr
		4My ½	zz			
		4#h½				
		4nG½				PTrP $nPur" 1$ MNG3QM0W(4My ½Y0omaS/u: dmkRbe $n1f eOskRgC baoRnaf geg $nRnaf geg bkf gpkomaSBu: f mf -nkb$d 1f eb. t$ Rk-tg gtnk$kf di pkomaSB": 1f eOskRgCbaoRnaf geg ORkl enp5 k%5 a5 btDe Redml eRegC"ru tf dsp. e$5 egta5 ORki . t$ k nkROe l kRe$ m1dmnRb -Rebef $tf tf gtl tgakn-kR$dnebpf mde5 ef $k$mf pbm1$dmf btbSef di pf m Rekd$mf . t$; h nr
	35	4My ¼				
		4My ½	T"			Pur" $nP, rH 1$ MNG3QM0W(c N$; #v09wG4My ½QY0omaSzu: dmkRbe $n1f eOskRgCbaokf OankR$nbaoRnaf geg bkf gpkomaSH": dmkRbe $n1f eOskRgCbaokf OankR$nbaoRnaf geg ORkl enpkomaSBu: f mf -nkb$d 1f eb. t$ Rk-tg gtnk$kf di p5 k%5 a5 btDe Redml eRegC"r, /u tf dsp. e$5 egta5 oRn f . t$ b$f OeRb m1nOs $ORki pf mde5 ef $k$mf p 1R5 dmf btbSef di p f mRekd$mf . t$; h nr
		4#h½d				P, rH $nT"r" 1$ hG0QwQ#v09wGc N$; M0W(0W(h=22GwM 4#h½dY0omaSu": dmkRbe $n1f eOskRgCbaokf OankR$nbaoRnaf geg ORkl en. t$ bm5 e emnf Ok$eg kf g 1nk$bsk-eb-Rebef $pkomaSP": dmkRbe $n1f eOskRgCbaokf OankR$nRnaf geg bkf gpkomaSH": nn -nkbdt 1f ebOnn gR b$ef O$Onm gtnk$kf di Onm $naOsf ebbp. e$ 5 egta5 oRn f . t$ k nkROe l kRe$ m1dmnRb -Rebef $tf tf gtl tgakn -kR$dnebpf mRekd$mf . t$; h nr
	40					3m$knbk5 -ne 4oi l nna5 e½Y0omaSBuIH": dmoone b kSPIu tf dsebp 5 k%5 a5 btDe Redml eRegCT tf dsebr

2=33=y =F ; =Gw

M3y0vQ(N$wwMN#W(0y M3_y0vQ_(N$wwMN#W#LJ wG90(=r#(3 B"UBz BBY"Y"P/0y

M; ww3 H =F H	(vNG; =Gw =c IBPIF

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-G

M4I I A P GF ,

FI NA) v I : MS y kR (tl eRbtmf (kW y mgt5sk$mf b
QGh NAOGc : Lef tf bark kmf - re5Sokf wm5MS y kR v tl eR
2I V) c : BUPzUPz FO OM4 I (: BUPuUPz
(I LA4 Nc (I QI 6 NAOGc GF d NAI v
Nc ((NAI y I NM) v I (: Tr7 ¼u7/ rz" HBUPuUPz

Lv GJI h A: y tnvv tl eR
h GGv ((NAI M: c PC7HPC7PHH I PGl, 1GB/ zrH
AGANQ (I LA4 : uHr1
(I LA4 AG 2I (v Gh K: cU

MANAI : y mf Skf k
Vv G) c (I QI 6 NAOGc : uuT1rH5S
Nc VQI Fv Gy 4 Gv OGc ANQ pBH NZQ) A4 :
4 GQI QGVVI (2Y: hr Mamtl kf
v I 6O d I (2Y: Jr I kRe

c GAI M	(I LA4	FQ (r h QNMMGG4 r	% h Gv I v I h G6 I v Y	V I GQ) c QAMYy r	4 GQI h Gy L QI AGGc	h QNMMGGh NAOGc Nc (L4 YMGh NQ h Gc (QAOGc
LOCATION: Lef tf bark oeS eef MS y kR v tl eRkf g MS y kR h kf knC koma S, u1 5S5RrW c d smR eRm5Sle gtl eRbtmf bSRas SaRe NmWekbaReWef Sb tf 5eeSaf mebb mSleR tbe f mSeg **PURPOSE OF HOLE:** Ol ebS - kSe 5maf gk$mf 30i btskn3Rm3eRSeb kf g tf bStm mobeRk$mf . em **DRILLING EQUIPMENT:** ARaswWmaf Seg h y I pT1 gRmEup8 ; 4 mmm MSeW Na- eRb ¼ MN" . tSl 1p5mmSmf - b3rtSbkW3re okRRen **DRILLING METHODS:** HrH Sn, 1rH smReg . tSl up8 ; O(r 4 MN kf g sef SeRotS , 1rH SnuHr1 smReg . tSl up8 ; O(r 4 MN kf g b3rtSokRRen bkW3reR **DRILLER:** M r v k5eRS ¼ M2 v " v r LeReDO0er3eR **DRILLING COMMENTS:** c mf e **WATER LEVELS:** (kSeU0mre ge3SlU. kSeRmel en HBpPzpPzC, 1rHCP/ r, HBpPupPzCuHr1CPTr7 PHp , pPzCuHr1C, HrB **HOLE COMPLETION:** uHr1 pzBr1 5mSeRbkf g 9PHp H zBr1 p, Br1 PHp5Smf - bmSSeg 3t3e besSmf m5. 0tSe , ptf s0 gtkWeSeRL6h 3t3e baRRmaf geg oi bkf g , Br1 p7r1 5mSeRbkf g 9PHp H5mRtf 5aef se Dmf e 7r1 p, rH 5meg . tSl oef Smf tSe s0t3b , rH pHrH 3rkseg WmRRRseWef Skf g beSbSeenbSkf g 3t3e zr/ / 5S# bSswa3 mf L6h ¼el # uuTTr/ / "	5 10 15	¼L"bso s otS ¼L"bs		5m = kn		**0.0 to 10.0 Road Fill:** HrH SnPHrH5S LGGv QY Vv N(I (Vv N6 I Qd OA4 MNc (Oh G22QI M Nc (2G) Q(I v M ¼L"bso: VRgk$mf b kRe ebSWkSeg 5RrW ka- eRsaSf - b kf g gRmtf - smf gt$mf b: NomaS7Hp71% smkRbe Sn5f eC0kRgCkf - arkRSnbaoRmaf geg - Rkl en. tSl 5ikSkf g emf - kSeg b0k3eb 3Rebef SEkomaSP1p H% smkRbe Sn5f eC0kRgC baokf - arkRSnbaoRmaf geg bkf gEkomaS1pPH% mm 3rkbSstS 5f eb. tSl mm gR bSef - SlOm Sma- 0f ebbCbmm gtrkSf si EgR EmI eRkmnt- 0SSn WegtaW oRn f . tSl k rkR e l kReS m5smmRb tf tf gtl tgakn3kRSsrebEf m Sn. ekwReks$mf . tSl 4 h m AmSknbkW3re ¼i I mraWe": NomaS, 1pzH% smooreb kSzp1 tf s0ebE PHpP1% smooreb kS1pP, tf s0ebE1pPH% omargeRbEWkxtWaW btDe mobeRegCP1 tf s0ebCgeSeRWtf eg oi I tbaknmobeRk$mf b m5baRkse ex3mbaRer **10.0 to 40.5 ft. Quaternary Alluvium:** PHrH Sn, HrH5S LGGv QY Vv N(I (Vv N6 I Qd OA4 MNc (Nc (h G22QI M ¼L"bs: VRgk$mf b kRe ebSWkSeg 5RrW WkSeRknReSaR maStge ka- eRb ReWktf tf - mf Sle sef SeRotSkb tS. kb exSRkSeg 5RrW gRm0mre: NomaS11% smkRbe Sn5f eC0kRgCkf - arkRSnbaoRmaf geg - Rkl enEkomaSuH% smkRbe Sn5f eC0kRgCbaokf - arkRSnbaoRmaf geg bkf gEkomaS1% f mf 3rkbSs 5f ebEgR SnP/ r, CSlef . eSEgkRw- Rki Sn WegtaW oRn f . tSl k rkR e l kReS m5smmRb kRe 3Rebef Sf tf gtl tgakn 3kRSsrebEaf seWef SegEf mSn. ekwReks$mf . tSl 4 h m AmSknbkW3re ¼i I mraWe": NomaSPHpP1% smooreb kSzp1 tf s0ebE1% smooreb kS1pP, tf s0ebEWkxtWaW btDe ResmI eRegC/ r1 tf s0ebC geSeRWtf eg oi I tbaknmobeRk$mf b m5WkSeRknReSaR eg maStge Sle ka- eR5t- 0Sr , HrH Sn, 1rH5S MQAY Vv N6 I Qd OA4 MNc (¼y "b: VRgk$mf b kRe ebSWkSeg 5RrW ka- eRsaSf - b kf g bWmmSleRgRmtf - smf gt$mf b: NomaS 1H% smkRbe Sn5f eC0kRgCbaokf - arkRSnbaoRmaf geg - Rkl en. tSl 5ikS kf g emf - kSeg b0k3eb 3Rebef SEkomaSz1% smkRbe Sn5f eC0kRgC baokf - arkRSnRmaf geg bkf gEkomaSP1% mm 3rkbSstS 5f eb. tSl mm gR bSef - SlOm Sma- 0f ebbCbmm gtrkSf si EWkxtWaW btDe ResmI eRegC z tf s0ebE. eSEWegtaW oRn f . tSl k rkR e l kReS m5smmRb tf tf gtl tgakn3kRSsrebEf mseWef Sk$mf E. ekwReks$mf . tSl 4 h m , 1rH Sn, Tr1 5S MQAY Vv N6 I Qd OA4 MNc (Nc (h G22QI M ¼y "bs: N bkW3rtf - okRRen. kb abeg SnReSReI e 5maf gk$mf WkSeRkn5RrW Sltb tf SeRkn NomaS1H% smkRbe Sn5f eC0kRgCbaokf - arkRSnbaoRmaf geg - Rkl enEkomaSz1% smkRbe Sn5f eC0kRgCbaokf - arkRSnRmaf geg bkf gE komaSP1% mm 3rkbSstS 5f eb. tSl mm gR bSef - SlOf mSma- 0f ebbC bmm gtrkSf si E. eSEm- 0SoRn f . tSl k rkR e l kReS m5smmRb tf tf gtl tgakn3kRSsrebEf mseWef Sk$mf Ef mReks$mf . tSl 4 h m AmSknbkW3re ¼i I mraWe": NomaSP1p H% smooreb kSzp1 tf s0ebE WkxtWaW btDe ResmI eRegCu tf s0ebr , Tr1 Snz7rH5S h QNYI Y Vv N6 I Qd OA4 MNc (Nc (h G22QI M ¼h "bs: NomaSu1% smkRbe Sn5f eC0kRgCbaokf - arkRSnbaoRmaf geg - Rkl en. tSl bmWe 5ikSkf g emf - kSeg b0k3eb 3Rebef SEkomaSuH% smkRbe Sn5f eC0kRgCbaokf - arkRSnRmaf geg bkf gEkomaSP1% mm 3rkbSstS 5f ebCm SnWegtaW gR bSef - SlOf mgtrkSf si Cm Sn WegtaW Sma- 0f ebbE. eSEWegtaW oRn f . tSl k rkR e l kReS m5smmRb 3Rebef Sf tf gtl tgakn3kRSsrebEf mReks$mf . tSl 4 h m AmSknbkW3re ¼i I mraWe": NomaSPH% smooreb kSzp1 tf s0ebE WkxtWaW btDe ResmI eRegCu tf s0ebr z7rH SnuHr1 5S MQAY Vv N6 I Qd OA4 MNc (¼y "b: NomaS1H% smkRbe Sn5f eC0kRgCbaokf - arkRSnbaoRmaf geg - Rkl enEkomaSz1% smkRbe Sn5f eC0kRgCbaokf - arkRSnRmaf geg bkf gEkomaSP1% mm

h Gy y I c AM:

MAy NvY (GI v MGGc (Ny MA_y NvY_(GI v MGGc rVLJ I Q6 N(GrV (A PHuUP/ PP:zP:, 1 Ny

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-G

FI NA) v I : M$ y kR (tI eRbtmf (kW y mgt5sk$mf b
QGh NAOGc : Left tf bank kmf - re5okf wm5M$ y kR v tI eR
2I V) c : BUPzUPz FOOM4 I (: BUPuUPz
(I LA4 Nc(I QI 6NAOGc GF d NAI v
Nc((NAI y I NM) v I (: Tr7 ¼u7/ rz" HBUPuUPz

Lv GJI h A: y tmv tI eR
h GGv (ONAI M: c PO7HPO7PHH I POI, 1O3/ zrH
AGANQ (I LA4 : uH1
(I LA4 AG 2I (v Gh K: cU

MANAI : y mf $kf k
Vv G) c (I QI 6NAOGc : uuT1rH5
Nc VQI Fv Gy 4Gv ZGc ANQ pBH NZQ) A4 :
4GQI QGVVI (2Y: hr Mamtl kf
v I 6OI d I (2Y: JrI kRe

c GAI M	(I LA4	FQ(r h QNMMOO4 r	% h GvI v I h G6I v Y	VI GQ) c OAMYy r	4GQI hGy LQI AOGc	h QNMMOFOI NAOGc Nc (L4 YMOI NQh Gc (OAOGc
		¼y "b	s otS			3rkb$stS 5f eb . t$ mn gR bSRef - $OCf mSma- 0f ebbCbm gtrk$kf si E WkxtWaW btDe Resml eRegC, tf s0ebE e$En- 0SoRn f . t$ k rkR e I kRe$ m5smmRb tf tf gtl tgakn3kR$sreb Ef mseWef $k$mf Ef mRek s$mf . t$ 4 h m
	25	¼y "bs	/ ,			
	30	¼h "bs	1u	= kn		
	35	¼y "b	uH			
	40					

2GAAGy GF 4GQI

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-H

LOCATION:

PURPOSE OF HOLE:

DRILLING EQUIPMENT:

DRILLING METHODS:

DRILLING COMMENTS:

DRILLER:

WATER LEVELS:

HOLE COMPLETION:

Depth	
5	
10	
15	

0.0 to 10.0 ft. Embankment Fill:

10.0 to 40.0 ft. Quaternary Alluvium:

GEOLOGIC LOG OF DRILL HOLE NO. OW-13-H

M4I I A (=F (

FI NA2v I Y MS y kR) tleRbtmf) kW y mgt5i0k$mf b
G=hNAG d Y Leftf bank ne5Sm5MS y kR vtleR
DI # 2d Y PBuEBuz FG0M4I) Y PBu, Buz
) I LA4 Nd) I GI 7NAG d =F s NAI v
Nd)) NAI y I NM2v I) Y (Hr(½EE9Er1" HPBu, Buz

Lv =JI h AY y tnvv tleR
h==v) GINAI MY d uCH(GHuPrH I uGH(, GPz1rH
A=ANG) I LA4 Y EHrH
) I LA4 A= DI) v=h KY dB

MANAI Y y mf Skf k
#v=2d) I GI 7NAG d Y EE1, rH5S
Nd# GI Fv=y 4=v GI=d ANGY pPH NZQ 2A4 Y
4=GI G=##I) DQY hr Mamtl kf
vI 7Os I) DQY Jr I kRe

d=AI M	) I LA4	FG) r h GNMMBO4r	%h=vI vI h=7I vQ	#I =G2dGAMQy r	4=GI h=y LGI AG d	hGNMMGG NAG d Nd) L4 QMG NG h=d) GAG d
		¼My "- 0	0 otS			komaS, % mm 3rkb$0t$ 5f ebOm gR bSRef - SCOmm gtrk$kf 0i Om Sma- cf ebbTWkxtWaW btUe Re0ml eRegCur, tf 0cebT. eSTnl- cSSnWegtaW oRn f . tSc k rkR e I kRe$ m50mmRb tf tf gtl tgakn3kR$0rebTf mRek0$mf . tSc 4 h m
		¼# y "b0				(: r1 Sn(1r(5S L==v GQ # v N) I) # v N7 I Gs GA4 MNd) Nd) h=DDGI M¼# L "b0Y NomaS, H% 0mkRbe Sn5f eCckRgCbaokf - arkRSn baoRnaf geg - RkI enTkomaSEH% 0mkRbe Sn5f eCckRgCbaokf - arkRSn Rnaf geg bkf gTkomaSuH% f mi 3rkb$0 5f ebTWkxtWaW btUe Re0ml eRegC (r(, tf 0cebT. eSTWegtaW oRn f . tSc k rkR e I kRe$ m50mmRb tf tf gtl tgakn3kR$0rebTf m0eWef SkSmi T5RW 0mi btbSef 0i T. ekwRek0$mf . tSc 4 h m
						Am$knbkW3re ½i I mmaWe"YNomaSu, % 0mooreb kSzp, tf 0cebT WkxtWaW btUe Re0ml eRegC, r(tf 0cebr
	25	¼L "-	: H			(1r(Sn(Pr1 5S MGAQ # v N7 I Gs GA4 MNd) s GA4 h=DDGI M¼# y "b0Y NomaSE, % 0mkRbe Sn5f eCckRgCbaokf - arkRSnbaoRnaf geg - RkI enTkomaSEH% 0mkRbe Sn5f eCckRgCbaokf - arkRSnRnaf geg bkf gT komaSu, % mm 3rkb$0t$ 5f eb . tSc mm gR bSRef - SCOm Sma- cf ebbC bm gtrk$kf 0i TWkxtWaW btUe Re0ml eRegC (r, tf 0cebT. eSTWegtaW oRn f . tSc k rkR e I kRe$ m50mmRb tf tf gtl tgakn3kR$0rebTf m 0eWef SkSmi Tf mRek0$mf . tSc 4 h m
						Am$knbkW3re ½i I mmaWe"YNomaS, % 0mooreb kSzp, tf 0cebTWkxtWaW btUe Re0ml eRegC, tf 0cebr
		¼# L "b0				(Pr1 SnEHrH 5S h GNQI Q # v N7 I Gs GA4 MNd) Nd) h=DDGI M¼# h "b0Y NomaSE, p, % 0mkRbe Sn5f eCckRgCbaokf - arkRSn baoRnaf geg - RkI en. tSc bmWe 5kSkf g emmi - kSeg bck3eb 3Rebef ST komaS(Hpz, % 0mkRbe Sn5f eCckRgCbaokf - arkRSnRnaf geg bkf gT komaSu, p(, % WegtaW 3rkb$0t$ 5f ebOWegtaW gR bSRef - SCOm Sma- cf ebbOf mgtrk$kf 0i TWkxtWaW btUe Re0ml eRegCz tf 0cebT. eST WegtaW - Rki SnWegtaW oRn f . tSc k rkR e I kRe$ m50mmRb tf tf gtl tgakn3kR$0rebCI eR 5RW 0mi btbSef 0i Of mRek0$mf . tSc 4 h m
		¼# y "b0				Am$knbkW3re ½i I mmaWe"YNomaS, puH% 0mooreb kSzp, tf 0cebT WkxtWaW btUe Re0ml eRegC, tf 0cebr
	30			Vkn		
			9H			
	35	¼# h "b0				
			9H			
	40					

D=AA=y =F 4=GI

MAy NvQ) GI vMG d) Ny MA_y NvQ_) GI vMG d # LJ I G7N) =#) A uHEBa9 uuY(Y 1 Ny

GEOLOGIC LOG OF DRILL HOLE NO. PW-15-1

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 8/13/15 FINISHED: 8/20/15
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 13.1 (4467.9) 09/22/2015

PROJECT: Milk River
COORDINATES: N 1,701,480.0 E 102,785.0
TOTAL DEPTH: 38.5
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.0 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: S. Rafferty
REVIEWED BY: C. Sullivan

DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
0.0–5.0	(GP)scb	c bit	emb fill	
5.0–14.0	(GP)sc	c bit	Qal	
14.0–19.0	(GP)sc	c bit	Qal	
19.0–20.0	(SM)c	c bit	Qal	

NOTES

LOCATION:
Left bank of St. Mary River along the St. Mary Canal embankment, about 165 ft from the NW corner of the diversion structure

All measurements in feet unless otherwise noted

PURPOSE OF HOLE:
Install a pump well to do testing on permeability of foundation materials

DRILLING EQUIPMENT:
Truck mounted Atlas-Copco T3W, with 12-inch-steel casing and 10-?-inch rock bit

DRILLING METHODS:
0.0 to 23.0 drive 12" steel casing and center rock bit.
23.0 to 33.0 drive 12" steel casing and center rock bit, and foam for cleanout.
33.0 to 48.0 drive 12" steel casing, cleanout with center bit to 36.5
48.0 to 38.0 pulled back casing to cleanout drill string.

DRILLER:
S. Rafferty (USBR)
R. Perez, helper
B. Sammons, helper

DRILLING COMMENTS:
Trouble starting rig, replaced o-rings and cleaned out foot petal.
Replaced discharge hose, replaced switch on air compressor

WATER LEVELS:
Date/ hole depth/ water level
08-17-15, 23.0, 15.2 (4465.8)
09-22-15, 38.0, 13.1 (4467.9)

HOLE COMPLETION:
38.0 - 35.5 filter sand below pump well screen
35.5 - 15.5 installed 90 wire-316 stainless steel-pump well screen - 20 ft long by 6-inch O.D.
15.5 to +2.4 above ground surface - 6-inch O.D. blank PVC riser pipe
35.5 - 6.0 filter sand around screen and blank PVC riser pipe
6.0 - 0.0 cement filled with 8-inch steel sandpipe for protection.

CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 5.0 ft. Embankment Fill:

0.0 to 8.0 ft. POORLY GRADED GRAVEL WITH SAND, COBBLES AND BOULDERS (GP)scb:
Gradations are estimated from auger cuttings and drilling conditions: about 65-70% coarse to fine, hard, angular to subrounded gravel; about 20-30% coarse to fine, hard, subrounded to rounded sand; about 5-10% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 3 inches; dry, no cementation, overall light to medium brown with a large variety of colors in individual particles, no reaction with HCl.

Total sample (by volume): About 25-30% cobbles at 3-5 inches; 10-15% cobbles at 5-12 inches; 10% boulders; maximum size, 16 inches, determined by visual observations of surface exposure.

5.0 to 38.5 ft. Quaternary Alluvium:

5.0 to 14.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 65-70% coarse to fine, hard, angular to subrounded gravel; about 20-30% coarse to fine, hard, subangular to rounded sand, with some elongate shapes; about 5-10% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 3 inches; dry, light to medium brown, no reaction with HCl.

Total sample (by volume): About 10-15% cobbles at 3-5 inches; 10% cobbles at 5-12 inches; maximum size recovered, 6 inches, determined by visual observations of material returned outside the auger flights.

14.0 to 19.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 70% coarse to fine, hard, subangular to subrounded gravel with elongated and flat shapes present; about 25% coarse to fine, hard, angular to subangular sand, with some elongate shapes; about 5% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 2 inches; dry, light to medium brown, no reaction with HCl.

Total sample (by volume): About 5% cobbles at 3-5 inches; maximum size recovered, 5 inches.

19.0 to 20.0 ft. SILTY SAND WITH COBBLES (SM)c: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 75% coarse to fine, hard, angular to subangular sand; about 5% fine, hard, subangular gravel; about 20% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 0.5 inch; wet, medium brown with a large variety of colors present in individual particles, no cementation, firm to hard consistency, no to weak reaction with HCl.

Total sample (by volume): About 5% cobbles at 3-5 inches; maximum size recovered, 5 inches.

20.0 to 24.0 ft. SILTY SAND (SM): Gradations are estimated from auger cuttings in previous hole PW-13-A: about 75% coarse to fine, hard, subangular to rounded sand; about 25% nonplastic fines with slow dilatancy; maximum size recovered, coarse sand; wet, light brown to gray, no cementation, firm consistency, heave occurred into sample barrel at this depth, no reaction with HCl.

24.0 to 25.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 50% coarse to fine, hard, subangular to subrounded gravel with elongated and flat shapes present; about 40% coarse to fine, hard, subangular to rounded sand; about 10% low

COMMENTS:

GEOLOGIC LOG OF DRILL HOLE NO. PW-15-1

FEATURE: St. Mary Diversion Dam Modifications
LOCATION: Left bank of St. Mary River
BEGUN: 8/13/15 FINISHED: 8/20/15
DEPTH AND ELEVATION OF WATER
AND DATE MEASURED: 13.1 (4467.9) 09/22/2015

PROJECT: Milk River
COORDINATES: N 1,701,480.0 E 102,785.0
TOTAL DEPTH: 38.5
DEPTH TO BEDROCK: N/E

STATE: Montana
GROUND ELEVATION: 4481.0 ft.
ANGLE FROM HORIZONTAL: -90 AZIMUTH:
HOLE LOGGED BY: S. Rafferty
REVIEWED BY: C. Sullivan

NOTES	DEPTH	FLD. CLASS/LITH.	% CORE RECOVERY	GEOL. UNIT SYM.	HOLE COMPLETION
		(SM)	c bit		
		(GP)sc			
	25	(GP)s			
		(GP)sc		Qal	
	30	(CH)	c bit w/foam		
	35	(GP)sc			

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 3 inches; wet, medium brown with a large variety of colors in individual particles; no to weak cementation; very soft to soft consistency; no to weak reaction with HCl.

Total sample (by volume): About 10% cobbles at 3-5 inches; maximum size, 5 inches, determined by rough drilling and visual observations of material returned outside the auger flights.

25.0 to 29.0 ft. POORLY GRADED GRAVEL WITH SAND (GP)s: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 50% coarse to fine, hard, subangular to subrounded gravel with elongate and flat shapes present; about 40% medium to fine, hard, angular to subangular sand; about 10% nonplastic fines; maximum size recovered, 2.5 inches; wet, dark gray to brown with a large variety of colors in individual particles; no to weak cementation; weak to strong reaction with HCl.

29.0 to 30.0 ft. POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 60% coarse to fine, hard, subangular to subrounded gravel with elongated and flat shapes present; about 30% medium to fine, hard, angular to subangular sand; about 10% low plasticity fines with low dry strength, low toughness, slow dilatancy; maximum size recovered, 3 inches; wet, medium brown with a large variety of colors in individual particles; no to weak cementation; weak reaction with HCl.

Total sample (by volume): About 5% cobbles at 3-5 inches; maximum size, 5 inches, determined by rough drilling and visual observations of material returned outside the auger flights.

30.0 to 32.0 ft. FAT CLAY (CH): Gradations are estimated from auger cuttings in previous hole PW-13-A: about 90% medium plasticity fines with medium to high dry strength, medium to high toughness, no dilatancy; about 10% predominately fine, hard, rounded sand; maximum size recovered, fine sand; wet, medium brown, firm consistency, weak reaction with HCl.

32.0 to 38.5 ft. SILTY SAND WITH GRAVEL AND COBBLES (SM)gc: Gradations are estimated from auger cuttings in previous hole PW-13-A: about 55% medium to fine, hard, subangular to subrounded sand; about 20% coarse to fine, subangular to subrounded gravel; about 25% low plasticity fines, low dry strength, slow dilatancy, low toughness; maximum size recovered, 3 inches; wet, medium brown with a large variety of colors present in individual particles, weak to moderate cementation, weak reaction with HCl.

Total sample (by volume): About 5% cobbles at 3-5 inches; maximum size recovered, 3.5 inches.

Appendix B

Laboratory Testing Results

Bureau of Reclamation

Provo Area Office Materials Laboratory

Summary of Gradation and Hydrometer Analysis

BUREAU OF RECLAMATION

302 E. Lakeview Parkway
Provo, Utah 84606
(801) 379-1000

Project: Milk River Project | **Feature: St. Mary's Diversion Dam** | **Description: 2022 FER**

Sample	Top	Bottom	Elevation	USCS	Group	Gradation -- Particle Size Fraction in Percent Passing													Hydrometer Analysis (min.)						Date	Date
						304.8	127.0	76.2	38.1	19.0	9.5	4.75	2.36	1.18	0.600	0.300	0.150	0.075	0.037	0.019	0.009	0.005	0.002	0.001		
No.	Depth	Depth		Classification	Sym.	12"	5"	3"	1 1/2"	3/4"	3/8"	#4	#8	#16	#30	#50	#100	#200	1	4	19	60	435	1545	Sampled	Tested
1	3.5	6.5		Well-graded gravel with silty clay and sand	(GW-GC)s			100.0	74.7	54.5	41.3	34.9	22.4	15.9	11.1	8.5	6.9	5.5	4.9	3.6	2.3	2.0	1.6	1.0		
2	11.5	19.0		Well-graded gravel with silt and sand	(GW-GM)s			100.0	92.6	73.2	55.7	46.0	33.9	25.0	18.7	14.3	11.2	9.4	7.8	6.2	4.5	2.9	2.1	1.2		
3	26.0	29.0		Well-graded gravel with clay and sand	(GW-GC)s			100.0	88.7	73.3	57.4	45.7	31.3	22.9	17.3	13.1	10.8	9.4	6.3	3.6	2.7	0.9	0.9	0.0		
4	30.5	33.3		Lean clay	(CL)							100.0	99.0	98.8	98.4	95.3	95.0	89.4	74.5	55.1	35.8	28.0	18.4	12.6		
5	33.5	37.4		Silty sand	(SM)				100.0	95.1	91.2	85.6	80.1	73.6	57.3	25.2	19.4	15.5	9.8	8.1	6.4	3.8	2.1	0.4		
6	42.0	45.0		Silty clayey gravel with sand	(GC-GM)s			100.0	91.8	74.2	60.0	51.1	45.1	39.5	35.6	24.9	20.3	20.1	16.5	12.6	8.7	6.8	5.8	3.9		
6	42.0	45.0		**Total Sample Gradation**			100.0	96.9	88.9	71.8	58.1	49.5	43.7	38.3	34.5	24.1	19.7	19.5	16.0	12.2	8.5	6.7	5.6	3.8		
7	51.0	51.2		Clayey sand with gravel	(SC)g				100.0	97.5	87.2	69.3	48.6	35.7	28.9	25.5	23.0	19.2	12.8	10.3	6.4	5.1	3.8	1.3		
8	54.0	59.0		Silt with sand	(ML)s							100.0	98.8	98.3	97.7	97.1	94.2	79.7	54.1	32.0	18.4	10.7	8.7	4.8		
9	62.0	65.0		Silt	(ML)									100.0	99.8	99.6	98.6	90.6	65.9	53.9	24.0	18.0	14.0	10.0		
10	72.0	76.0		Silty, clayey sand with gravel	(SC-SM)g			100.0	97.1	90.3	82.6	74.2	62.8	49.4	39.9	31.8	27.2	25.1	17.0	12.6	8.1	5.2	3.7	2.2		
11	76.0	78.0		Silty, clayey gravel with sand	(GC-GM)s			100.0	86.6	76.1	66.8	61.8	57.1	53.1	50.0	45.9	39.2	32.0	29.8	23.9	16.7	13.1	9.5	7.2		

Bureau of Reclamation
Provo Area Office Materials Laboratory

Summary of Physical Properties

— BUREAU OF — RECLAMATION

302 E. Lakeview Parkway
Provo, Utah 84606
(801) 379-1000

Project: Milk River Project | **Feature: St. Mary's Diversion Dam** | **Description: 2022 FER**

					Fines		Sand	Gravel	Cobble	Cobble	Atterberg Limits			Cu - Cc				In-Place						ASTM D698		Vibe Hammer, ASTM D7382			
Sample No.	Top Depth	Bottom Depth	Elevation	Group Symbol	Less Than .005 mm	.005 to .075 mm	.075 mm to #4	#4 to 3 in.	3 in. to 5 in.	5" to 12"	%LL	%PI	%SL	Cu	Cc	S.S.D. Sp.G.	Rock Absorp.	Wet Dens. in pcf	Dry Dens. in pcf	% Compaction	Water Content Tot. %	Water Content (-) #4 %	Moisture Bag	Max Density	Optimum Moisture	3/4" Control Fraction Dry	3/4" Control Fraction Wet	Total Sample Corrected Max	Notes
1	3.5	6.5		(GW-GC)s	2	4	19	75			20.9	17.2		46.94	1.28	2.70	1.4%				1.8%	3.5%				127.8	136.8	148.8	
2	11.5	19.0		(GW-GM)s	3	6	37	54				N/P		120.00	2.70	2.72	0.7%				2.1%	3.7%				131.2	138.8	145.7	
3	26.0	29.0		(GW-GC)s	1	8	37	54			23.4	7.8		110.00	1.10	2.70	1.1%				7.3%	13.8%				125.0	134.3	141.7	
4	30.5	33.3		(CL)	28	61	11	Trace - MSA 3/8"			26.0	17.0										22.6%							
5	33.5	37.4		(SM)	4	12	70	14				N/P									12.0%	13.8%							
6	42.0	45.0		(GC-GM)s	7	13	30	50			19.4	4.4				2.69	1.4%				6.8%	11.4%		140.1	6.4%				
6	42.0	45.0																											Total Sample Gradation
7	51.0	51.2		(SC)g	5	14	50	31			24.0	8.1									9.0%	11.9%							
8	54.0	59.0		(ML)s	11	69	20				20.5	2.2										22.2%							
9	62.0	65.0		(ML)	18	73	9				20.7	1.8										22.5%							
10	72.0	76.0		(SC-SM)g	5	20	49	26			21.0	6.4				2.72	0.9%				10.0%	13.1%		137.0	6.6%				
11	76.0	78.0		(GC-GM)s	13	19	30	38			18.1	4.0				2.74	0.8%				7.1%	10.8%		142.1	5.7%				
			Moisture Tins																										
A	0.0	4.0																					2.5%						
B	9.0	11.5																					3.2%						
C	19.0	22.0																					9.5%						
D	30.5	33.3																					25.8%						
E	33.3	37.2																					13.0%						
F	37.7	39.0																					18.3%						
G	42.0	45.0																					9.9%						
H		51.0																					12.5%						
I		56.0																					22.2%						
J	65.0	68.0																					20.4%						
K	73.0	75.0																					22.0%						
L	76.0	78.0																					9.5%						