RJH CONSULTANTS, INC.

FEASIBILITY STUDY APPROVAL
Pursuant to Colorado Revised Statutes 37-60-121 &122, and in accordance with policies adopted by the Board, the CWCB staff has determined this Feasibility Study meets all applicable requirements for approval.
Signed 6/26/2020 Date

GEOTECHNICAL AND
WATER RESOURCES ENGINEERING

LOAN FEASIBILITY AND EVALUATION REPORT

QUEEN DAM

KIOWA COUNTY, COLORADO

Submitted to
Amity Mutual Irrigation Company
204 S. Main
P.O. Box 187
Holly, Colorado 81047

Submitted by
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In Association with the
Amity Mutual Irrigation Company
204 S. Main
P.O. Box 187
Holly, Colorado 81047

March 2020
Project 17123

COLORADO LICENSED ROBERT J. HUZJAK 25734 3/11/2020 PROFESSIONAL ENGINEER

Robert J. Huzjak, P.E.
Project Manager

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

SECTION 1 - INTRODUCTION

1.1 Purpose

The purpose of the project is to mitigate dam safety concerns associated with internal erosion of the dam embankment material at the outlet works of Queen Dam. Internal erosion issues have been documented for over thirty years at the Queen Dam outlet works. Increased internal erosion was observed in 2017, and the Colorado Office of the State Engineer (SEO) ordered a storage restriction to limit the water level in the Queen Dam reservoir. The storage restriction was a temporary dam safety action, and rehabilitation of the dam embankment and remediation of internal erosion were required by the SEO.

Queen Dam is important to the Amity Mutual Irrigation Company (Amity) because is one of the lower reservoirs on the Amity Great Plain Reservoir System, which supplements the water supplies of the Amity and Fort Lyon canals during low stages of the Arkansas River. It is also one of the most efficient reservoirs in the system. This reservoir has very little dead pool space compared to the other reservoirs on the system. This means the Amity is able to use the majority of water placed in the reservoir for crop irrigation. In addition, it holds approximately 35,000 acre-feet (ac-ft), which is a significant amount of the Amity Great Plains Storage Decree holding.

The primary crops are alfalfa hay, corn, milo and wheat. In a good water year, Alfalfa produces 4 to 6 tons per acre, corn 150 bushels per acre, milo 120 bushels per acre. Wheat will produce 40 to 100 bushels per acre depending on if the crop gets full irrigation or the farmer only is able to irrigate once in the spring.

Amity is requesting funding assistance from the Colorado Water Conservation Board (CWCB) to implement the dam safety repairs at the outlet works. The repairs are needed because Queen Dam is a critical part of infrastructure needed to irrigate 34,682 acres of land, which provide a vital economic resource to the region.

1.2 Project Location

Queen Dam is a significant-hazard dam located in Kiowa County, Colorado approximately 12 miles north of Lamar, Colorado. The area surrounding the dam is flat, undeveloped, and generally comprised of farms. The dam is accessed from the south via County Road WW. The Project location is shown on Figure 1.1.

1.3 Objectives

The objectives of this report are to present the data collected, work performed to evaluate the dam safety issues at the outlet works, alternatives to address outlet works dam safety issues, and a proposed implementation schedule for the Queen Dam Outlet Works Rehabilitation. The selected concept-level alternative and cost opinion presented in this report were developed to enable an evaluation of the project technical requirements and associated costs. The selected alternative will be refined during final design based on additional analyses specific to the selected alternative. These specific analyses may result in modifications to the concepts presented in this report. Supporting calculations for the alternative included in final design will be developed and presented in the design report that will be developed in future design phases.

1.4 Scope of Work

RJH performed the following scope of work:

- Collected data needed to identify site conditions and support evaluation of rehabilitation alternatives.
- Performed an inspection of the outlet works and prepared an Outlet Inspection Report.
- Performed a geotechnical investigation and prepared a Geotechnical Data Report.
- Developed concept-level alternatives to mitigate seepage and erosion at the outlet works.
- Prepared a preliminary elevation-capacity curve.
- Estimated quantities of primary materials required for construction and prepared an overall opinion of probable project costs (OPCC) to construct the Project.
- Developed a Project schedule for design and construction of the outlet works rehabilitation.
- Prepared this report.

1.5 Project Personnel

The following personnel from RJH are responsible for the technical work contained in this report:

Project Manager	Robert J. Huzjak, P.E.

Geotechnical Engineer	Adam B. Prochaska, Ph.D., P.E., P.G.(1)
Hydraulic Engineer	Brena Sheridan, P.E.

Note 1. Licensed in states other than Colorado.

Sections of this report that provide information about the owner/sponsor were developed by Amity.

1.6 Existing Conditions

The dam embankment and appurtenant features were constructed in the late 1890s. The dam was constructed as an earthen embankment and is approximately 1,800 feet long with a maximum embankment height of 25 feet. The embankment crest is at about Elevation (El.) 3889 with upstream and downstream slopes generally at 3H:1V (horizontal:vertical).

The embankment impounds reservoirs within two natural depressions; Neeskah Reservoir and Queen Reservoir. The two reservoirs are connected hydraulically by means of an excavated channel. Queen Reservoir is located immediately upstream of the dam embankment and southeast of Neeskah Reservoir. According to documentation provided by the SEO, the reservoirs collectively have a capacity of 23,040 ac-ft and a surface area of 1,930 acres.

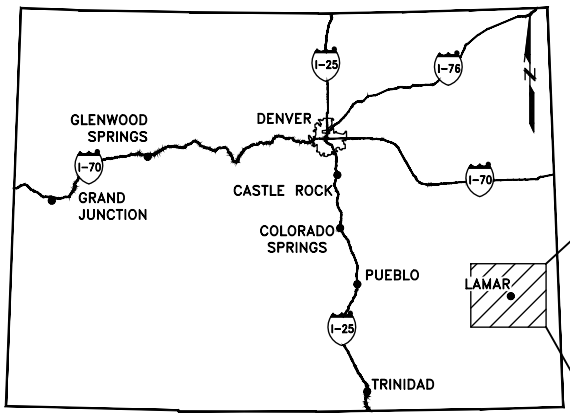
The outlet works is located in the middle of the embankment at the maximum section and discharges to Pawnee Canal. The outlet works is comprised of masonry headwalls and wingwalls, three 30-inch diameter wrought-iron riveted conduits, and open arched masonry outlet conduit. The conduits are approximatively 18 feet long and discharge to an approximate 28 feet long, 11-feet wide by 5.5 feet tall masonry open arched conduit. Three slide gates with manual operators are located at the upstream headwall. Based on a drawing showing "the general form of construction adopted" presented in the United States Department of Agriculture (USDA) *Plans of Structures in Use on Irrigation Canals in the United States* (USDA, 1903), the conduits were embedded in brick and stone masonry laid in cement, and the masonry headwall, wingwalls, and open-arched culvert were constructed with sandstone and limestone blocks. The masonry is described as having exposed rock-faced sandstone laid in cement with limestone (buried) backings. As-constructed information is not available for review and the geometry of the masonry structures could not be verified. Conditions of the headwall, wingwalls, and conduit encasement is unknown.

Seepage and erosion issues have been documented since 1985 at the Queen Dam outlet works. SEO inspection reports document the reservoir has been generally dry between 2001 and 2015. In 2016, the reservoir was filled to a gage height of 19.0 feet. At this time, water was observed "squirting" through the downstream left (east) masonry wingwall of the outlet works. In July 2017, an excavation was performed at the downstream embankment crest above the outlet works. This excavation encountered a void measuring several feet. The excavation was immediately backfilled and the reservoir drawn down. After inspection by the SEO Dam Safety staff, the SEO ordered to restrict the level of water stored by the dam to a maximum gage height of 14.0 feet.

1.7 Potential Failure Modes

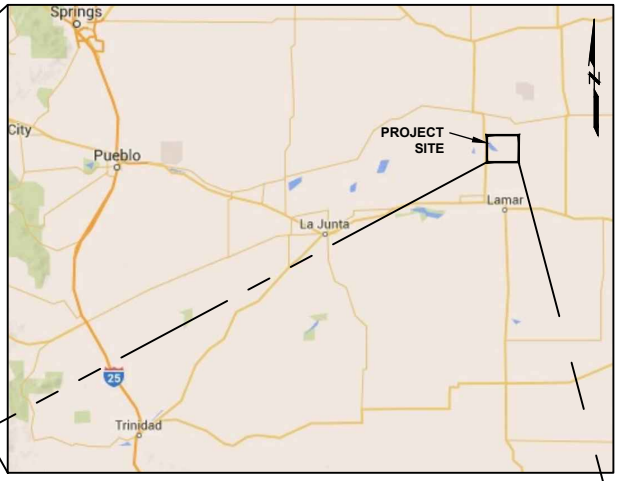
Based on field observations and geotechnical data collected, it is our opinion that seepage and internal erosion is occurring through the embankment section near the outlet works. The embankment dam outside of the limits of the outlet works was not considered and potential failure modes were only evaluated at the outlet works. We identified the following potential failure modes (PFM) that the outlet works rehabilitation concept needs to mitigate:

- Internal erosion along the outlet works conduits and masonry culvert due to a defect along the conduits including a crack, void, or zone of low compaction density possibly caused by the shape of the conduits and masonry encasement, and the configuration of the seepage collars.
- Internal erosion of embankment at the downstream wingwall contact from a gap developing due to settlement of dam fill adjacent to a rigid structure.
- Internal erosion of embankment into the masonry conduit at deteriorated joints.



PROJECT VICINITY MAP

(NOT TO SCALE)



PROJECT LOCATION MAP

(NOT TO SCALE)

PROJECT AERIAL MAP

(NOT TO SCALE)

RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	SITE LOCATION MAP
	PROJECT NO. 17123	March 2020 Figure 1.1

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SECTION 2 - SPONSOR

The Amity is the successor in interest of the project operated by the Arkansas Valley Sugar Beet and Irrigated Land Company, which was formed as a for profit company in approximately 1887. The stockholders formed the Amity Mutual Irrigation Company on April 22, 1936 as a Colorado Nonprofit Corporation.

Amity was formed as a Colorado Nonprofit Corporation as a Mutual Irrigation Company and operated under the Internal Revenue Code 501 (c) 12.

The Amity canal system and Great Plains Reservoirs serve 120 stockholders on 34,682 acres of irrigated land located east of Wiley to the Kansas state line in Prowers County, Colorado.

Amity's source of revenue is from share assessments. Existing rates are $31.00 per share.

SECTION 3 - WATER RIGHTS AND WATER DEMANDS

3.1 Water Rights

The water decreed for the facility is a fully developed absolute decree dated August 1, 1896. The Amity owns the Great Plains Reservoir Decree. This storage decree is for 265,552 ac-ft of water stored in the system. The water is diverted from the Arkansas River through the Fort Lyon Canal headgate in Otero County, Colorado. It is delivered from the Fort Lyon Canal into the Kicking Bird Canal in Bent County, Colorado. The decree is carried in the Kicking Bird to the Great Plains Reservoirs in Kiowa County, Colorado, to be used on the Amity irrigated land in Prowers County, Colorado.

The water decree is for 1150 cfs, appropriation date 8/01/1886, adjudication date 2/3/1927, to fill the reservoirs of the Great Plains Reservoir System in the amount of 265,552 ac-ft on an annual basis.

Water rights status is appropriated decree absolute.

3.2 Water Supply and Demand

The Amity relies on its Great Plains Storage rights as an integral source of its annual irrigation water. The Amity has a direct flow right on the Arkansas River for 283.50 cfs with an appropriation date of February 21, 1887, a second main stem direct flow right of 500 cfs with an appropriation date of August 30, 1893. It has four side stream water rights as follows:

1. Big Bend, Priority Date April 1, 1893 for 700 cfs.
2. Gould's Draw, Priority Date April 1, 1893 for 700 cfs.
3. Big Sandy Creek, Priority Date April 1, 1893 for 510 cfs.
4. May Valley Drain, Priority Date October 5, 1908.

The Amity also has an alternate point of diversion for 50,000 ac-ft of the Great Plains Decree in John Martin Reservoir.

The Amity was also awarded a storage account under the 1980 Operating Plan to the Arkansas River Compact Concerning John Martin Reservoir for its percentage of conservation storage as set forth under the Compact.

These water rights are all used together by the Amity to irrigate 34,682 acres.

The water rights for the facility are adequate for the purpose of the facility in most years. Queen Reservoir is one of the first of the Great Plains Reservoirs to be filled by the Amity because it is one of the most efficient vessels.

The capacity of Queens Reservoir is 35,000 ac-ft of the total 265,552 ac-ft storage decreed for the Great Plains Reservoir System.

There are several canal companies in the region that have a similar off river reservoir storage system. The Fort Lyon Canal Company and Holbrook Mutual Irrigation Company both have off river storage used together with their direct flow rights.

SECTION 4 - ANALYSIS OF ALTERNATIVES

4.1 General

RJH collected data and performed concept-level analyses to identify existing conditions, identify potential failure modes (PFMs), and develop concepts to address the PFMs and rehabilitate the outlet works.

4.2 Data Collection

Data collection included a topographic survey, outlet works inspection, and subsurface exploration. The following sections describe information obtained.

4.2.1 Survey

Wachob & Wachob, Inc. under contract to RJH performed a topographic survey of the embankment dam and appurtenant site features in January and February 2018. In addition, the survey recorded site features and boring locations. Two permanent survey control monuments were established downstream of the dam embankment and to the east and west of the discharge channel. The horizontal and vertical coordinate systems are Colorado State Plane South Zone (NAD83) and North American Vertical Datum of 1988 (NAVD88), respectively. Existing conditions and topography in the vicinity of the outlet works is shown on Figure 4.1.

4.2.2 Outlet Works Inspection

An inspection of the masonry conduit and three 30-inch riveted wrought-iron conduits was performed in January 2018. The conduits were inspected with video camera survey equipment, and the masonry conduit was visually inspected. Key data from the inspection include:

- Mortar joints were severely deteriorated or missing between masonry units at several locations.
- Cracks between the masonry blocks were up to 5 inches wide.
- At many locations, a 1/2-inch probe was easily pushed 1.2 to 5 feet through the cracks into the soils behind the masonry blocks of the conduit.
- Lamination and minor corrosion were present along the wrought-iron conduits.

Additional information is provided in the Outlet Inspection Report in Appendix A.

4.2.3 Subsurface Exploration

RJH performed a subsurface exploration in January 2018 to assess the soil and groundwater conditions at the outlet works. Two borings (B-101 and B-103) were performed through the embankment crest. B-102 was performed at the embankment toe to the east (left looking downstream) of the outlet works wingwall. The borings extended a maximum depth of 50 feet below the ground surface (bgs). Materials encountered consisted of embankment fill, alluvium, and residuum. Boring locations are shown on Figure 4.1. The work performed and data collected is provided in the Geotechnical Data Report in Appendix B. A summary of the subsurface condition is provided below.

Up to 19.5 feet of fill was encountered in the borings drilled from the embankment crest, and about 2 feet of fill was encountered in the boring performed at the embankment toe. The embankment fill primarily consisted of moist to wet, soft to very soft fine grained soil that classified as lean clay, lean clay with sand, and sandy clay. The embankment fill was underlain by alluvium in all of the borings. Approximately 28 feet of alluvium was encountered in the borings drilled from the embankment crest, and 33.8 feet of alluvium was encountered in the boring drilled at the embankment toe. The alluvium primarily consisted of low to medium plastic, wet, very soft to medium stiff clayey soil that classified as lean clay, lean clay with sand, and sandy clay. The clayey alluvium generally transitioned to a 3- to 7-foot layer of fine to medium grained, wet, loose to medium dense sand just above a residuum layer. The residuum was encountered for the remaining depth of each boring and was a stiff to hard, medium to high plasticity clay. Subsurface sections are shown on Figures 2.1 and 2.2 in Appendix B.

Groundwater was encountered in all the borings at the completion of drilling at approximately El. 3860.7 to 3863.9, which is approximately 0.7 to 2.5 feet below the upstream conduit invert (El. 3863.2). Recovered soil samples within about 9 feet above the measured water levels were wet. The reservoir was generally dry at the time of drilling. Groundwater levels may have not reached equilibrium at the time of drilling and may not represent the static groundwater surface. Groundwater levels are expected to vary with reservoir level.

4.3 Alternatives

RJH developed two concepts to address the PFMs: removing and replacing a portion of the outlet works structure, and total removal and replacement of the outlet works. Each

alternative includes removal of the masonry conduit and downstream outlet works wingwalls and installation of a diaphragm sand filter. Implementation of either of these alternatives would address the identified dam safety deficiency and restore full operation of the reservoir to Amity.

Implementation of each alternative would provide the following benefit to Amity: The Queens reservoir has the capacity to produce two runs of water approximately 15,000 ac-ft (30,000 ac-ft total) to the Amity stockholders. In an optimal year, the Amity has 10 to 12 runs per year. The average amount of runs under the Amity is 8 runs per year. In a water short year, the amount of water stored in Queens Reservoir will make the difference between having a good yield year and a poor year or even a year with system crop failures.

The following describes each alternative.

4.4 Alternative 1

Alternative 1 includes removal of the masonry conduit and downstream wingwalls and slip lining the existing conduits. The upstream masonry headwall, wingwalls, existing conduits, and slide gates would remain. A general plan, profile, and sections are shown on Figures 4.2, 4.3, and 4.4. This alternative includes the following primary components:

- Slip lining the existing conduits with new 26-inch-diameter steel pipes or high-density polyethylene (HDPE) pipes and extending the new pipes 54 feet downstream to a new stilling basin. A cured in-place pipe (CIPP) was considered and eliminated because of high cost and technical concerns with obtaining adequate contact and provide a tight seal to prevent seepage between the existing rivets and CIPP liner .
- Grouting the annulus between the new pipes and the existing conduits.
- Constructing a reinforced concrete encasement around the new pipe downstream of the existing conduits.
- Installing a new downstream concrete stilling basin and riprap protection.
- Installing a diaphragm sand filter.
- Excavating approximately 1,500 cubic yards of soil at the outlet works.
- Excavating approximately 2,600 cubic yards of soil to daylight the discharge channel.

Replacing the existing conduits with smaller pipes would reduce the overall hydraulic capacity of the outlet works. Rating curves for the sliplined conduit options are shown on Figure 4.8. The U.S. Bureau of Reclamation (Reclamation) document *Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Works* (Reclamation, 1982) provides general evacuation time rates to evacuate for significant hazard dams. This reduction would prolong the time to evacuate the reservoir and does not meet the Reclamation guidelines; however, the *Rules and Regulations for Dam Safety and Dam Construction* (2007 SEO Rules) (SEO, 2007) have no evacuation requirements for significant hazard dams.

In January 2020, the SEO published the *Rules and Regulations for Dam Safety and Dam Construction* (2020 SEO Rules) (SEO, 2020), which require outlet works systems for all dam hazard classifications to be designed to release the top five feet of reservoir storage in five days. Reservoir evacuation was evaluated for the sliplined conduit options, and the top five feet of reservoir storage could be released in approximately 16 days. The new reservoir evacuation criterion cannot be achieved with a sliplined conduit option; however, it may be possible to obtain a waiver from the SEO to allow a longer drawdown period.

The upstream masonry headwall and wingwalls would remain for Alternative 1. The as-constructed wall geometries and conditions of the masonry units behind the wall are unknown. Construction would require excavating the embankment downstream of the walls to remove the masonry tunnel, sliplining the existing conduits, constructing a stilling basin and supporting the upstream masonry walls during construction.

4.5 Alternative 2

Alternative 2 includes the removal of the entire outlet works and replacement of the outlet works components. A general plan, profile, sections, and details are shown on Figures 4.5, 4.6, and 4.7. This alternative includes the following:

- Removing the outlet works and upstream and downstream masonry walls.
- Installing a new 54-inch diameter concrete encased steel pipe.
- Installing a new intake structure with trash rack.
- Installing a new hydraulic slide gate at the intake structure.
- Installing a downstream valve vault with regulating valves to control flow (optional).
- Installing a new downstream concrete stilling basin and riprap protection.

- Replacing the upstream headwall with an earthen embankment.
- Installing a diaphragm sand filter.
- Excavating and fill placement approximately 2,400 cubic yards of soil at the outlet works.
- Excavating approximately 2,600 cubic yards of soil to daylight the discharge channel.

Alternative 2 increases the seepage length along the conduits and under the dam by constructing an embankment in place of the existing masonry headwall. The hydraulic capacity and controls are improved and meet the Reclamation reservoir evacuation guidelines. Rating curves for the conduit replacement options are shown on Figure 4.8. The hydraulic capacity for Alternative 2 does not meet the new SEO requirements for reservoir evacuation with the considered 54-inch diameter conduit size. Two, approximately 72-inch-diameter steel pipes would be required to meet the new criterion; however, in RJH's opinion, a waiver should be able to be obtained from the SEO to allow design and construction of the 54-inch diameter conduit because the outlet works capacity would meet Reclamation criteria. Table 4.1 provides the Reclamation criteria and the capacity of the 54-inch pipe conduit.

TABLE 4.1
ATERNATIVE 2 DRAWDOWN

Drawdown Stage	Hydraulic Height Change (ft)	Reclamation Drawdown Requirement (days)	Calculated Drawdown for 54-inch Conduit (days)
75%	5.0	20-30	16.1
50%	9.9	40-50	32.1
25%	14.9	70-90	50.7
10% Storage	16	50-60	55.9

In addition, risks and potential issues during construction associated with the upstream masonry headwall, wingwalls, and existing conduit encasement are removed.

4.6 Opinion of Probable Cost (OPCC)

RJH developed a Class 4 estimate of OPCC in general accordance with ASTM E 2516 for the two alternatives. Cost opinions were developed and considered the size of the

project, estimated quantities for primary work elements based on the concept-level design, and unit costs from the following sources:

- Published and non-published bid price data for similar work.
- R.S. Means Heavy Construction Cost Data 2018.
- Previous experience and judgement.

The "Base Construction Subtotal" (BCS) for each project component is the sum of the construction costs for primary work elements. The sum of the BCS, mobilization/demobilization, bonds, and insurance are defined as the "Direct Construction Cost" (DCC). Summary of the OPCC is presented in Table 4.2 for the two alternatives. Appendix C contains additional OPCC information for each alternative considered. The cost difference between pipe materials associated with Alternative 1 is insignificant.

TABLE 4.2
OUTLET WORKS REHABILITATION ALTERNATIVES OPCC

Alternative	Opinion of Probable Cost (OPCC, 2018) ($)
1	$505,000
2	$1,025,000

A Class 4 estimate is appropriate for concept-level design evaluation when the design is between 1 to 15 percent complete. The overall reliability of a Class 4 estimate is between about minus 15 to 30 percent and plus 20 to 50 percent of the OPCC.

4.7 Alternatives Evaluation

In RJH's opinion, each alternative is technically feasible and each alternative addresses the identified PFMs. A summary of the advantages and disadvantages for each alternative is presented in Table 4.3.

TABLE 4.3
OUTLET WORKS ALTERNATIVES SUMMARY OF ADVANTAGES AND DISADVANTAGES

Alternative	Advantages	Disadvantages
1	• Lowest OPCC – Approximately $520,000 less than Alternative 2 • Potentially shorter construction period • Upstream headwall and wingwalls would remain, preserving the historic nature of the structures • HDPE and Steel are common slip lining methods for dams and are proven concepts • Cost difference between HDPE and Steel pipe is insignificant	• Reduces the hydraulic capacity by reducing the diameter of the existing conduits. Reduced capacity does not meet Reclamation or SEO Hydraulic criteria. • Proper cleaning of the conduits for slip lining and grouting may be difficult • Geometry and condition of the upstream masonry headwall and wingwalls unknown, which could influence the stability of the structures and safety during construction • High risk for additional costs associated with unforeseen conditions (e.g., condition of conduit encasement, reconstruction of portions of headwall-wingwalls, etc.) that may be exposed during construction, which could increase costs and construction duration • Service life dependent on existing components and would likely require additional maintenance
2	• Reduces risks associated with Alternative 1 by total removal and replacement of the outlet works • Improves hydraulic capacity and controls by upgrading gate components and piping • Longer service life and lower maintenance costs by replacing all original outlet works components with current standards of practice components • Increases the length of the seepage path by replacing the headwall with an earthen embankment • Hydraulic capacity meets Reclamation criteria	• Highest OPCC – Approximately $520,000 more expensive • Longer construction period • Requires approximately 600 cubic yards of borrow to construct the upstream embankment • Hydraulic capacity does not meet SEO, January 2020 criteria

4.8 Conclusions

Based on the work completed for the concept-level evaluation, RJH offers the following general conclusions:

1. Both Alternative 1 and 2 are technical feasible in addressing the seepage and erosion at the outlet works.
   a. The OPCC for Alternative 1 is about $520,000 less than Alternative 2.
   b. Additional risks and uncertainties are associated with Alternative 1 that may require additional modifications that could increase cost if modification to the upstream masonry wall is needed. There is also a high risk for Alternative 1 that unforeseen conditions would be encountered during construction. If encountered, these could increase the cost and lengthen the schedule.
2. Alternative 1 reduces the hydraulic capacity of the outlet works.
3. Alternative 1 leaves the manually operated slide gates, masonry headwall, and wingwalls, which would require additional maintenance throughout the outlet works service life.
4. Alternative 2 provides improved hydraulic capacity and control and a longer service life.

4.9 Recommendations

In RJH's opinion, the selection of Alternative 2 is the most feasible and cost-effective option for the rehabilitation of the outlet works. The selected alternative removes risks and uncertainties associated with keeping the upstream masonry headwall, wingwalls, and conduits. In addition, the existing outlet works is over 100 years old, which likely exceeds the intended service life. Replacement of the outlet works would reduce the overall frequency of maintenance and associated costs.

QUEEN RESERVOIR
OPERATIONAL HWL
3883.0

DAM ℄
CREST EL 3889.0

EXISTING SLIDE GATES
(TYP OF 3)

EXISTING MASONRY BLOCK
HEADWALL AND WINGWALLS

B-101

B-103

EXISTING 30" DIA RIVETED
WROUGHT-IRON PIPE
(TYP OF 3)

EXISTING MASONRY
BLOCK TUNNEL

B-102

EXISTING MASONRY
BLOCK RETAINING WALLS

EXISTING 36-INCH
DIAMETER TREE STUMP

PAWNEE CANAL

SURVEY MONUMENT
EL. 3875.14
N 1596839.45
E 3822153.02

SURVEY MONUMENT
EL. 3876.75
N 1596810.58
E 3822375.34

3890 3885 3880 3875 3870 3865 3874

N

0 15 30 60
SCALE IN FEET

NOTES:

1. SURVEY PERFORMED BY WACHOB & WACHOB INC. FEBRUARY 2018. HORIZONTAL DATUM IS COLORADO STATE PLANE SOUTH ZONE (NAD 83) AND VERTICAL DATUM IS NAVD 1988.

LEGEND:

B-101	RJH BORING LOCATION
3875	EXISTING INDEX CONTOUR
	SURVEY MONUMENT

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	EXISTING CONDITIONS PLAN
		PROJECT NO. 17123	March 2020 Figure 4.1

P:\17123 - QUEEN RESERVOIR\CAD\FIGURES\17123_EXISTING_CONDITIONS_PLAN.DWG 1/16/2020 3:30 PM

APPROXIMATE LIMITS OF EXCAVATION

APPROXIMATE 5.5' TALL x 11' WIDE MASONRY BLOCK TUNNEL (TO BE REMOVED)

B-101

B-102

B-103

EXISTING MASONRY BLOCK WALLS (TO BE REMOVED)

EXISTING MASONRY BLOCK HEADWALL AND WING WALLS (TO REMAIN)

1
4.3

RIPRAP OVER BEDDING

EXISTING SLIDE GATES (TYP OF 3, TO REMAIN)

PAWNEE CANAL

(3) 26" DIA HDPE OR STEEL PIPES (NOTE 3)

QUEEN RESERVOIR OPERATIONAL HWL 3883.0

STILLING BASIN

2H:1V

EXISTING 30" DIA RIVETED WROUGHT-IRON PIPE (TYP OF 3, TO REMAIN) (NOTE 2)

DRAIN OUTLET

8" DIA DRAIN PIPE

SAND FILTER WITH DRAIN SYSTEM

DAM ℄
CREST EL 3889.0

3875
3870
3865
3876
3880

0 5 10 20 30
SCALE IN FEET

NOTE:

1. SURVEY PERFORMED BY WACHOB & WACHOB INC. FEBRUARY 2018. HORIZONTAL DATUM IS COLORADO STATE PLANE SOUTH ZONE (NAD 83) AND VERTICAL DATUM IS NAVD 1988.
2. NEW PIPES TO EXTEND THROUGH EXISTING 30" DIA PIPES.
3. CURED-IN PLACE PIPE (CIPP) CAN BE SELECTED AS AN ALTERNATIVE TO LINING THE EXISTING RIVETED STEEL CONDUITS IF CONDITIONS WARRANT.

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #1 - PLAN
		PROJECT NO. 17123	March 2020 Figure 4.2

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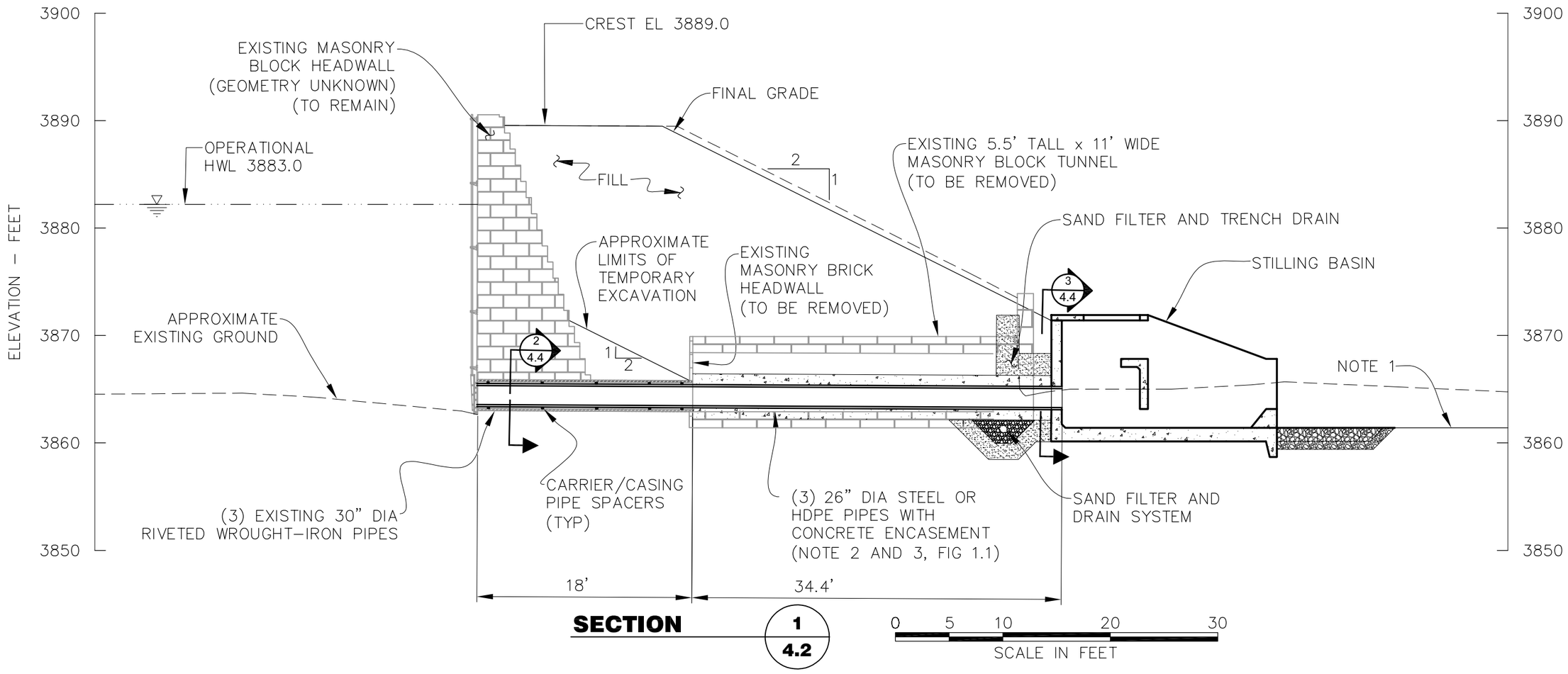


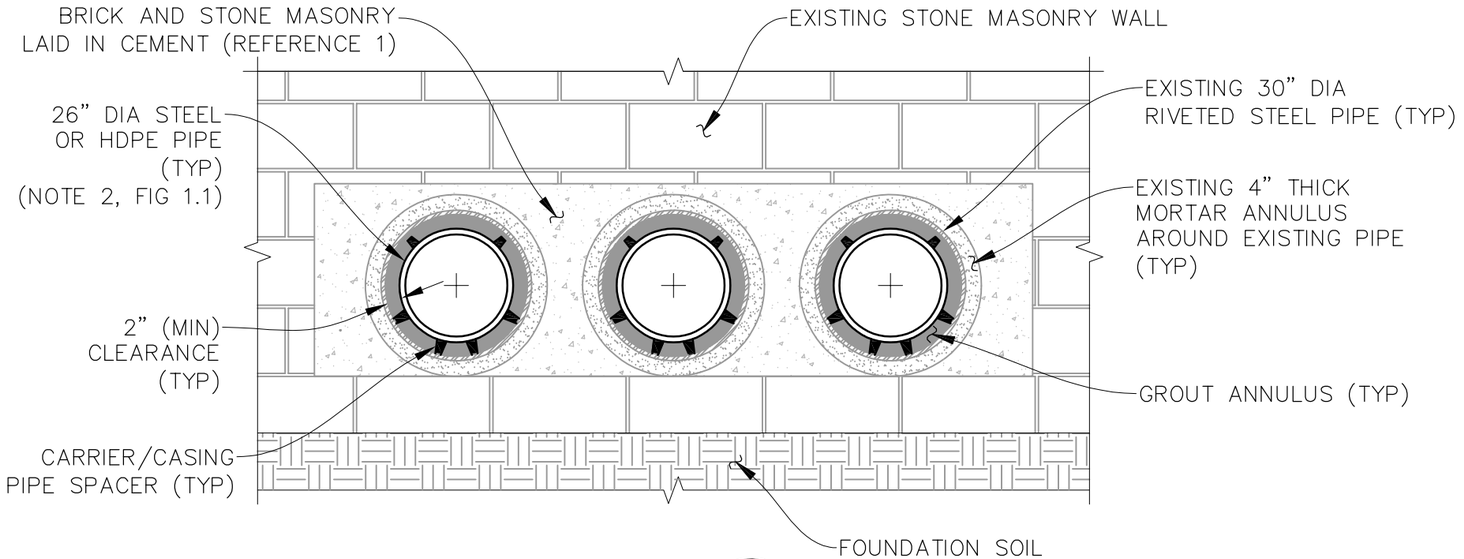
REFERENCE:

1. U.S. DEPARTMENT OF AGRICULTURE, PLANS OF STRUCTURES IN USE ON IRRIGATION CANALS IN THE UNITED STATES (1903).

NOTE:

1. CHANNEL DAYLIGHTS APPROXIMATELY 500 FEET DOWNSTREAM.

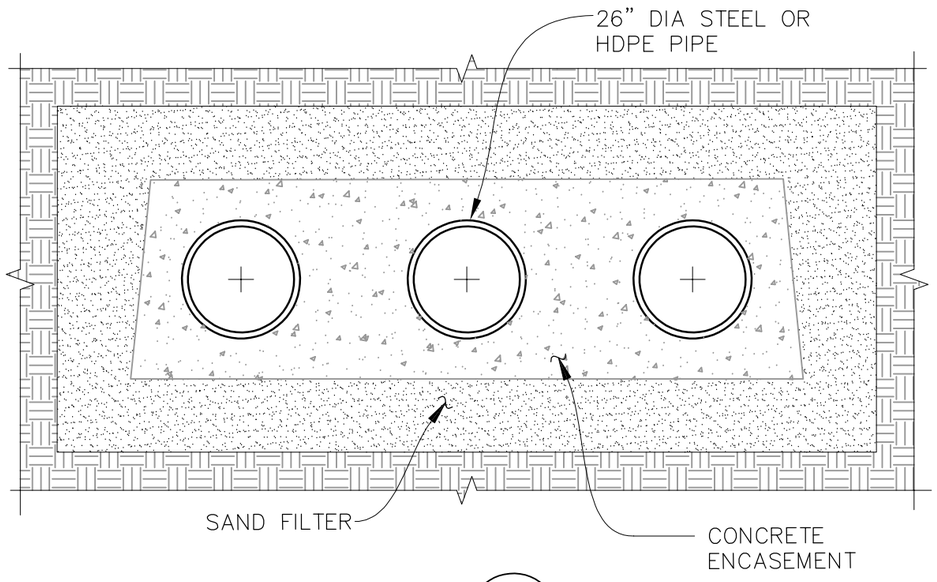
AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #1 - PROFILE
		PROJECT NO. 17123	March 2020 Figure 4.3



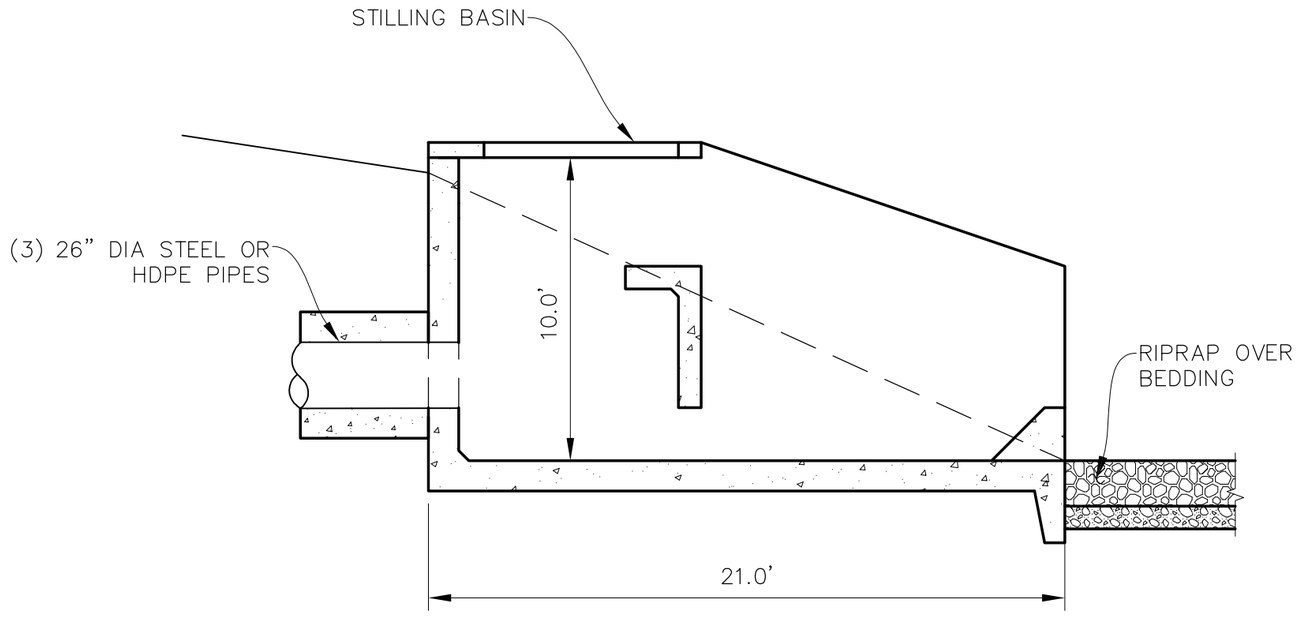
SECTION 2/4.3 N.T.S.

REFERENCE:

1. U.S. DEPARTMENT OF AGRICULTURE, PLANS OF STRUCTURES IN USE ON IRRIGATION CANALS IN THE UNITED STATES (1903).



SECTION 3/4.3 N.T.S.



STILLING BASIN

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #1 - TYPICAL SECTIONS AND DETAILS
		PROJECT NO. 17123	March 2020 Figure 4.4

APPROXIMATE LIMITS OF EXCAVATION

DAM ℄
CREST EL 3889.0

54" DIA STEEL PIPE WITH CONCRETE ENCASEMENT

EXISTING MASONRY BLOCK HEADWALL AND WINGWALLS (TO BE REMOVED)

APPROXIMATE 5.5' TALL x 11' WIDE MASONRY BLOCK TUNNEL (TO BE REMOVED)

8" DIA DRAIN PIPE

VALVE VAULT

30" DIA STEEL PIPE

RIPRAP OVER BEDDING

B-101

B-102

B-103

3885

3880

3870

3865

3H:1V

2H:1V

4
4.6

RIPRAP OVER BEDDING

PAWNEE CANAL

INTAKE STRUCTURE

EXISTING SLIDE GATES (TYP OF 3) (TO BE REMOVED)

DRAIN OUTLET

STILLING BASIN

SAND FILTER WITH DRAIN SYSTEM

EXISTING MASONRY BLOCK WALLS (TO BE REMOVED)

EXISTING 30" DIA RIVETED WROUGHT-IRON PIPE (TYP OF 3) (TO BE REMOVED)

QUEEN RESERVOIR OPERATIONAL HWL 3883.0

0 10 20 40 60

SCALE IN FEET

NOTE:

1. SURVEY PERFORMED BY WACHOB & WACHOB INC. FEBRUARY 2018. HORIZONTAL DATUM IS COLORADO STATE PLANE SOUTH ZONE (NAD 83) AND VERTICAL DATUM IS NAVD 1988.

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #2 - PLAN
		PROJECT NO. 17123	March 2020 Figure 4.5

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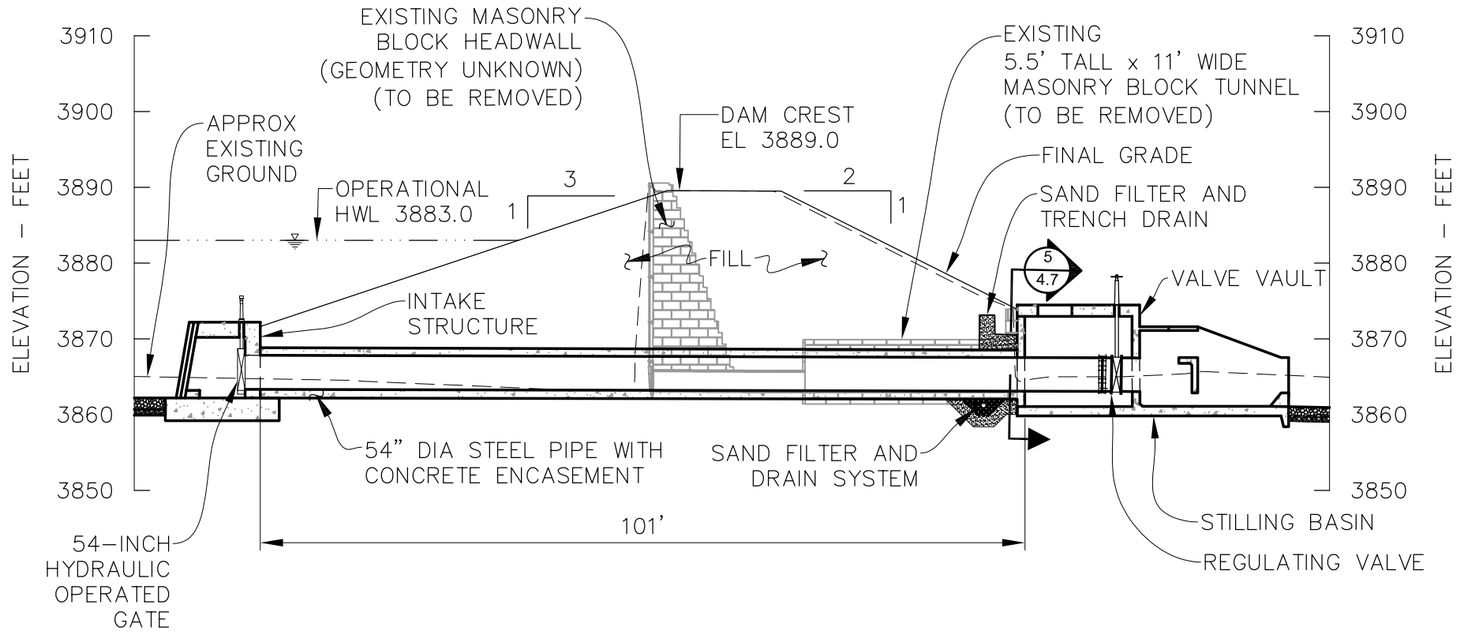

SECTION 4 / 4.5

0 10 20 40 60
SCALE IN FEET

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #2 - PROFILE
		PROJECT NO. 17123	March 2020 Figure 4.6

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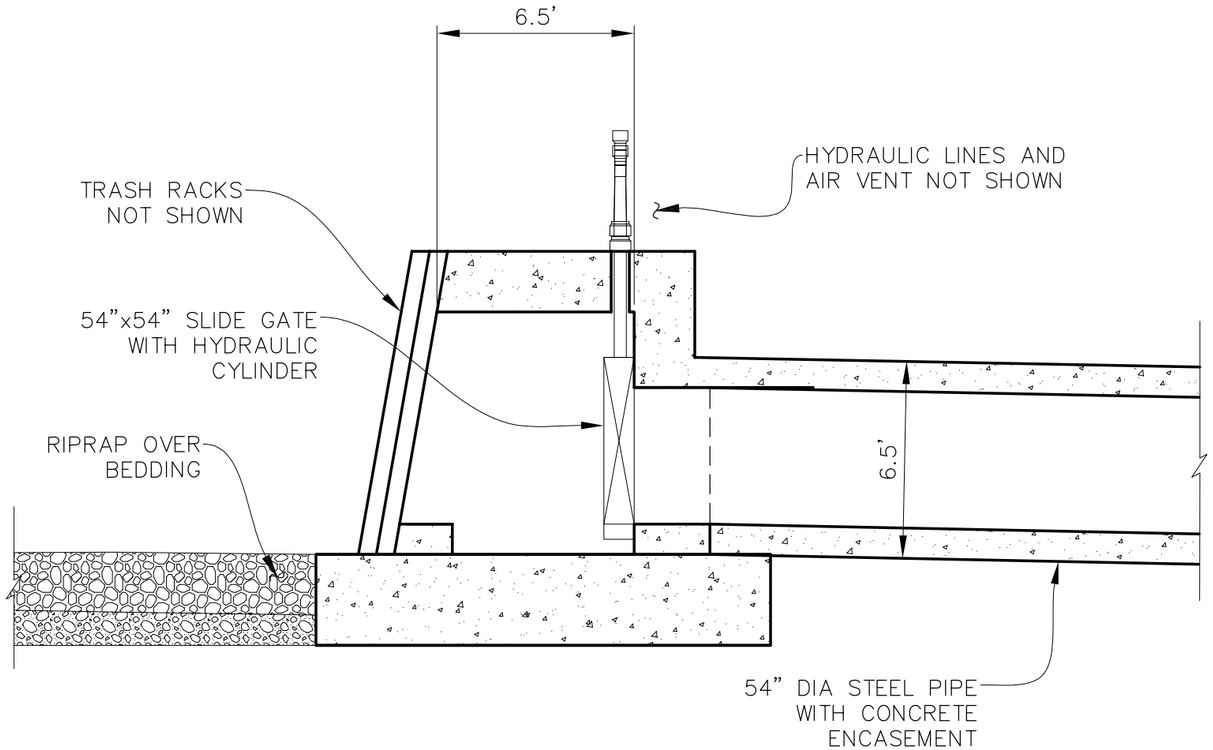
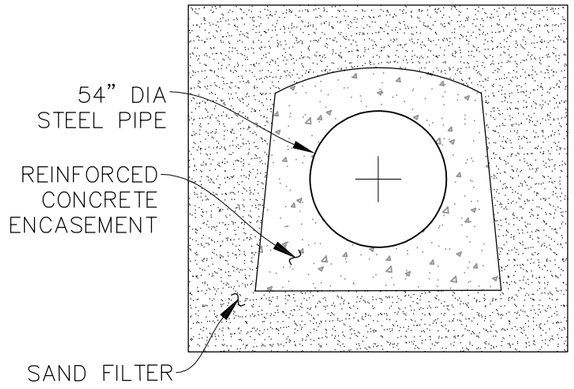


INTAKE STRUCTURE

0 2.5 5 10 15

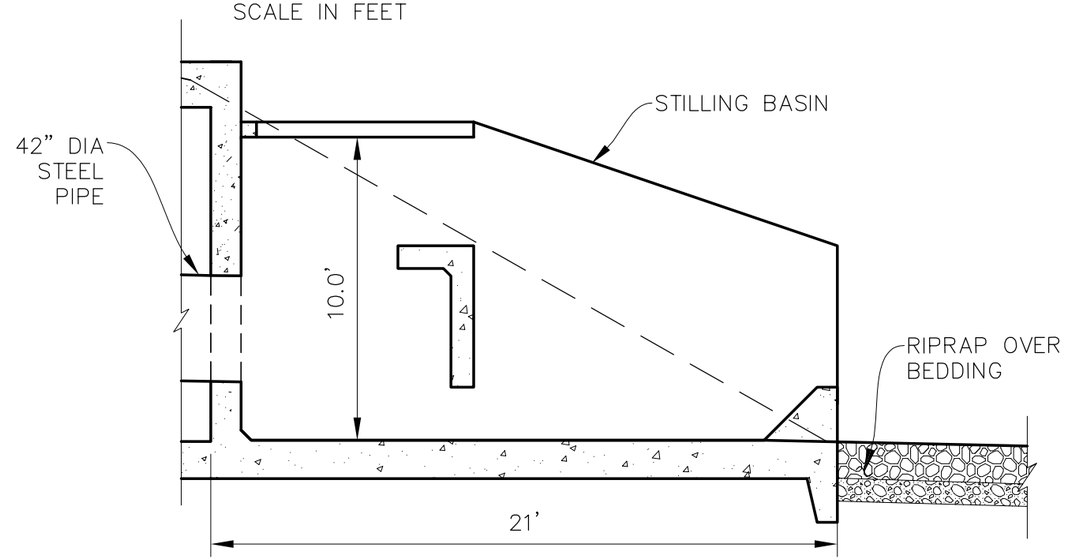
SCALE IN FEET



SECTION 5 / 4.6

0 2.5 5 10 15

SCALE IN FEET



STILLING BASIN

0 2.5 5 10 15

SCALE IN FEET

AMITY MUTUAL IRRIGATION COMPANY	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	ALTERNATIVE #2 - TYPICAL SECTIONS AND DETAILS
		PROJECT NO. 17123	March 2020 Figure 4.7

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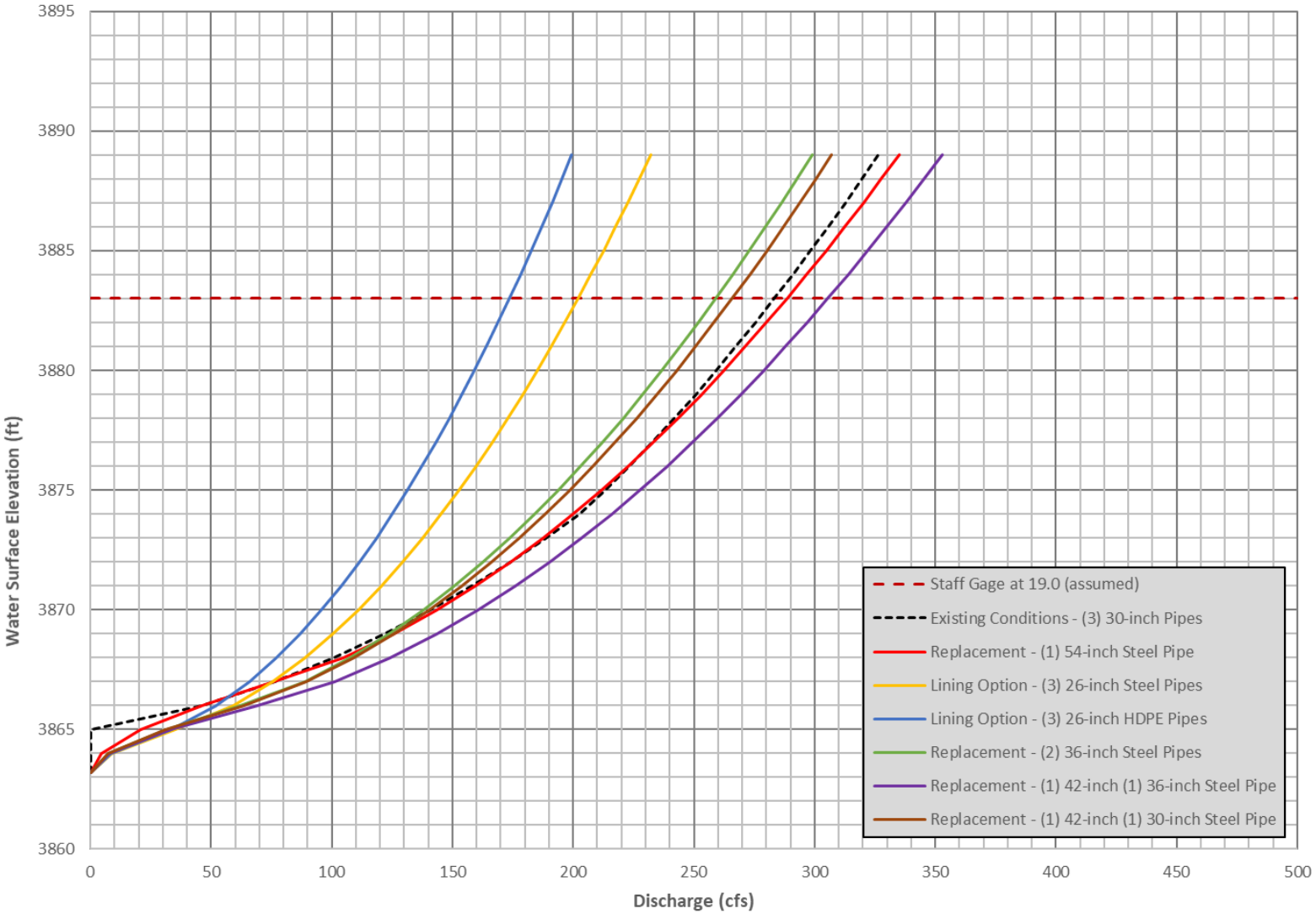


REPRODUCE IN COLOR	RJH CONSULTANTS, INC.	PAWNEE CANAL QUEEN RESERVOIR KIOWA COUNTY, CO	OUTLET WORKS RATING CURVES
		PROJECT NO. 17123	March 2020 **Figure 4.8**

P:\17123 - Queen Reservoir\Engineering\Reports\Loan_Feasibility_Report\Report Figures\17123-20-01-16-Figure-4.8.docx

SECTION 5 - IMPACTS

The alternatives developed to address the PFMs would have few impacts on the man-made environment. Alternative 1 retains the upstream headwall and wingwalls, which would preserve the historic nature of the structure. Alternative 2 would remove all components of the outlet works system. The alternatives would have little to no impact on the natural environment. Construction would occur when the reservoir is dry and no aquatic resources would be impacted. Alternative 1 would impact reservoir operations because it reduces the outlet works discharge capacity.

Mitigation of dam safety concerns at Queen Dam would have positive impacts on communities, and local and regional water resources management. The reservoir would provide the storage necessary to benefit local and regional farmers, and the risks associated with dam safety concerns would be mitigated. Alternative 2 would result in a greater societal benefit because the outlet works system would provide a longer service life.

SECTION 6 - FINANCIAL PLAN

6.1 Loan Amount

The Total project cost is currently to be about $1.025 million. This cost opinion was developed in 2018. Amity understands that the final loan amount will depend on the final cost of the project. Therefore, the requested loan amount is $1.2 million to provide some contingency funding and to account for economic inflation or change that may occur during design and construction. The requested loan term is 30 years, and the requested annual interest rate is 1.0 percent.

6.1.1 Financing Sources

The project is expected to be financed internally through an increase of assessments, and grants and loans as available. Amity intends to request grant funding from the CWCB. Any grant funding will be used to offset the final loan amount.

6.1.2 Revenue and Expenditure Projections

6.1.3 Loan Repayment Sources

Loan repayment sources will be from assessments on stockholders.

6.1.4 Financial Impacts

Amity has $148,289.21 debt with the CWCB for a loan for rehabilitation of the Nee No She Dam with a repayment amount per year of $17,778.39. Amity has favorable tax status being a 501 (c) 12 company and does not pay significant taxes. Amity has no water rates for the water diverted by it. It does charge a per share assessment to the stockholders.

6.1.5 TABOR

Amity is not a government entity and is not subject to TABOR.

6.1.6 Collateral

Amity owns canals, diversion structures, and dams.

6.1.7 Creditworthiness

Currently, Amity has 34,682.86 shares at $31.00 per share for a total 2019 budget of $1,075,168.00.

SECTION 7 - IMPLEMENTATION SCHEDULE

A proposed project implementation schedule is presented in Table 7.1. A desired construction start date of July 2021 is scheduled.

TABLE 7.1
PROJECT IMPLEMENTATION SCHEDULE

Item	Schedule Date
Loan Application and Feasibility Study to CWCB	March 2020
Feasibility Study Review and Approved by CWCB	March 2020
Funding Approved by CWCB Board	April 2020
Final Project Engineering Design Started	April 2020
Permitting Started	April 2020
Project Design Completed	January 2021
Designs, Plans, and Specifications Submitted to SEO	February 2021
SEO Approves Project	May 2021
Bidding and Procurement	June 2021
All Permitting Obtained	June 2021
Project Construction Started	July 2021
Project Construction Completed	December 2021
Project Closeout and Construction Completion Documents to the SEO	March 2022

7.1 Permitting and Institutional Feasibility

Permitting from and coordination with a number of governmental agencies will be required to construct the project. Following is a listing of the agencies and the anticipated permits that will be required.

7.1.1 State Engineers Office

The outlet works modification must be designed and constructed in accordance with the 2020 SEO Rules. Review and approval of project designs, plans, specifications, and construction by the SEO will be required.

7.1.2 Kiowa County

A construction permit is expected to be required to construct the Project.

SECTION 8 - LIMITATIONS

The information presented in this report is suitable for concept design purposes only. The information in this report is based primarily on data obtained from review of existing documents, data, and studies for the subject site. Also, the nature and extent of variations between specific subsurface data may not become evident until construction. Timely and comprehensive observation and evaluation of actual subsurface conditions, supported by appropriate field and laboratory testing, will be critical during the construction phase. Variations in the subsurface profile described herein should be anticipated.

RJH has endeavored to conduct our professional services for this Project in a manner consistent with a level of care and skill ordinarily exercised by members of the engineering profession currently practicing in Colorado under similar conditions as this project. RJH makes no other warranty, expressed or implied.

Opinions of Probable Project Costs presented in this report are based on our professional opinion of the cost to construct the Project as described in this report. The estimated costs are based on the sources of information described herein, and our knowledge of current construction cost conditions in the locality of the Project. Actual Project construction costs are affected by a number of factors beyond our control. Therefore, conditions and factors that arise as Project development proceeds through design and construction may result in construction costs that differ from the estimates documented in this report.

This report has been prepared for use by Amity Mutual Irrigation Company and for exclusive application to the Queen Dam Outlet Works modification.

SECTION 9 - REFERENCES

Colorado Office of the State Engineer (SEO) (2007). *Rules and Regulations for Dam Safety and Dam Construction,* January.

Colorado Office of the State Engineer (SEO) (2020). *Rules and Regulations for Dam Safety and Dam Construction,* January.

U.S. Department of Agriculture, Office of Experiment Stations-Bulletin No. 131 (1903). *Plans of Structures in Use on Irrigation Canals in the United State*s.

U.S. Department of Interior, Bureau of Reclamation ACER Technical Memorandum No. 3 (1982). *Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low-Level Outlet Works.*

APPENDIX A

OUTLET WORKS INSPECTION REPORT

RJH CONSULTANTS, INC.

GEOTECHNICAL AND
WATER RESOURCES ENGINEERING

OUTLET WORKS INSPECTION REPORT

QUEEN DAM PROJECT

KIOWA COUNTY, COLORADO

Submitted to
Amity Mutual Irrigation Company
204 South Main Street
Holly, Colorado 81047

Submitted by
RJH Consultants, Inc.
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com

May 2018
Project 17123

Robert J. Huzjak, P.E.
Project Manager

TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

SECTION 1 - INTRODUCTION

1.1 Purpose

The purpose of this Outlet Works Inspection Report (Report) is to present the findings of the outlet works inspection performed by RJH Consultants, Inc. (RJH) for Queen Dam. This work was performed in general accordance with a contract between RJH and Amity dated September 22, 2017. RJH received authorization to proceed on December 13, 2017.

1.2 Background and Site Description

Queen Dam is located in Kiowa County, Colorado about 15 miles north of Lamar, Colorado. Queen Dam is an earthen embankment that has a maximum height of about 25 feet and is about 1,800 feet long. The storage volume at maximum operational pool is about 23,040 acre-feet (ac-ft) and the surface area at maximum normal pool is about 1,930 acres. The dam was constructed in the early 1890s and is classified as a large, significant hazard dam by the Colorado Office of the State Engineer (SEO). Record drawings for the dam are not available.

The outlet works consists of three, 30-inch diameter riveted steel conduits through the dam that discharge into a masonry stone-lined tunnel in the downstream part of the embankment. Three manually-operated gates are located on the upstream ends of the conduits to regulate flow. A stone masonry wall forms the upstream dam face and the wingwalls at the gates. Stone masonry retaining walls form both sides of the discharge channel downstream of the tunnel for about 25 feet until the discharge channel transitions to an earthen channel.

1.3 Scope of Work

The following is a summary of key participants involved during the inspection:

Robert Huzjak, P.E.	Project Manager
Brena Sheridan, P.E.	Field Inspector
Mark Perry, P.E.	SEO Dam Safety Engineer
Terry Howland	Amity Mutual Irrigation Company

SECTION 2 – OUTLET INSPECTION

2.1 Inspection Conditions

The outlet inspection was performed on January 17, 2018 and the reservoir was nearly empty. The outlet conduits and discharge channel were dewatered to allow for inspection. A layer of ice 1 to 3 inches thick was located at the conduits springline after dewatering. The ice was broken by hand to allow access to the conduits. The ice could not be fully removed from the bottom of the conduits and obstructed observation of the conduit inverts. Inspection of the 30-inch diameter conduits was performed using a video camera survey and the stone masonry tunnel was inspected by visual examination. A summary of the inspection findings is presented in the sections below. Video recording of the conduit inspection is included in Appendix B.

2.2 Conduit Inspection

The three, 30-inch diameter conduits were accessed from the downstream tunnel with the upstream slide gates partially open. The upstream slide gates were not exercised. According to the SEO inspection reports and discussion with Terry Howland, the mechanical operators were replaced in 2012.

The conduits are about 18 feet long and consist of steel with single-riveted seams and joints. The width and height of the conduit interiors were measured intermittently and based on the measurements the conduits are essentially circular. Lamination and reduced conduit wall thickness was observed within the conduits and appeared to be more significant at the downstream end of the conduits. Soundings were taken in the west (right looking downstream) conduit by occasionally tapping a hammer along the interior surface of the conduit to identify if there may be voids behind the riveted steel. No voids were identified at the locations sounded. Some minor corrosion and deterioration on the pipe interior was identified but no cracks, holes, or joint separations were observed.

2.3 Stone Masonry Tunnel

The stone masonry-lined tunnel is 28 feet long and horseshoe shaped, approximately 11-feet-wide by 5.5-feet-tall. The tunnel was inspected from upstream to downstream. At several locations, mortar was missing or severely deteriorated between the stone blocks and cracks and voids were observed. A 1/2-inch diameter, 5-foot-long metal soil probe

was used to probe between the stone blocks. Material behind the stone blocks was observed to be soft, saturated fine-grained soils (silt and clay). The deficiencies observed between the stone blocks are summarized in Table 2.1.

TABLE 2.1
STONE MASONRY TUNNEL OBSERVATIONS

Location	Distance Downstream (ft)	Crack/Void Width (inch)	Probed Depth (ft)	Description
Left (East) Wall	0	2	5	At conduit headwall/tunnel interface
	6	0.5 to 5	1.4	Crack full height of tunnel
	18	0.5 to 2	1.2	Crack full height of tunnel
Right (West) Wall	0	1 to 2	2.7	At conduit headwall/tunnel interface
	5	2 to 3	5	Crack full height of tunnel
	22	1	1.3	Crack 3 feet tall

SECTION 3 – INSPECTION CONCLUSIONS

Based on the work performed for the outlet inspection, RJH offers the following conclusions:

1. The 30-inch diameter riveted steel conduits are in relatively good condition with no significant deficiencies observed.
2. The wall thickness and allowable stress of the steel conduits are not known.
3. The conduits may be approaching the end of their expected service life, having been in service for over 100 years.
4. Erosion of the embankment material is likely occurring through the stone masonry tunnel joints and is a significant dam safety concern.

APPENDIX A

PHOTOGRAPHS

Photograph 1: Stone masonry upstream dam face and slide gates.

Photograph 2: Stone masonry downstream retaining walls.

Photograph 3: 30-inch diameter riveted steel outlet conduit.

Photograph 4: Conduit headwall/tunnel interface.

Photograph 5: Void between conduit headwall and left tunnel wall interface, showing soil probe in void

Photograph 6: Left tunnel wall void, 6 feet downstream of headwall.

Photograph 7: Right tunnel wall void, 5 feet downstream of headwall.

APPENDIX B

CONDUIT VIDEO INSPECTION (ELECTRONIC COPY ONLY)

APPENDIX B

GEOTECHNICAL DATA REPORT

RJH CONSULTANTS, INC.

GEOTECHNICAL AND
WATER RESOURCES ENGINEERING

GEOTECHNICAL DATA REPORT

QUEEN DAM PROJECT

KIOWA COUNTY, COLORADO

Submitted to

Amity Mutual Irrigation Company
204 South Main Street
Holly, Colorado 81047

Submitted by

RJH Consultants, Inc.
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com

May 2018
Project 17123

COLORADO LICENSED
ROBERT J. HUZJAK
25734
5/10/18
PROFESSIONAL ENGINEER

Robert Huzjak, P.E.
Project Manager

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

SECTION 1 - INTRODUCTION

1.1 Purpose

The purpose of this Geotechnical Data Report (Report) is to present geotechnical data collected at Queen Dam in the area of the outlet works. The data was collected to support evaluation of dam safety concerns related to seepage and erosion at the outlet works structure. Evaluation and interpretation of the collected data are not included in this Report.

1.2 Background and Site Description

Queen Dam (Site) is located in Kiowa County, Colorado approximately 12 miles north of Lamar. The Site is accessed from County Road WW via gravel or un-surfaced access roads. A Site location map is shown on Figure 1.1.

According to information published by the U.S. Department of Agriculture (USDA, 1903), the dam embankment and appurtenant features were constructed in the late 1890s. The dam embankment is approximately 1,800 feet long with a maximum embankment height of about 25 feet, but is commonly 10 to 15 feet tall. The embankment crest is at about Elevation (El.) 3889 and the upstream and downstream slopes are generally 3H:1V (horizontal:vertical).

The embankment impounds reservoirs within two natural depressions. Queen Reservoir is located immediately upstream of the embankment, and Neeskah Reservoir is located northwest of Queen Reservoir. The two reservoirs are hydraulically connected by means of an excavated channel. According to documentation provided by the Colorado Office of the State Engineer (SEO), Neeskah Reservoir is also referred to as Queen Reservoir, or Neeskah-Queen Reservoir. Collectively, Queen and Neeskah Reservoirs have a capacity of 23,040 acre-feet (ac-ft) and a surface area of 1,930 acres according to SEO inspection reports. Throughout this Report, the facility will be referred to as Queen Dam. The dam and outlet works are located at the southwestern extent of Queen Reservoir. The SEO classifies Queen Dam as a large, significant hazard dam.

The outlet works structure is located near the middle of the embankment at its maximum section. The outlet works is comprised of stone masonry headwalls, wingwalls, and three 30-inch-diameter wrought-iron riveted pipes that discharge to an approximate 10-foot by 5.5-foot stone masonry arch tunnel. The transition from the pipes to the arch tunnel is

approximately beneath the downstream edge of the embankment crest. The tunnel terminates at a masonry headwall with masonry retaining walls. Three slide gates with mechanical operators are located on the upstream headwall. The downstream embankment slope is locally steepened to about 2H:1V in the vicinity of the downstream masonry headwall. Site features and locations are shown on Figure 1.2.

A channel, designated as Pawnee Canal, was excavated immediately downstream of the outlet works with a bottom width of about 15 feet and side slopes ranging from approximately 1.5H:1V to 2H:1V. An approach channel similar in dimension to the Pawnee Canal was also excavated through the reservoir upstream of the outlet works. A staff gage is mounted to the upstream headwall; however, approximately 3 feet of sediment and debris obscures the bottom of the staff gage. RJH Consultants, Inc. (RJH) considered that the bottom of the gage (0 feet) is set at the upstream conduit invert at El. 3863.2.

According to available construction records (USDA, 1903), the embankment was constructed from a fine loam soil obtained from borrow areas within the reservoir and channel excavations. Fill was placed by drag and wheel scrapers in 12-inch lifts. The material was "tramped" by men and teams to break down the fill to a fine loose powder. The three riveted wrought-iron conduits were embedded in "brick and stone masonry laid in cement." Exposed walls were "rough faced" stone masonry and the main wall "backed" with limestone. All foundations were "heavy" sandstone blocks. Settlement after construction and prior to first fill was reportedly "scarcely apparent;" however, settlement was observed when the reservoir was filled and water stood against the embankment to a depth of 8 feet. The documented total settlement was 2.25 feet in the area of the outlet works according to the USDA reference.

Seepage and erosion issues at the outlet works have been documented since 1985. According to the SEO inspection reports and discussions with Amity, the reservoir has been generally dry from about 2001 to 2016. In 2016, the reservoir was filled to a gage height of 19.0 feet at which time Amity observed water "squirting" through the eastern downstream stone masonry retaining wall of the outlet works. In July 2017, Amity performed an excavation at the downstream embankment crest above the outlet works to investigate the seepage and encountered a void in the embankment. Amity described the void as being several feet wide. The excavation was immediately backfilled and the reservoir was drawn down. After inspection by the SEO Dam Safety staff, the SEO ordered to restrict the level of water stored by the dam to a maximum gage height of 14.0 feet.

1.3 Scope of Work

RJH performed the following geotechnical engineering services:

- Developed a project-specific health and safety plan (HASP)
- Coordinated utility clearances with Colorado 811
- Subcontracted Elite Drilling Services (Elite) of Denver, Colorado to provide equipment and perform the borings
- Logged and visually classified soil samples and developed field boring logs
- Backfilled borings with cement-bentonite grout
- Performed quality assurance review of collected samples and field logs by a senior geotechnical engineer
- Performed laboratory tests on select soil samples
- Prepared final boring logs based on the field descriptions of the materials encountered, quality assurance review, and laboratory test results
- Prepared this Geotechnical Data Report

1.4 Authorization

This work was performed in general accordance with a contract between RJH and Amity dated September 22, 2017. RJH received authorization to proceed on December 13, 2017.

1.5 Project Personnel

The following personnel from RJH are responsible for the work contained in this Report:

Project Manager	Robert Huzjak, P.E.
Technical Review	Adam Prochaska, Ph.D., P.E., P.G.(1)
Lead Geotechnical Engineer	Jason Shamrock, P.E.

Note: 1. Licensed in states other than Colorado.

SECTION 2 - SUBSURFACE EXPLORATION

2.1 General

Three borings were performed between January 29 and 31, 2018. The boring locations were selected to evaluate subsurface conditions in the vicinity of the outlet works. The boring locations, existing topography, and site features are shown on Figure 1.2. Horizontal coordinates and ground surface elevations at the boring locations are provided in Table 2.1.

TABLE 2.1
SUMMARY OF BORINGS

Boring	Northing[1] (ft)	Easting[1] (ft)	Ground Surface Elevation[2] (ft)	Depth to Approximate Top of Groundwater (ft bgs[3])	Approximate Groundwater Elevation[2] (ft)	Total Boring Depth (ft bgs[3])
B-101	1596954.8	3822284.1	3889.8	28.4	3861.4	50.0
B-102	1596909.9	3822287.6	3878.3	14.4	3863.9	50.0
B-103	1596943.6	3822248.7	3889.6	28.9	3860.7	50.0

Notes:
1. Horizontal Datum is Colorado State Plane South Zone (NAD83).
2. Vertical Datum is NAVD88.
3. Below ground surface.

2.2 Surveying

RJH subcontracted Wachob & Wachob, Inc. of Colorado City, Colorado to provide surveying services for the Project. The survey was performed in January and February of 2018 and included:

- Topographic survey of the embankment, and up to 450 feet from the toe of the upstream and downstream embankment slopes.
- Boring locations and site features.
- Establish two permanent survey control monument points.

The horizontal and vertical coordinates system is Colorado State Place South Zone (NAD83) and North American Vertical Datum of 1988 (NAVD88), respectively. Topography and site features in the vicinity of the outlet works are shown on Figure 1.2.

2.3 Exploratory Drilling

RJH retained Elite to provide equipment and to perform drilling work. Borings were executed using a track-mounted Central Mine Equipment (CME) 850x drill rig equipped with an automatic hammer.

Borings were advanced using a 6-inch outside-diameter (O.D.) (3.25-inch inside-diameter (I.D.)) hollow-stem augers (HSA). An auger plug was placed at the bottom of the auger string during drilling to prevent soil cuttings from entering the augers. At each sample interval the auger plug was removed and samples were generally obtained at about 2.5- or 5-foot intervals using the following methods:

- 1.375-inch I.D. (2.0-inch O.D.) standard split-spoon sampler (ASTM D 1586). These samples are denoted with the prefix "S" on the boring logs.
- 2.0-inch I.D. (2.5-inch O.D.) modified California sampler (ASTM D 3550) lined with brass liners. These samples are denoted with the prefix "CA" on the boring logs.
- 3.0-inch O.D. thin-walled (Shelby) tube sample (ASTM D 1587). Samples are denoted with the prefix "U" on the boring logs.

A standard penetration test (SPT) was performed in general accordance with ASTM D 1586 at each split-spoon sample location. The SPT consists of driving a standard split-spoon sampler 18 inches through the subsurface using a 140-pound hammer dropped from a distance of 30 inches. The number of blows, or hammer strikes, required to drive the split-spoon sampler through three successive 6-inch increments is recorded. At each SPT location, RJH calculated the "standard penetration resistance" or SPT N-value, which is the sum of the number of blows required to drive the split-spoon sampler through the second and third 6-inch increment. The SPT N-values presented were not corrected to account for overburden pressures, hammer energy, etc. Hammer blowcounts were also recorded for each 6-inch interval of penetration while advancing the modified California sampler. These blowcounts differ from SPT data; however, can be used to provide a relative indication of the consistency of fine-grained soils and relative density of coarse-grained soils. A summary the SPT N-values using the standard split-spoon is presented in Table 2.2.

TABLE 2.2
SPT N-VALUE SUMMARY

Geologic Unit	Total SPT Tests	Minimum N-Value	Maximum N-Value	Average N-Value
Fill	14	1	16	5
Alluvium	32	0	20	5
Residuum	7	22	67	48

Bulk samples of auger cuttings were obtained from the upper 20 feet of the borings performed from the embankment crest. These samples are denoted with the prefix "Bu" on the boring logs in Appendix B.

At completion of sampling, the borings were backfilled with cement-bentonite grout using tremie placement through the hollow-stem auger. Additional grout was placed to the ground surface about an hour after completion of the boring and then soil was placed in and above the bore hole.

2.4 Logging Procedures

RJH observed drilling procedures, recorded relevant drilling information, visually classified soil samples, and prepared a field log of materials encountered at each boring location. Soil samples were classified in general accordance with ASTM D 2488 (visual-manual method) and pocket penetrometer measurements were obtained on selected samples.

Samples were packaged and transported in general accordance with ASTM D 4220. Recovered split-spoon samples were placed in sealed plastic bags to help preserve the natural moisture content of the material. Samples recovered from the modified California sampler were kept in brass liners that were capped and sealed with vinyl tape. One Shelby tube sample was obtained during the subsurface exploration and was capped and sealed with vinyl tape. Bulk samples were packaged in plastic bags and sealed with duct tape.

RJH prepared final boring logs based on field and laboratory classifications, quality assurance office review of samples, and indirect observations (i.e., drill chatter, drill resistance, etc.), as appropriate. Between recovered samples the stratigraphy presented on the boring logs is interpreted. Standard terms and definitions used on the boring logs and in this Report are provided in Appendix A. The boring logs are provided in Appendix B and select photographs of the soils are in Appendix C.

2.5 Water Level Measurements

Groundwater was encountered in all of the borings during the subsurface exploration. Water level measurements were obtained in each boring during or at the completion of the drilling and are summarized in Table 2.1. Measurements were obtained using an electronic water level indicator and the results are included on the boring logs provided in Appendix B and on Figures 2.1 and 2.2. Water levels recorded during drilling may be higher or lower than the hydrostatic groundwater level.

SECTION 3 - LABORATORY TESTING

Laboratory testing was performed on select soil samples obtained during subsurface exploration. RJH subcontracted Advanced Terra Testing of Lakewood, Colorado to perform the laboratory tests. The testing included:

- Nine natural moisture content tests (ASTM D 2216).
- Six density tests (ASTM D 2937).
- Six particle size analyses (ASTM D 6913).
- Six Atterberg limits tests (ASTM D 4318).
- Four U.S. Bureau of Reclamation (USBR) Crumb tests.

Laboratory test results are provided in Appendix D and are summarized in Table 3.1.

TABLE 3.1
LABORATORY TESTING SUMMARY

Boring ID	Geologic Unit	Sample ID	Approximate Sample Interval (ft bgs)	Approximate Sample Elevation[6] (ft)	USCS Classification (Group Symbol)	Moisture Content (%)	Dry Density (pcf)	Gravel[1][5] (%)	Sand[2][5] (%)	Fines[3],[5] (%)	Liquid Limit[4] (%)	Plasticity Index[4] (%)	USBR Crumb Test Grade[7]
B-101	Fill	S-2	2.5 - 4.0	3887.3		14.4							
B-103	Fill	S-3	5.0 - 6.5	3884.6		17.5							
B-101	Fill	CA-1	7.5 - 8.5	3882.3	Lean Clay (CL)	20.2	95.1		7	93	35	17	
B-103	Fill	CA-1	12.5 - 13.5	3877.1	Lean Clay (CL)	23.4 20.9	96.2 93.8		6	94	34	16	
B-101	Fill	S-5	12.5 - 14.0	3877.3		25.2							
B-101	Fill	U-1	16.5 - 18.5	3873.3	Sandy Lean Clay (CL)	18.7	110.8	1	37	32	35	21	1
B-102	Alluvium	CA-1	6.5 - 7.5	3871.8	Lean Clay (CL)	25.9	93.5		13	87	41	25	1
B-103	Alluvium	S-9	22.5 - 24.0	3867.1	Lean Clay (CL)	35.2	--		6	95	39	21	1
B-101	Alluvium	CA-2	25.0 - 26.0	3864.8	Lean Clay (CL)	31.6	90.1		5	95	35	16	1

Notes:
1. Portion of sample by weight retained on the No. 4 sieve or larger (ASTM D 6913).
2. Portion of sample passing by weight the No. 4 and retained on the No. 200 sieves (ASTM D 6913).
3. Portion of sample passing by weight toe No. 200 sieve (ASTM D 6913).
4. Atterberg limits testing performed on portion of the sample passing the No. 40 sieve (ASTM D 4318).
5. Values rounded to the nearest whole number.
6. Elevation at middle of the sample interval.
7. USBR Crumb Test Rating 1 designation as "Non-Dispersive."

SECTION 4 - SITE AND SUBSURFACE CONDITIONS

4.1 Surficial and Bedrock Geology

According to published geologic mapping (Sharps, 1976 and Voegeli, et al., 1957-58), the natural soils at the embankment consists of Pleistocene-aged (0.01 to 1 million years) undifferentiated Quaternary deposits and Holocene-aged (less than 0.01 million years) Slopewash. Quaternary deposits are comprised of re-worked sand and gravel with clay and silt. Slopewash is comprised of sandy silt deposited by sheetwash and ephemeral rills. The referenced mapping shows bedrock as the Upper Cretaceous-aged (56 to 100 million years) Smokey Hill Marl Member of the Niobrara formation. Bedrock units associated with this formation consists of yellowish-white chalk with thin beds of limestone.

4.2 Surface Conditions

The existing natural topography at the Site is primarily flat with grades typically flatter than 20H:1V. The reservoir level was significantly drawn down at the time of subsurface exploration and a relatively small pool remained at the center of the reservoir. Erosion rills and rutting measuring less than 6 inches deep were present on the downstream embankment slope and extended the entire length of the slope in the vicinity of the outlet works. The rutting appeared to be a result of tracked equipment travelling to and from the embankment crest. Sod cover appeared to be minimal or absent in the area of the outlet works. A 36-inch-diameter stump was present near the downstream end of the east masonry retaining wall at the discharge end of the outlet structure. Appendix C contains select photographs in the vicinity of the outlet works.

4.3 Subsurface Conditions

4.3.1 General

The subsurface materials encountered in the borings consisted of fill, alluvium, and residuum. Bedrock was not encountered in the borings. Subsurface cross sections are on Figures 2.1 and Figure 2.2 and locations of the cross sections are on Figure 1.2. The subsurface sections are generalized and do not include all subsurface information. Additional subsurface information is provided on the boring logs in Appendix B.

4.3.2 Embankment Fill

Fill was placed to construct the dam embankment and outlet works. Fill was encountered at the ground surface in each boring and ranged in thickness from 2 feet in B-102 to 19.5 feet in B-103. The bottom of the fill ranged from El. 3870.1 to El. 3876.3. The fill primarily consisted of low to medium plasticity fine grained soil, with the upper 2 feet generally containing various amounts of sand and gravel. The maximum particle size observed in the fill was about 1.5 inches and was in the upper 2 feet. Due to limitation of the sampling equipment, larger rock fragments may have not been captured or transported to the ground surface as the borings were advanced through the subsurface. Cobble- to boulder-sized rock fragments were observed on the embankment slopes and crest in the area of the outlet works. The fill material in the upper 2 feet visually classified as stiff to very stiff gravelly lean clay with sand, lean clay, and lean clay with gravel. The apparent moisture content was dry to moist.

Underlying the upper 2 feet of fill the soil was primarily fine grained consisting of soft to very soft lean clay with variable amounts of fine to medium grained sand. Tested fill samples classified as lean clay and sandy lean clay according to the Unified Soil Classification System (USCS). Liquid limits of the samples were 35, 34, and 35; and the plasticity indices were 17, 16, and 21, respectively. The sand fraction was typically less than 15 percent; however, a localized layer contained about 37 percent sand in B-101 between approximate depths of 16.5 and 18.5 feet below ground surface (bgs). Pocket penetrometer readings ranged from 3.5 tons per square foot (tsf) to less than 0.25 tsf. Consistency of fill decreased with depth and became very soft between 12.5 and 15 feet below the embankment crest and extended to the bottom of the fill. N-values were less than or equal to 2 and pocket penetrometers readings were less than 0.25 tsf within this zone. Dry unit weights ranged from 93.8 to 110.1 pounds per cubic foot (pcf), averaging 99.0 pcf. The apparent moisture content was moist to wet. Moisture content testing was performed on seven fill samples and ranged from 14.4 to 25.2 percent, averaging 20.0 percent. The majority of the samples reacted strongly with hydrochloric acid (HCl). One USBR Crumb Test yielded a Grade 1 non-dispersive rating.

4.3.3 Alluvium

Alluvium, or alluvial soils, is defined as material that is transported and deposited by flowing water. Alluvium was encountered in all borings underlying the fill. Thickness of alluvium was approximately 28.0 feet in the borings performed on the embankment crest (B-101 and B-103) and 33.8 feet in B-102 performed at the embankment toe. Fine and coarse grained alluvium was encountered in all the borings.

The upper alluvium primarily consisted of fine-grained soils with fine to medium grained sand. The sand content increased with depth and the particle size became coarser with depth. The fine grained alluvium visually classified as low to medium plasticity lean clay, lean clay with sand, and sandy clay. Tested samples classified as lean clay according to the USCS. The samples yielded liquid limits of 41, 39, and 35 with plasticity indices of 25, 21, and 16, respectively. The consistency ranged from very soft to very stiff with pocket penetrometer measurements ranging from less than 0.25 to 3.00 tsf. Moisture contents ranged from 25.9 to 35.2 percent, averaging 30.9 percent. All the samples yielded a Grade 1, non-dispersive rating, in accordance with the USBR Crumb test. A very soft to soft zone was encountered in all the borings from approximate El. 3870.1 to El. 3857.6 where pocket penetrometer readings were less than 0.25 tsf and N-values less than 2. Three samples yielded a Grade 1, non-dispersive rating, in accordance with the USBR Crumb test. Laboratory test results are summarized in Table 3.1 and are included in Appendix D.

A layer of coarse grained alluvium was encountered in each boring beneath the fine grained alluvium and above residuum. The coarse grained alluvium was 3.8 to 6.5 feet thick and the top of this layer was at approximate El. 3846.6 and El. 3849.8. The coarse-grained alluvium field classified as loose to medium dense, clayey sand and poorly graded sand with clay. N-values ranged from 6 to 18. Recovered samples of alluvium samples reacted strongly with HCl. The apparent moisture content was moist to wet.

4.3.4 Residuum

Residuum, or residual soil, is defined as material that results from the physical and chemical weathering of bedrock. Residuum was encountered beneath the alluvium in all borings and extended to the total depths explored. Borings extended up to 14.3 feet into residuum at B-102, which is at the embankment toe. The residuum visually classified as stiff to hard, medium to high plasticity clay with up to 15 percent fine grained sand. N-values ranged from 22 to 67. Gypsum crystals were occasional throughout the samples and all the samples reacted strongly with HCl. The apparent moisture content was primarily moist.

4.4 Groundwater Conditions

Water was encountered in all borings during and at the completion of drilling. Measured depths to water are presented in Table 2.1. Water level elevations ranged from approximately El. 3860.7 to 3863.9, which is about 0.7 to 2.5 feet below the invert of the

upstream end of the outlet works pipe. Measured water levels are on Figures 2.1 and 2.2 and are on the boring logs in Appendix B.

Boring B-102 was not completed the same day the drilling was initiated and the water level was obtained prior to the start of drilling the following day. The water levels at B-101 and B-103 were obtained prior to backfilling the borings on the same day the drilling occurred. In these borings, water was heard seeping through the hollow-stem augers at the completion of sampling. B-101 and B-103 borings were left open for about 30 minutes prior to obtaining the water level and backfilling. Recovered soil samples were observed to be wet above the measured groundwater level. Groundwater may not have reached equilibrium at the time of drilling and measured water levels may not represent the static groundwater surface. Groundwater is expected to fluctuate based on reservoir levels, precipitation, season, temperature, and other factors.

SECTION 5 - LIMITATIONS

This Report has been prepared for the exclusive use of RJH and Amity Mutual Irrigation Company to support evaluation of seepage and erosion issues at the outlet works. The purpose of the subsurface exploration was to collect subsurface data and to develop a generalized understanding of subsurface conditions in the vicinity of the outlet works. RJH and Amity are not responsible for technical interpretations of this data by others.

RJH has endeavored to conduct our professional services for this Project in a manner consistent with a level of care and skill ordinarily exercised by members of the engineering profession currently practicing in Colorado under similar conditions as this Project. RJH makes no other warranty, expressed or implied.

The methods used in this study indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect variations in subsurface conditions that may exist between sampling locations.

The nature and extent of variations between borings may not become evident until construction. Timely and comprehensive observation and evaluation of actual subsurface conditions, supported by appropriate field and laboratory testing, will be critical during construction as variations from anticipated subsurface conditions may be encountered.

SECTION 6 - REFERENCES

Sharps, J.A. (1976). Geologic Map of the Lamar Quadrangle Colorado and Kansas. U.S. Geological Survey, Map I-944.

U.S. Department of Agriculture, Office of Experiment Stations-Bulletin No. 131 (1903). *Plans of Structures in Use on Irrigation Canals in the United State*s.

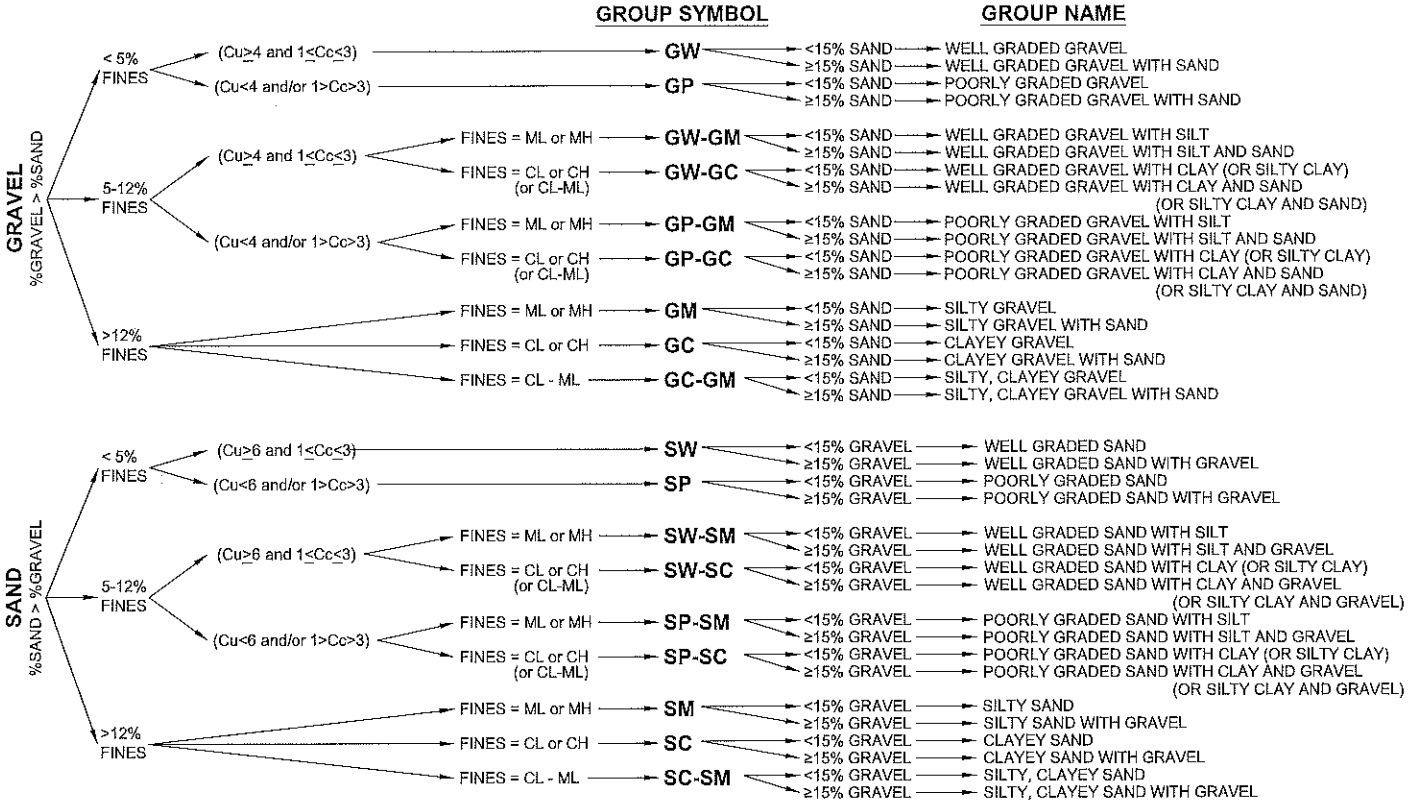
Voegeli, P.T, Hershey, L.A., Coffin, D.L., and Irwin, J.H. (1957-58). Geologic Map of Prowers County, Colorado. U.S. Geologic Survey, Water Supply Paper 1772, Plate 1.

APPENDIX A

SUBSURFACE EXPLORATION STANDARD TERMS AND DEFINITIONS

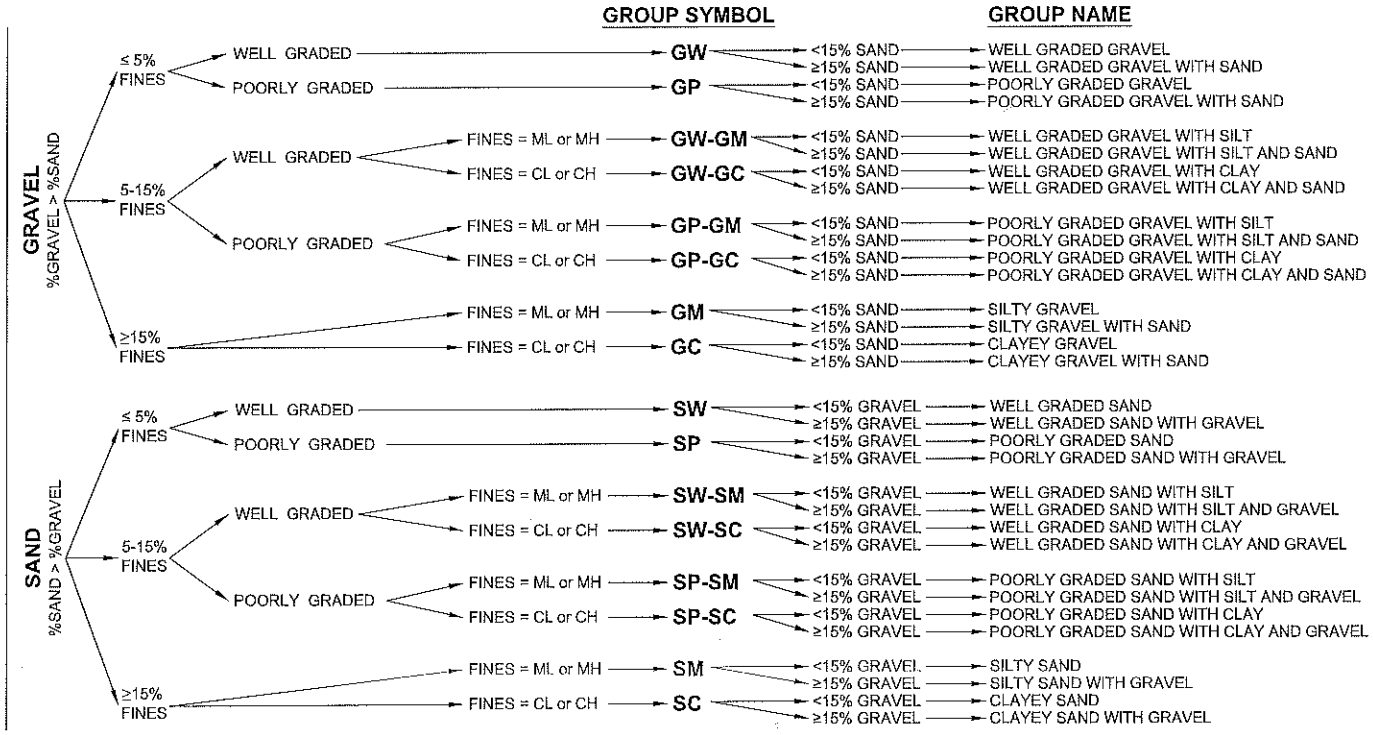
COARSE GRAINED SOILS
(< 50% FINES)

A) FLOWCHART APPLIED TO LABORATORY TESTED SOIL SAMPLES.
ADAPTED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.



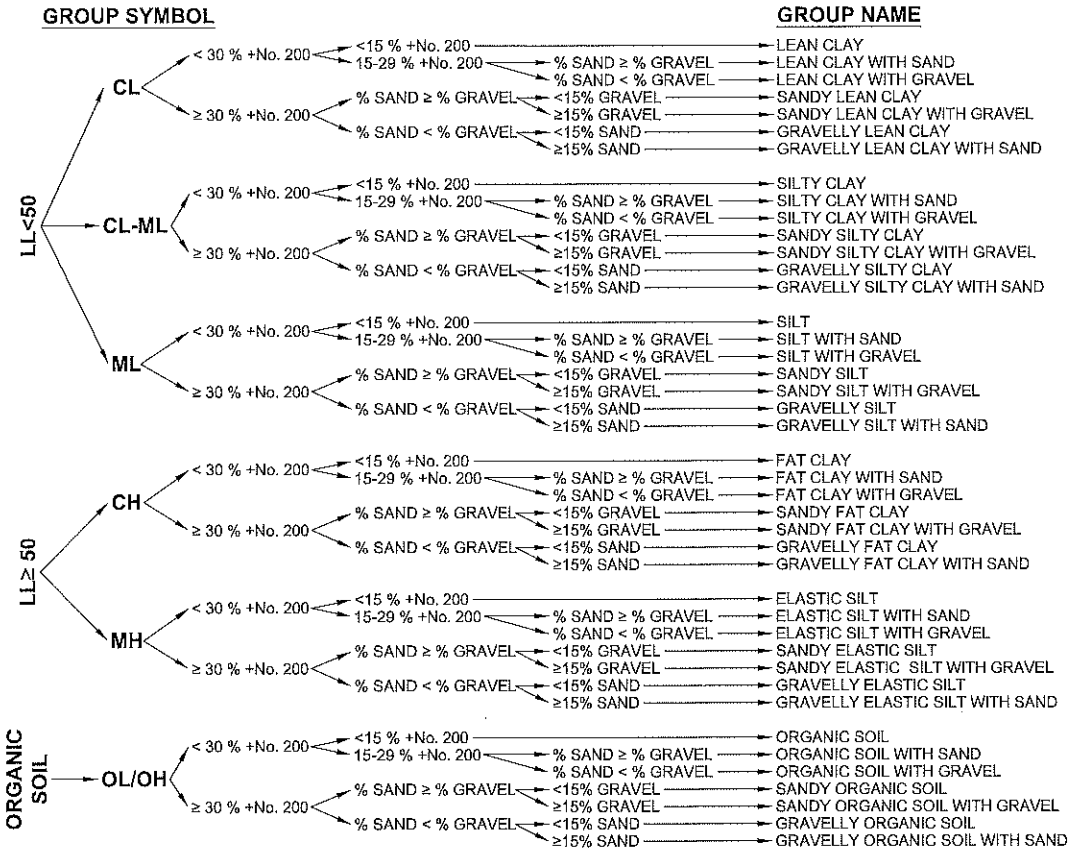
B) FLOWCHART APPLIED TO FIELD CLASSIFIED SOIL SAMPLES.
ADAPTED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE)*.

FOR SOILS WITH < 50% FINES

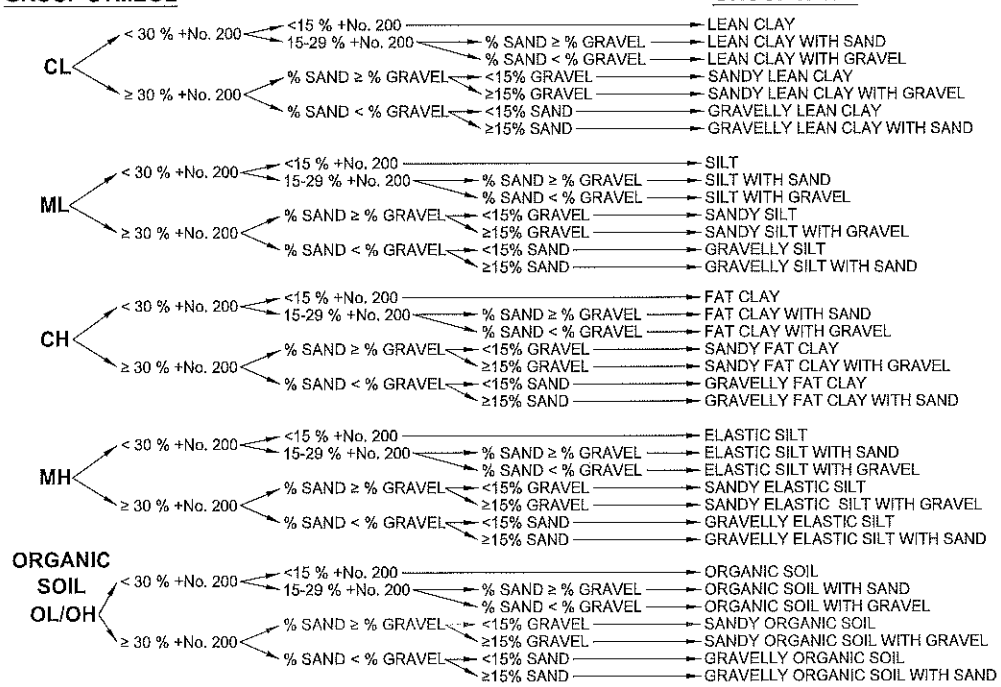


FINE GRAINED SOILS
(≥ 50% FINES)

A) FLOWCHART APPLIED TO LABORATORY TESTED SOIL SAMPLES.
ADAPTED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.



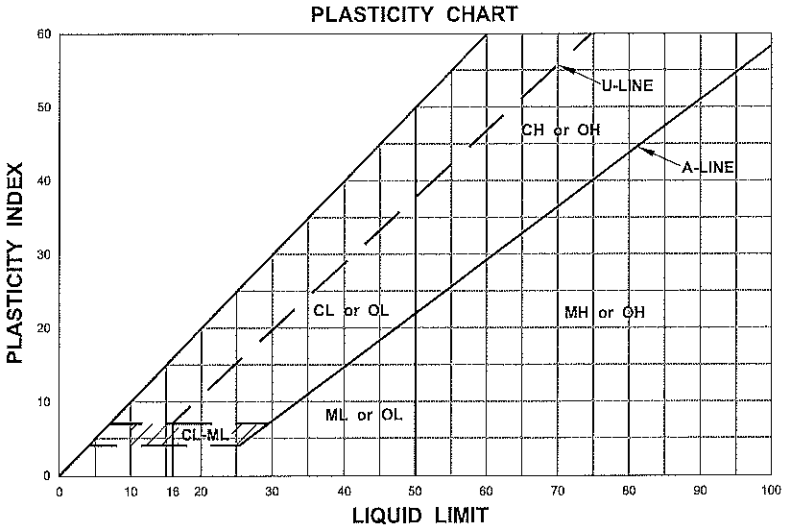
B) FLOWCHART APPLIED TO FIELD CLASSIFIED SOIL SAMPLES.
ADAPTED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE)*.



NOTE:

1. THE PLASTICITY CHART ON THE FOLLOWING PAGE WAS USED TO IDENTIFY THE GROUP SYMBOL FOR FLOWCHART A.
   A COMBINATION OF THE VISUAL MANUAL CRITERIA ON THE FOLLOWING PAGE WERE USED TO IDENTIFY THE GROUP SYMBOL FOR FLOWCHART B.

SOIL PLASTICITY CHARACTERISTICS



A) IDENTIFICATION OF FINES GROUP SYMBOL FROM LABORATORY TESTS.
REPRODUCED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.

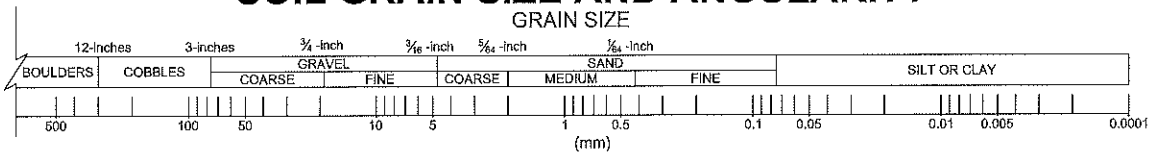
B) IDENTIFICATION OF FINES GROUP SYMBOL FROM VISUAL-MANUAL CRITERIA.
REPRODUCED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE).*

DRY STRENGTH	
DESCRIPTION	CRITERIA
NONE	CRUMBLES TO POWDER WHILE HANDLING.
LOW	CRUMBLES TO POWDER WITH SOME FINGER PRESSURE.
MEDIUM	BREAKS INTO PIECES OR CRUMBLES WITH CONSIDERABLE FINGER PRESSURE.
HIGH	CANNOT BE BROKEN WITH FINGER PRESSURE. BREAKS INTO PIECES BETWEEN THUMB AND HARD SURFACE.
VERY HIGH	CANNOT BE BROKEN BETWEEN THUMB AND HARD SURFACE.
DILATANCY (RESISTANCE TO SHAKING)	
DESCRIPTION	CRITERIA
NONE	NO VISIBLE CHANGE IN SPECIMEN.
SLOW	WATER APPEARS SLOWLY ON THE SURFACE OF THE SPECIMEN DURING SHAKING AND DOES NOT DISAPPEAR OR DISAPPEARS SLOWLY UPON SQUEEZING.
RAPID	WATER APPEARS QUICKLY ON THE SURFACE OF THE SPECIMEN DURING SHAKING AND DISAPPEARS QUICKLY UPON SQUEEZING.

TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	
DESCRIPTION	CRITERIA
LOW	ONLY SLIGHT PRESSURE IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP ARE WEAK AND SOFT.
MEDIUM	MEDIUM PRESSURE IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP HAVE MEDIUM STIFFNESS.
HIGH	CONSIDERABLE EFFORT IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP HAVE HIGH STIFFNESS.
PLASTICITY	
DESCRIPTION	CRITERIA FOR A ⅛-INCH (3 mm) THREAD.
NON-PLASTIC	THREAD CANNOT BE ROLLED.
LOW	THREAD CAN BARELY BE ROLLED AND THE LUMP CANNOT BE FORMED WHEN DRIER THAN THE PLASTIC LIMIT.
MEDIUM	THREAD IS EASY TO ROLL AND NOT MUCH TIME IS REQUIRED TO REACH THE PLASTIC LIMIT. THE THREAD CANNOT BE RE-ROLLED SEVERAL TIMES AFTER REACHING THE PLASTIC LIMIT. THE LUMP CRUMBLES WHEN DRIER THAN THE PLASTIC LIMIT.
HIGH	IT TAKES CONSIDERABLE TIME ROLLING AND KNEADING TO REACH THE PLASTIC LIMIT. THE THREAD CAN BE RE-ROLLED SEVERAL TIMES AFTER REACHING THE PLASTIC LIMIT. THE LUMP CAN BE FORMED WITHOUT CRUMBLING WHEN DRIER THAN THE PLASTIC LIMIT.

SYMBOL	DRY STRENGTH	DILATANCY	TOUGHNESS AND PLASTICITY	PLASTICITY
ML	NONE - LOW	SLOW - RAPID	LOW	LOW TO NON-PLASTIC
CL	MEDIUM - HIGH	NONE - SLOW	MEDIUM	LOW TO MEDIUM
MH	LOW - MEDIUM	NONE - SLOW	LOW TO MEDIUM	LOW TO MEDIUM
CH	HIGH - VERY HIGH	NONE	HIGH	HIGH

SOIL GRAIN SIZE AND ANGULARITY



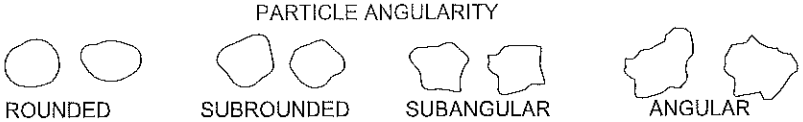


TABLE 1.1
CRITERIA FOR DESCRIBING SOIL STRUCTURE[1]

Description	Criteria
Stratified	Alternating layers of varying material or color with layers greater than or equal to 1/4 inch thick (6 mm)
Laminated	Alternating layers of varying material or color with layers less than 1/4 inch thick (6 mm)
Fissured	Breaks along definite plates of fracture with little resistance to fracturing
Slickensided	Fracture planes appear polished or glossy, sometimes striated
Blocky	Cohesive soil that can be broken down into small angular lumps which resist further breakdown
Lensed	Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay
Homogeneous	Same color and appearance throughout

Note:
1. Modified from ASTM D 2488 *Description and Identification of Soils (Visual-Manual Procedure)* and differ from the U.S. Bureau of Reclamation *Engineering Geology Field Manual* (2001).

TABLE 1.2
RELATIVE DENSITY OF SANDS ACCORDING TO RESULTS OF STANDARD PENETRATION TEST[1]

Number of Blows N	Relative Density
0-4	Very Loose
5-10	Loose
11-30	Medium
31-50	Dense
Over 50	Very Dense

Note:
1. Modified from Terzaghi, Peck, and Mesri (1996).

TABLE 1.3
GUIDE FOR STIFFNESS OF FINE-GRAINED SOILS[1]

Description	Criteria	Estimated Unconfined Compressive Strength (TSF)
Very Soft	Extrudes between fingers when squeezed	<0.25
Soft	Molded by light finger pressure	0.25-0.50
Medium	Molded by strong finger pressure	0.50-1.00
Stiff	Readily indented by thumb or penetrated with great effort	1.00-2.00
Very Stiff	Readily indented by thumbnail	2.00-4.00
Hard	Indented with difficulty by thumbnail	>4.00

Note:
1. Reproduced from NAVFAC (1986).

TABLE 1.4
CRITERIA FOR DESCRIBING SOIL MOISTURE CONDITION[1]

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below the water table

Note:
1. Reproduced from ASTM 2488 *Description and Identification of Soils (Visual-Manual Procedure).*

TABLE 1.5
CRITERIA FOR DESCRIBING SOIL CEMENTATION[1][2]

Description	Criteria
Weak	Crumbles or breaks with handling or little finger pressure
Moderate	Crumbles or breaks with considerable finger pressure
Strong	Will not crumble or break with finger pressure

Notes:
1. Reproduced from ASTM 2488 *Description and Identification of Soils (Visual-Manual Procedure).*
2. The absence of cementation was not recorded on boring logs.

TABLE 1.6
CRITERIA FOR DESCRIBING SOIL REACTION WITH HCL[1]

Description	Criteria
None[2]	No visible reaction
Weak	Some reaction, with bubbles forming slowly
Strong	Violent reaction, with bubbles forming immediately

Notes:
1. Reproduced from ASTM 2488 Description and Identification of Soils (Visual-Manual Procedure).
2. The absence of a reaction was not recorded on boring logs.

ASTM D 2487 (2011). *Standard Classification of Soils for Engineering Purposes (USCS)*. June.

ASTM D 2488 (2009). *Standard Practice for Description and Identification of Soils (Visual-Manual Method)*. July.

Bates, Robert C. and Jackson, Julia A. (1984). *Dictionary of Geologic Terms,* 3rd Edition.

Hunt, Roy E. (Hunt) (2005). *Geotechnical Investigation Handbook.*

Terzaghi, Karl, Peck, Ralph B., and Mesri, Gholamreza. (Terzaghi, Peck, and Mesri). (1996). *Soil Mechanics in Engineering Practice.*

U.S. Bureau of Reclamation (USBR) (2001). *Engineering Geology Field Manual.*

APPENDIX B

BORING LOGS

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596954.8, E 3822284.1 ft
Ground El: 3889.8 ft Total Depth: 50.0 ft
Groundwater El: 3861.4 ft On Date: 01-30-2018

Start Date: 01-30-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-101**
Sheet 1 of 4

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	1	S - 1	4/7/8	1.5	0.6	Gravel-sized content observed and classified from auger cuttings (S-1 and S-2).		S-1, Bu-1: Gravelly Lean Clay with Sand Mostly fines, low to medium plasticity; 30-40% gravel, fine to coarse grained, angular to subangular; 15-25% sand, fine to medium grained, subangular to subrounded; maximum particle size = 1 inch; very stiff; dry to moist; brown and gray; trace roots and organics; calcite throughout; strong reaction with HCl; (CL); [Fill]
3887.8	2							
	3	S - 2	3/2/2	1.5	1.2			S-2, S-3, CA-1, Bu-1: Lean Clay Mostly fines, medium plasticity; less than 10% sand, fine grained; soft; dry to moist; brown and gray; strong reaction with HCl; (CL); [Fill] *2.5 to 4.0 ft: less than 10% gravel, fine to coarse grained, angular to subangular; maximum particle size = 0.875 inches;*
	4							
	5					Bag sample (Bu-1) of auger cuttings obtained from 0 to 10 feet bgs.		*5.0 to 6.5 ft: moist;*
	6	S - 3	3/2/3	1.5	1.3	PP = 1.50 tsf		
	7							
	8	CA - 1	4/4	1.0	0.8	PP = 2.50 tsf		*7.5 to 8.5 ft: trace calcite nodules;*
3880.6	9							
	10							S-4, S-5, S-6, Bu-1, Bu-2: Lean Clay Mostly fines, low to medium plasticity; less than 10% sand, fine grained; very soft to soft; moist to wet; brown; strong reaction with HCl; (CL); [Fill] *10.0 to 11.5 ft: Fines are low plasticity;*
	11	S - 4	1/1/2	1.5	1.2	PP = 2.00 tsf		
	12							
	13	S - 5	1/1/1	1.5	1.5	PP = < 0.25 tsf		*12.5 to 16.5 ft: moist to wet;*
	14							
	15							

Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596954.8, E 3822284.1 ft
Ground El: 3889.8 ft Total Depth: 50.0 ft
Groundwater El: 3861.4 ft On Date: 01-30-2018

Start Date: 01-30-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-101**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	16	S - 6	1/2/1	1.5	0.4	Bag sample (Bu-2) of auger cuttings obtained from 10 to 20 feet bgs. PP = < 0.25 tsf		
3873.3	17	U - 1		2.0	1.6	Shelby tube (U-1) advanced with 250 psi to 300 psi Down Pressure; PP = 2.00 tsf.		U-1, Bu-2: Sandy Lean Clay Mostly fines, medium to high plasticity; 35-40% sand, fine grained; soft to medium stiff; moist to wet; brown; strong reaction with HCl; (CL); [Fill]
	18							
	19							
3870.6	20	S - 7	WOR/1/1	1.5	1.3	PP = 1.00 tsf		S-7, Bu-2: Lean Clay Mostly fines, medium to high plasticity; 5-15% sand, fine grained; soft to medium stiff; moist to wet; dark brown; strong reaction with HCl; (CL); [Alluvium]
	21							
3867.8	22							
	23	S - 8	WOH/WOH/WOH/ WOH	2.0	2.0	PP < 0.25 tsf Split-spoon sampler (S-8) advanced 24 inches from the weight of the hammer (W.O.H.). Soil dispersed when placed in sample bag.		S-8, S-9, CA-2: Lean Clay Mostly fines, low to medium plasticity; less than 10% sand, fine grained; very soft; wet; brown; strong reaction with HCl; (CL); [Alluvium]
	24							
	25	CA - 2	WOH/2	1.0	1.0	Visible free water within soils at S-8 and CA-2.		
	26							
	27							*27.5 to 29.0 ft: light yellowish brown;*
	28	S - 9	WOH/WOH/WOH	1.5	0.5	Split-spoon sampler (S-9) advanced 18 inches from the W.O.H. Soil dispersed/displaced when placed in sample bag. Groundwater level at 28.4 feet bgs approximately 30 minutes after completion of drilling.		
	29							
3860.3	30							S-10, S-11: Lean Clay Mostly fines, medium to high plasticity; less than 10% sand,

Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596954.8, E 3822284.1 ft
Ground El: 3889.8 ft Total Depth: 50.0 ft
Groundwater El: 3861.4 ft On Date: 01-30-2018

Start Date: 01-30-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-101**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	31	S - 10	WOH/1/2	1.5	1.3			fine grained; soft to medium stiff; wet; brown to light yellowish brown; strong reaction with HCl; (CL); [Alluvium]
	32							
	33	S - 11	WOH/WOH/1	1.5	1.5			*32.5 to 34.0 ft: very soft;*
	34							
3855.3	35	S - 12	WOH/1/2	1.5	1.5			S-12: Sandy Lean Clay Mostly fines, medium plasticity; 30-40% sand, fine to medium grained, subangular to subrounded; soft to medium stiff; moist to wet; brown to yellowish brown; strong reaction with HCl; (CL); [Alluvium]
	36							
3852.8	37							
	38	S - 13	WOH/4/4	1.5	1.5	PP < 0.25 tsf		S-14, S-13: Lean Clay with Sand Mostly fines, medium to high plasticity; 15-25% sand, fine to medium grained, subangular to subrounded; soft to medium stiff; wet; yellowish brown; trace calcite nodules; strong reaction with HCl; (CL); [Alluvium]
	39							
	40							
	41	S - 14	WOH/2/2	1.5	0.4			
	42							
3846.6	43							
	44							S-15: Poorly Graded Sand with Clay Mostly sand, fine to medium grained, subangular to subrounded; 5-15% fines, low to medium plasticity; loose; moist to wet; yellowish brown; strong reaction with HCl; (SP-SC); [Alluvium]
	45							

Continued on next sheet

Notes: Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596954.8, E 3822284.1 ft
Ground El: 3889.8 ft Total Depth: 50.0 ft
Groundwater El: 3861.4 ft On Date: 01-30-2018

Start Date: 01-30-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-101**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	46	S - 15	3/3/3	1.5	1.5			
	47							
3842.3	48							S-16: Lean Clay Blocky; mostly fines, medium to high plasticity; less than 10% sand, fine grained; very stiff to hard; moist; yellowish brown; calcite and gypsum crystals throughout; strong reaction with HCl; (CL); [Residuum]
	49	S - 16	10/20/37	1.5	1.5			
3839.8	50					Bottom of Boring at 50.0 feet bgs.		End of boring log at 50.00 ft
	51							
	52							
	53							
	54							
	55							
	56							
	57							
	58							
	59							
	60							

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596909.9, E 3822287.6 ft
Ground El: 3878.3 ft Total Depth: 50.0 ft
Groundwater El: 3863.9 ft On Date: 01-30-2018

Start Date: 01-29-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-102**
Sheet 1 of 4

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	1	S - 1	3/2/2	1.5	1.0	Gravel-sized content observed and classified from auger cuttings (S-1); PP = 3.50 tsf.		S-1: Lean Clay Mostly fines, medium plasticity; 5-15% sand, fine grained; less than 10% gravel, fine to medium grained, angular to subrounded; maximum particle size = 1.5 inches; stiff to very stiff; dry to moist; dark brown; trace roots and organics; occasional calcite nodules; strong reaction with HCl; (CL); [Fill]
3876.3	2							
	3	S - 2	2/2/3	1.5	1.4	PP= 3.00 tsf		S-2, S-3, S-4, CA-1: Lean Clay Mostly fines, low to medium plasticity; 5-15% sand, fine grained; medium to very stiff; moist; dark brown to brown; strong reaction with HCl; (CL); [Alluvium]
	4							
	5							*5.0 to 6.5 ft: stiff to very stiff; trace calcite nodules;*
	6	S - 3	2/1/2	1.5	0.8	PP = 1.50 tsf		
	7	CA - 1	2/1	1.0	1.0	PP = 1.00 tsf		
	8	S - 4	1/1/1	1.5	0.6	PP < 0.25 tsf		*7.5 to 9.0 ft: Fines are medium to high plasticity; medium stiff to stiff; moist to wet; dark brown; occasional veins iron staining;*
	9							
3868.8	10							S-5, S-6, S-7, S-8, S-9: Lean Clay Mostly fines, low to medium plasticity; 5-15% sand, fine grained; very soft; wet; brown; strong reaction with HCl; (CL); [Alluvium]
	11	S - 5	WOH/1/1	1.5	1.5			
	12					Soil dispersed/displaced when placed in sample bag at intervals S-5 and S-6.		
	13	S - 6	WOH/1/1	1.5	1.5			
	14							
	15					Drilling stopped at 44.0 feet bgs on 1/29/2018. Groundwater level at 14.4 feet bgs prior to the start of drilling on 1/30/2018.		

Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596909.9, E 3822287.6 ft
Ground El: 3878.3 ft Total Depth: 50.0 ft
Groundwater El: 3863.9 ft On Date: 01-30-2018

Start Date: 01-29-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-102**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	16	S - 7	WOH/WOH/1	1.5	1.3	Soil dispersed/displaced when placed in sample bag at interval S-7.		*15.0 to 16.5 ft: less than 10% sand, fine grained; moist to wet; yellowish brown;*
	17							
	18	S - 8	1/1/1	1.5	1.4			*17.5 to 19.0 ft: Laminated; 5-15% sand, fine to medium grained, subangular to subrounded; moist to wet; yellowish brown and dark brown to light yellowish brown;*
	19							
	20	S - 9	1/1/1	1.5	1.4			*20.0 to 21.5 ft: moist to wet;*
	21							
3856.3	22							S-10, S-11, S-12: Sandy Lean Clay Mostly fines, medium plasticity; 30-40% sand, fine to medium grained, subangular to subrounded; very soft; moist to wet; yellowish brown; strong reaction with HCl; (CL); [Alluvium]
	23	S - 10	1/2/2	1.5	1.3			
	24							
	25	S - 11	1/1/3	1.5	1.5	PP < 0.25 tsf		*25.0 to 26.5 ft: soft to medium stiff; moist;*
	26							
	27							
	28	S - 12	3/6/10	1.5	1.3			
3849.8	29							S-12, S-13: Clayey Sand Mostly sand, fine to medium grained, subangular to subrounded; 25-35% fines, medium plasticity; medium dense; moist; yellowish brown; strong reaction with HCl; (SC); [Alluvium]
	30							

Continued on next sheet

Notes: Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596909.9, E 3822287.6 ft
Ground El: 3878.3 ft Total Depth: 50.0 ft
Groundwater El: 3863.9 ft On Date: 01-30-2018

Start Date: 01-29-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-102**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	31	S - 13	5/7/10	1.5	1.5			
3846.3	32							S-14, S-15: Poorly Graded Sand with Clay Mostly sand, fine to medium grained, subangular to subrounded; 5-15% fines, low to medium plasticity; medium dense; moist; yellowish brown; strong reaction with HCl; (SP-SC); [Alluvium]
	33	S - 14	5/7/11	1.5	1.4			
	34							
	35							
3842.6	36	S - 15	3/4/7	1.5	1.5			S-15, S-16, S-17, S-18, S-19, S-20: Lean Clay Blocky; mostly fines, medium plasticity; 5-15% sand, fine to coarse grained, subangular to subrounded; stiff to hard; moist; brownish yellow; occasional seams of high plasticity clay and clusters of gypsum crystals throughout; strong reaction with HCl; (CL); [Residuum]
	37							
	38	S - 16	15/27/40	1.5	1.5	PP = 4.00 tsf		
	39							
	40							
	41	S - 17	7/19/36	1.5	1.5	PP > 4.50		
	42							
	43	S - 18	6/9/13	1.5	1.5			*42.5 to 50.0 ft: Laminated; yellowish brown and gray; trace layers of poorly graded sand with iron staining; trace gypsum crystals;*
	44							
	45							

Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596909.9, E 3822287.6 ft
Ground El: 3878.3 ft Total Depth: 50.0 ft
Groundwater El: 3863.9 ft On Date: 01-30-2018

Start Date: 01-29-2018 End Date: 01-30-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-102**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	46	S - 19	6/12/18	1.5	1.5			
	47							
	48							
	49	S - 20	14/27/40	1.5	1.5			
3828.3	50					Bottom of Boring at 50.0 feet bgs.		End of boring log at 50.00 ft
	51							
	52							
	53							
	54							
	55							
	56							
	57							
	58							
	59							
	60							

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596943.6, E 3822248.7 ft
Ground El: 3889.6 ft Total Depth: 50.0 ft
Groundwater El: 3860.7 ft On Date: 01-31-2018

Start Date: 01-31-2018 End Date: 01-31-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-103**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	1	S - 1	10/10/6	1.5	0.1	Gravel-sized content observed and classified from auger cuttings (S-1).		S-1, Bu-1: Lean Clay with Gravel Mostly fines, low to medium plasticity; 5-15% sand, fine to coarse grained, angular to subrounded; less than 10% gravel, fine to coarse grained, angular to subrounded; maximum particle size = 0.75 inches; stiff to very stiff; dry; grayish brown; (CL); [Fill]
3887.6	2							
	3	S - 2	2/2/2	1.5	0.3			S-2, Bu-1: Lean Clay Mostly fines, medium plasticity; 5-15% sand, fine to medium grained, subangular to subrounded; soft; dry to moist; brown; strong reaction with HCl; (CL); [Fill]
	4							
3885.1	5	S - 3	2/3/2	1.5	0.9	PP = 2.75 tsf		S-3, S-4, S-5, CA-1, S-6, S-7, Bu-1: Lean Clay Mostly fines, low to medium plasticity; less than 10% sand, fine grained; very soft to stiff; moist; yellowish brown to brown; strong reaction with HCl; (CL); [Fill] *5.0 to 6.5 ft: soft;*
	6							
	7					Bag sample (Bu-1) of auger cuttings obtained from 0 to 15 feet bgs.		*7.5 to 9.0 ft: soft to medium stiff;*
	8	S - 4	2/3/2	1.5	0.8	PP = 2.25 tsf		
	9							
	10							*10.0 to 11.5 ft: soft to medium stiff;*
	11	S - 5	2/2/3	1.5	1.0			
	12							
	13	CA - 1	3/3	1.0	0.8			*12.5 to 13.5 ft: medium stiff to stiff; dark brown to gray;*
	14					PP = 2.25 tsf		
	15							

Continued on next sheet

Notes: Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596943.6, E 3822248.7 ft
Ground El: 3889.6 ft Total Depth: 50.0 ft
Groundwater El: 3860.7 ft On Date: 01-31-2018

Start Date: 01-31-2018 End Date: 01-31-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-103**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	16	S - 6	WOH/1/1	1.5	1.1	PP < 0.25 tsf		*15.0 to 16.5 ft: soft to medium stiff;*
	17							
	18	S - 7	WOH/WOH/1	1.5	1.5			*17.5 to 19.0 ft: very soft to soft;*
	19							
3870.1	20	S - 8	WOH/WOH/1	1.5	1.5			S-8, S-9, CA-2, S-10, S-11: Lean Clay Mostly fines, low to medium plasticity; less than 10% sand, fine grained; very soft to soft; moist to wet; brown; strong reaction with HCl; (CL); [Alluvium] *20.0 to 21.5 ft: Fines are medium to high plasticity; very soft to soft; moist to wet; brown; trace roots;*
	21							
	22							
	23	S - 9	WOH/WOH/WOH	1.5	1.5	Split-spoon sampler (S-9) adavanced 18 inches from the W.O.H. Soil dispersed/displaced when placed in sample bag.		*22.5 to 24.0 ft: very soft; wet;*
	24							
	25	CA - 2	WOH/2	1.0	1.0			*25.0 to 32.0 ft: very soft; moist to wet; brown to light yellowish brown; trace iron staining;*
	26							
	27							
	28	S - 10	WOH/WOH/1	1.5	1.5			
	29					Groundwater level at 28.9 feet bgs approximately 30 minutes after completion of drilling.		
	30							

Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596943.6, E 3822248.7 ft
Ground El: 3889.6 ft Total Depth: 50.0 ft
Groundwater El: 3860.7 ft On Date: 01-31-2018

Start Date: 01-31-2018 End Date: 01-31-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-103**

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	31	S - 11	WOH/1/2	1.5	1.3	PP < 0.25 tsf		*30.0 to 31.5 ft: moist to wet;*
3857.6	32							S-12: Lean Clay with Sand Mostly fines, low to medium plasticity; 15-25% sand, fine to medium grained, subangular to subrounded; soft; moist to wet; light brown; strong reaction with HCl; (CL); [Alluvium]
	33	S - 12	1/2/2	1.5	1.5	PP = 0.50 tsf		
	34							
3855.1	35							S-13, S-14: Sandy Lean Clay Mostly fines, low to medium plasticity; 30-40% sand, fine to medium grained, subangular to subrounded; soft to stiff; moist to wet; yellowish brown; strong reaction with HCl; (CL); [Alluvium]
	36	S - 13	1/2/3	1.5	1.5	PP = 1.50 tsf		
	37							
	38							
	39							
	40							*40.0 to 41.0 ft: medium stiff to stiff; moist;*
3848.6	41	S - 14	2/5/15	1.5	1.5			S-14, S-15: Poorly Graded Sand with Clay Mostly sand, fine to medium grained, angular to subrounded; 5-15% fines, low to medium plasticity; loose; moist to wet; yellowish brown; strong reaction with HCl; (SP-SC); [Alluvium]
	42							
	43							
	44							
	45							Continued on next sheet

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

RJH CONSULTANTS, INC.

LOG OF SOIL BORING

Project name: Queen Reservoir
Project No: 17123
Boring Location: N 1596943.6, E 3822248.7 ft
Ground El: 3889.6 ft Total Depth: 50.0 ft
Groundwater El: 3860.7 ft On Date: 01-31-2018

Start Date: 01-31-2018 End Date: 01-31-2018
Driller: Dan - Elite Logged By: JJS
Bedrock Depth: Not encountered Checked By: MSS

Drilling Rig: CME 850 Track-Mounted Drill Rig
Equipment: 3-1/4 (I.D.) Hollow Stem Augers

Borehole ID: **B-103**
Sheet 4 of 4

Elevation	Depth (ft)	Type - No	Blows per 6 inch	Penetration (ft)	Recovery (ft)	Remarks	Graphic Lithology	Description and Classification of Materials
	46	S - 15	3/4/5	1.5	1.5			
	47							
3842.1	48							S-16: Lean Clay Blocky; mostly fines, medium to high plasticity; less than 10% sand, fine grained; very stiff; moist; light yellowish brown; occasional seams of high plasticity clay and clusters of gypsum crystals throughout; strong reaction with HCl; (CL); [Residuum]
	49	S - 16	9/15/26	1.5	1.5	PP = 4.50 tsf		
3839.6	50					Bottom of Boring at 50.0 feet bgs.		End of boring log at 50.00 ft
	51							
	52							
	53							
	54							
	55							
	56							
	57							
	58							
	59							
	60							

Notes Lithology between recovered samples is interpreted. Contacts are approximate. All depths measured along boring axis. Maximum observed particle size was limited by sampling techniques and sampler size. Backfilled to the ground surface using cement-bentonite grout.

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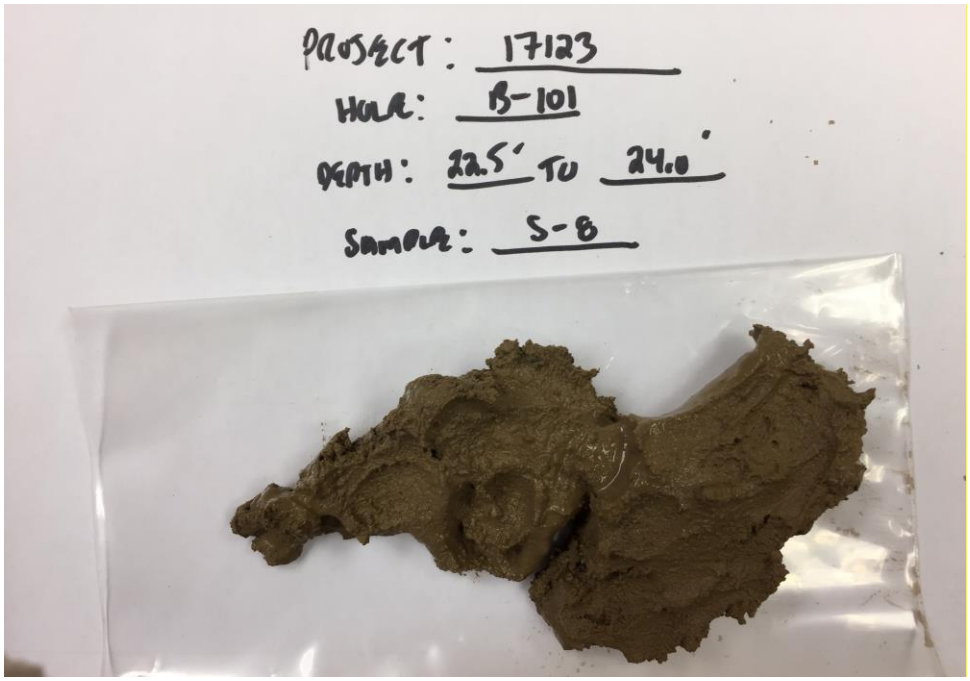
APPENDIX C

PHOTOGRAPHS

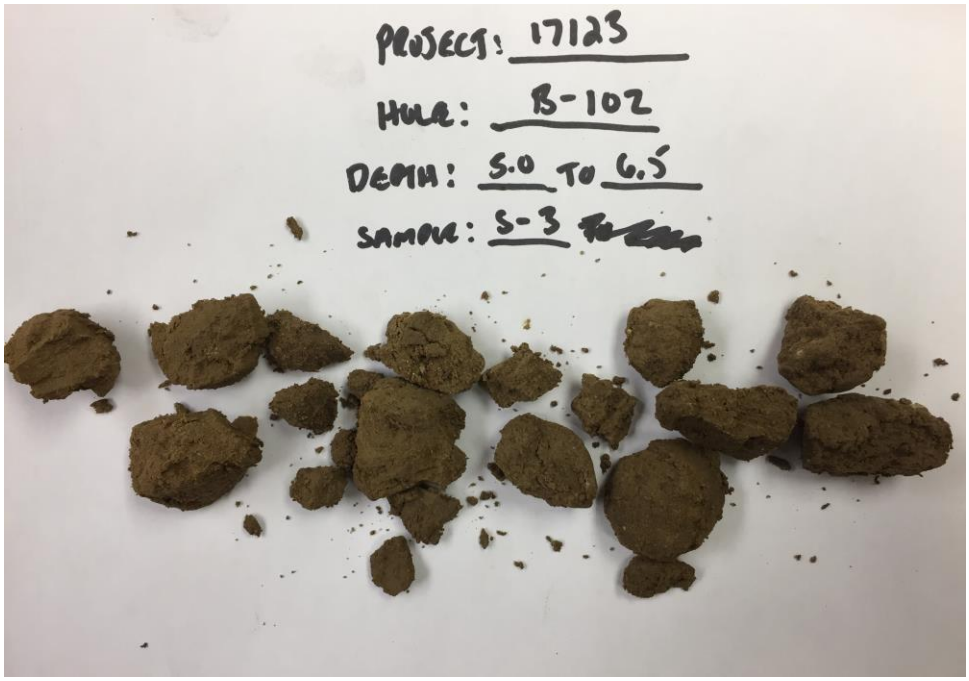
Photograph 1: Erosion Rills on Downstream Embankment Slope (East of Outlet Works).

Photograph 2: Rutting on Downstream Embankment Slope (East of Outlet Works).

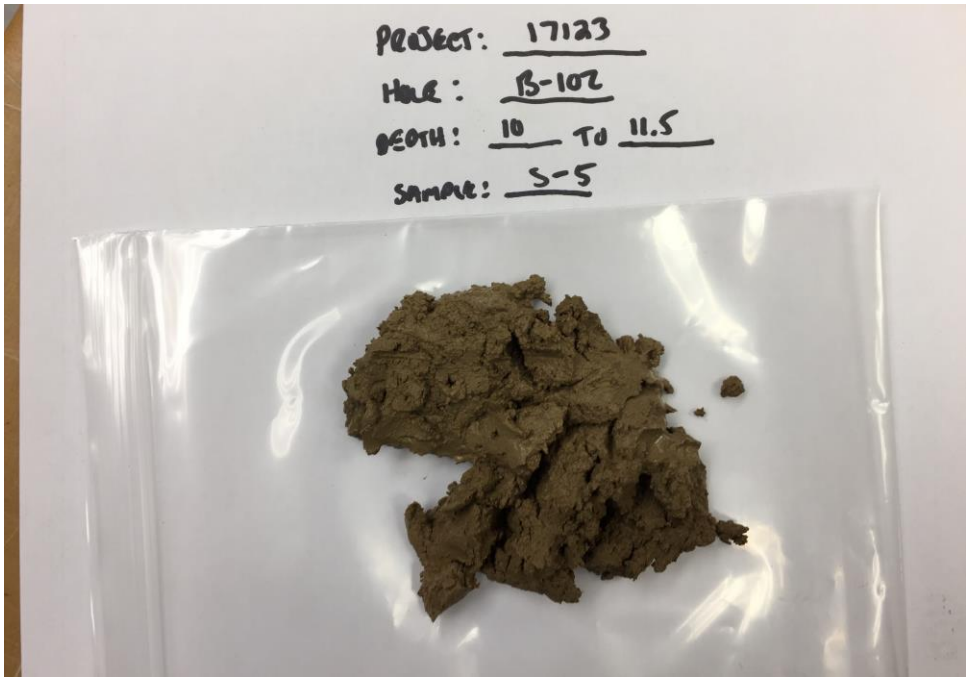
Photograph 3: 36-inch Diameter Tree Stump at Tunnel End Wall (red circle), Left Retaining Wall, and the outlet works.



Photograph 4: Soil Sample (S-8) at B-101 from 22.5 to 24.0 feet bgs.

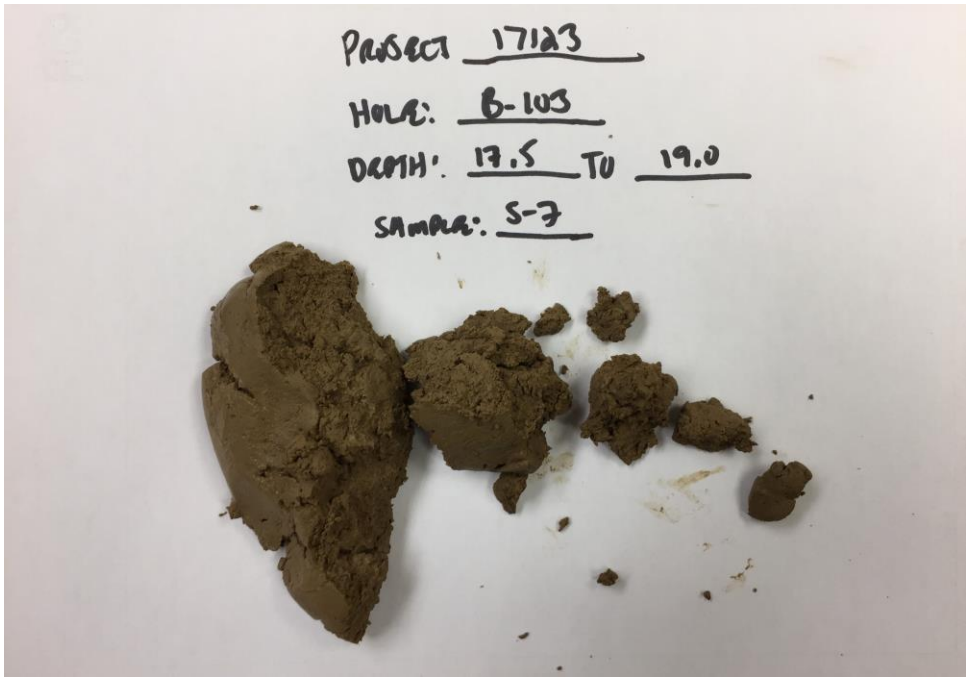


Photograph 5: Soil Sample (S-3) at B-102 from 5.0 to 6.5 feet bgs.

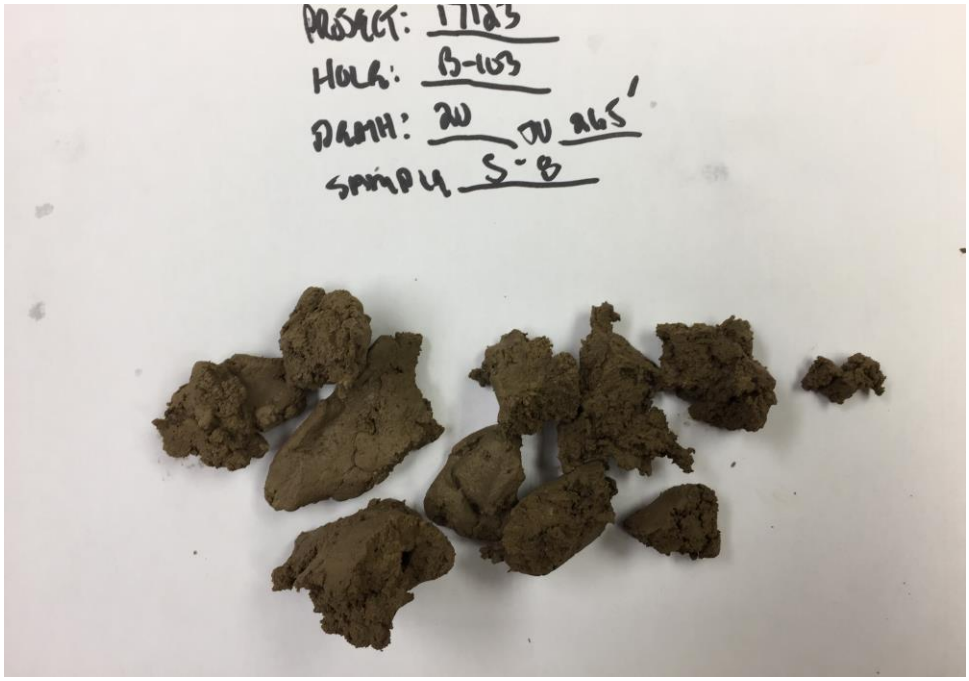


Photograph 6: Soil Sample (S-5) at B-102 from 10.0 to 11.5 feet bgs.

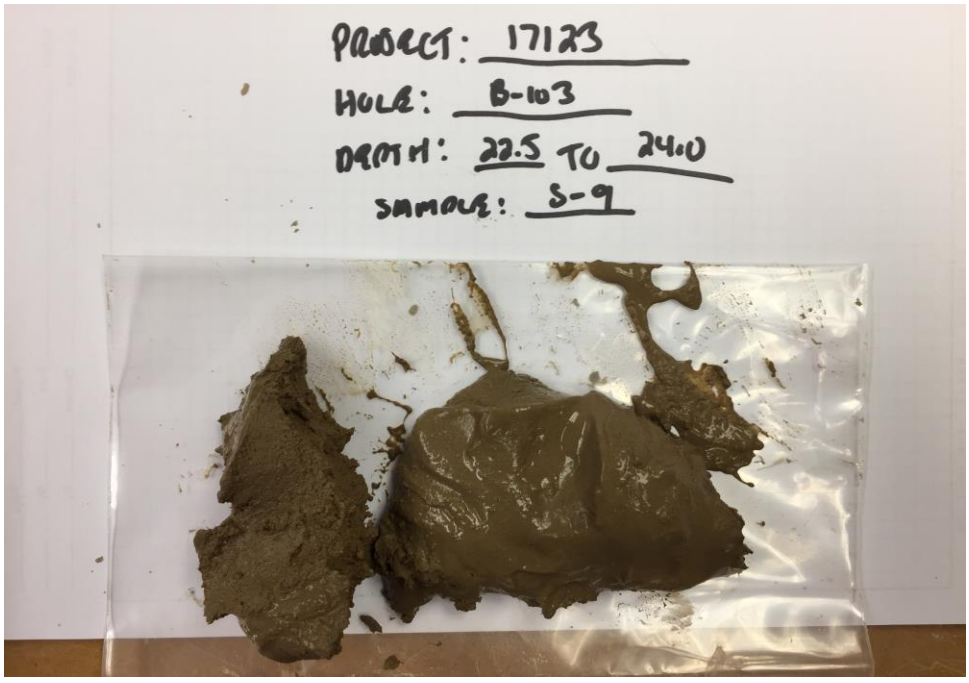
Photograph 7: Soil Sample (S-11) at B-102 from 25.0 to 26.5 feet bgs.



Photograph 8: Soil Sample (S-7) at B-103 from 17.5 to 19.0 feet bgs.



Photograph 9: Soil Sample (S-8) at B-103 from 20.0 to 21.5 feet bgs.



Photograph 10: Soil Sample (S-9) at B-103 from 22.5 to 24.0 feet bgs.

Photograph 11: Soil Sample (S-16) at B-103 from 48.5 to 50.0 feet bgs.

APPENDIX D

LABORATORY TEST RESULTS

ADVANCED TERRA TESTING

Moisture
ASTM D 2216

CLIENT	RJH Consultants			JOB NO.	2679-118
PROJECT	Queen Dam & Reservoir			LOCATION	Eads, CO
PROJECT NO.	17123				
BORING NO.	B-101	B-103	B-101	B-103	
DEPTH	2.5-4.0'	5-6.5'	12.5-14.0'	22.5-24.0'	
SAMPLE NO.	S-2	S-3	S-5	S-9	
DATE SAMPLED					
DATE TESTED	2/19/18	2/19/18	2/19/18	2/19/18	
TECHNICIAN	BDF	BDF	BDF	BDF	
DESCRIPTION					
Mass of Wet Pan and Soil (g):	533.20	378.05	761.47	107.46	
Mass of Dry Pan and Soil (g):	467.99	323.97	611.05	80.30	
Mass of Pan (g):	14.48	14.31	14.27	3.11	
Moisture (%):	**14.4**	**17.5**	**25.2**	**35.2**	
BORING NO.					
DEPTH					
SAMPLE NO.					
DATE SAMPLED					
DATE TESTED					
TECHNICIAN					
DESCRIPTION					
Mass of Wet Pan and Soil (g):					
Mass of Dry Pan and Soil (g):					
Mass of Pan (g):					
Moisture (%):					
BORING NO.					
DEPTH					
SAMPLE NO.					
DATE SAMPLED					
DATE TESTED					
TECHNICIAN					
DESCRIPTION					
Mass of Wet Pan and Soil (g):					
Mass of Dry Pan and Soil (g):					
Mass of Pan (g):					
Moisture (%):					
NOTES					

Data entry by: CRP Date: 2/21/2018
Checked by: CRP Date: 3/7/18
File name: 2679_118_Moisture ASTM D2216_0.xls

ADVANCED TERRA TESTING

Moisture and Density
ASTM D 2216 and ASTM D 7263

CLIENT	RJH Consultants			JOB NO.	2679-118
PROJECT	Queen Dam & Reservoir			LOCATION	Eads, CO
PROJECT NO.	17123				
BORING NO.		B-101	B-101	B--101	B-102
DEPTH		16.5-18.5'	7.5-8.5'	25-26'	6.5-7.5'
SAMPLE NO.		U-1	CA-1	CA-2	CA-1
DATE SAMPLED					
DATE TESTED		03/02/18	03/02/18	03/02/18	03/02/18
TECHNICIAN		BDF	BDF	BDF	BDF
DESCRIPTION					
Mass of Wet Pan and Soil (g):		348.31	109.06	142.73	158.95
Mass of Dry Pan and Soil (g):		295.60	91.84	110.03	128.00
Mass of Pan (g):		13.92	6.64	6.70	8.52
Moisture (%):		**18.7**	**20.2**	**31.6**	**25.9**
Diameter (in):		2.80	1.94	1.94	1.94
Height (in):		8.48	3.72	3.75	4.00
Mass of Wet Soil and Ring (g):		2447.50	536.65	551.95	475.14
Mass of Ring (g):		644.10	207.16	207.48	110.34
Wet Density (lbs/ft³):		**131.6**	**114.4**	**118.6**	**117.8**
Dry Density (lbs/ft³):		**110.8**	**95.1**	**90.1**	**93.5**
Wet Density (kg/m³):		**2108**	**1832**	**1900**	**1887**
Dry Density (kg/m³):		**1775**	**1524**	**1443**	**1498**

BORING NO.		B-103	B-103
DEPTH		12.5-13.5'	12.5-13.5'
SAMPLE NO.		CA-1	CA-1
DATE SAMPLED			
DATE TESTED		03/02/18	03/05/18
TECHNICIAN		BDF	BDF
DESCRIPTION			
Mass of Wet Pan and Soil (g):		87.58	67.77
Mass of Dry Pan and Soil (g):		72.58	57.19
Mass of Pan (g):		8.33	6.53
Moisture (%):		**23.4**	**20.9**
Diameter (in):		1.94	1.94
Height (in):		3.35	3.00
Mass of Wet Soil and Ring (g):		426.11	510.69
Mass of Ring (g):		118.23	247.40
Wet Density (lbs/ft³):		**118.7**	**113.3**
Dry Density (lbs/ft³):		**96.2**	**93.8**
Wet Density (kg/m³):		**1901**	**1816**
Dry Density (kg/m³):		**1541**	**1502**
NOTES			

Data entry by:	SKS	Date:	3/9/2018
Checked by:	CAL	Date:	3/12/18
File name:	2679_118_Moisture and Density ASTM D7236_0.xls		

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-103
JOB NO.	2679-118	DEPTH	22.5-24.0'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	S-9
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/08/18	DESCRIPTION	--
TECHNICIAN	SKS		

Plastic Limits

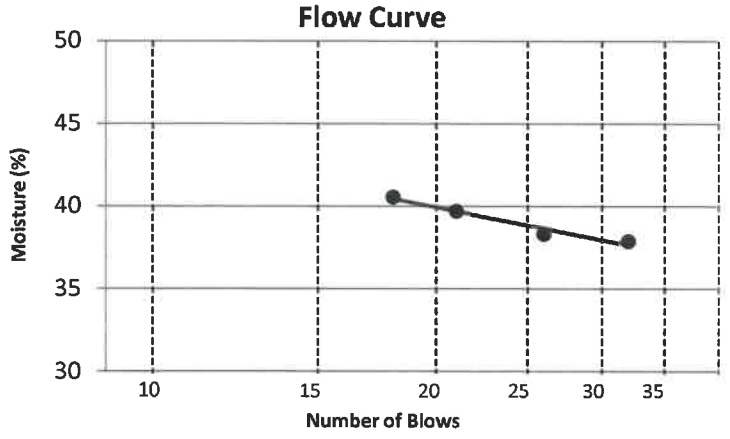
Mass of Wet Pan and Soil (g):	7.76	7.82
Mass of Dry Pan and Soil (g):	6.76	6.84
Mass of Pan (g):	1.12	1.14
Moisture (%)	**17.8**	**17.3**

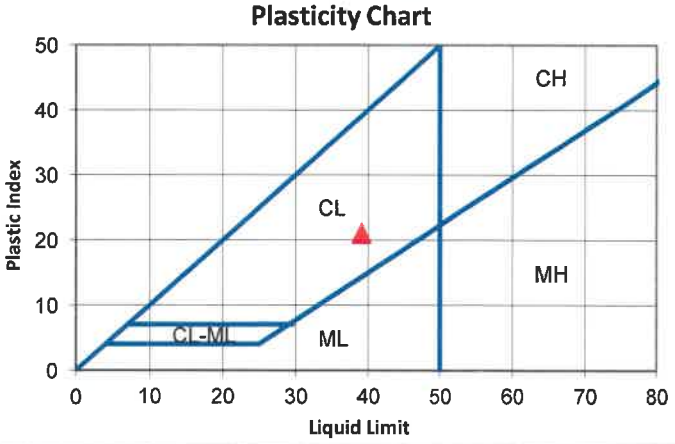
Liquid Limits

Number of Blows	18	21	26	32
Mass of Wet Pan and Soil (g):	10.77	11.03	11.14	10.13
Mass of Dry Pan and Soil (g):	7.98	8.21	8.36	7.64
Mass of Pan (g):	1.09	1.10	1.09	1.09
Moisture (%)	**40.6**	**39.7**	**38.3**	**37.9**

Plastic Index

Plastic Limit:	**18**	Atterberg Classification:	CL
Liquid Limit:	**39**	Method:	A
Plastic Index:	**21**		





NOTES

Data entry by:	SKS	Date:	3/9/2018
Checked by:	CAL	Date:	3/12/18
File name:	2679_118_Atterberg ASTM D4318_2.xls		

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	16.5-18.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	U-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/07/18	DESCRIPTION	--
TECHNICIAN	SKS		

Plastic Limits

Mass of Wet Pan and Soil (g):	7.00	7.18
Mass of Dry Pan and Soil (g):	6.26	6.42
Mass of Pan (g):	1.13	1.16
Moisture (%)	**14.5**	**14.5**

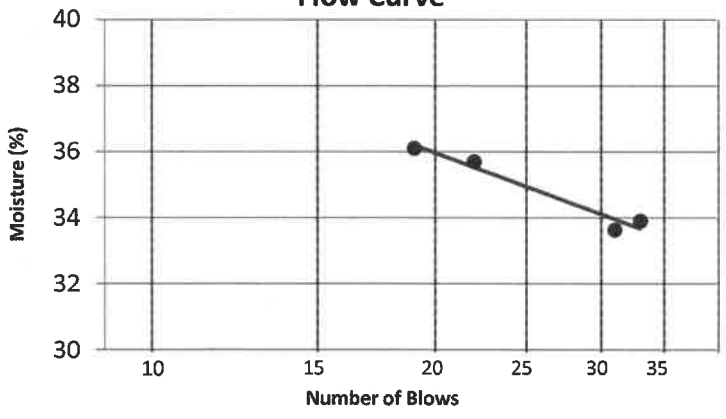
Liquid Limits

Number of Blows	19	22	33	31
Mass of Wet Pan and Soil (g):	12.53	14.88	14.63	14.90
Mass of Dry Pan and Soil (g):	9.51	11.26	11.21	11.43
Mass of Pan (g):	1.15	1.10	1.13	1.14
Moisture (%)	**36.1**	**35.7**	**33.9**	**33.6**

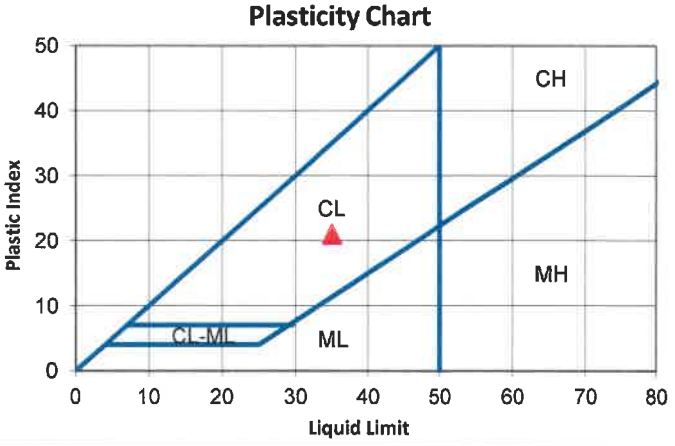
Plastic Index

Plastic Limit:	**14**	Atterberg Classification:	CL
Liquid Limit:	**35**	Method:	A
Plastic Index:	**21**		

Flow Curve



Plasticity Chart



NOTES

Data entry by: SKS Date: 3/8/2018

Checked by: CH Date: 3/12/18

File name: 2679_118_Atterberg ASTM D4318_1.xls

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	25-26'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-2
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/13/18	DESCRIPTION	--
TECHNICIAN	SKS		

Plastic Limits

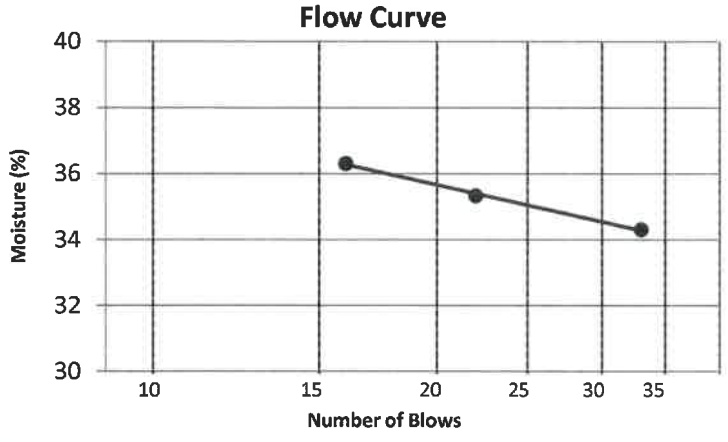
Mass of Wet Pan and Soil (g):	7.21	7.26
Mass of Dry Pan and Soil (g):	6.27	6.30
Mass of Pan (g):	1.18	1.13
Moisture (%)	**18.6**	**18.5**

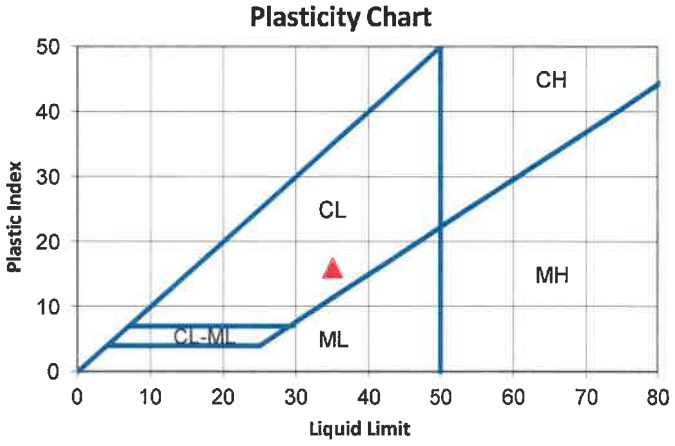
Liquid Limits

Number of Blows	16	22	33
Mass of Wet Pan and Soil (g):	12.70	12.52	11.53
Mass of Dry Pan and Soil (g):	9.62	9.56	8.88
Mass of Pan (g):	1.14	1.17	1.14
Moisture (%)	**36.3**	**35.3**	**34.3**

Plastic Index

Plastic Limit:	**19**	Atterberg Classification:	CL
Liquid Limit:	**35**	Method:	A
Plastic Index:	**16**		





NOTES

Data entry by: SKS
Checked by: CRP
File name: 2679_118_Atterberg ASTM D4318_4.xls

Date: 3/14/2018
Date: 3/14/18

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-103
JOB NO.	2679-118	DEPTH	12.5-13.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/09/18	DESCRIPTION	--
TECHNICIAN	BDF		

Plastic Limits

Mass of Wet Pan and Soil (g):	7.76	7.85
Mass of Dry Pan and Soil (g):	6.74	6.82
Mass of Pan (g):	1.14	1.14
Moisture (%)	**18.2**	**18.2**

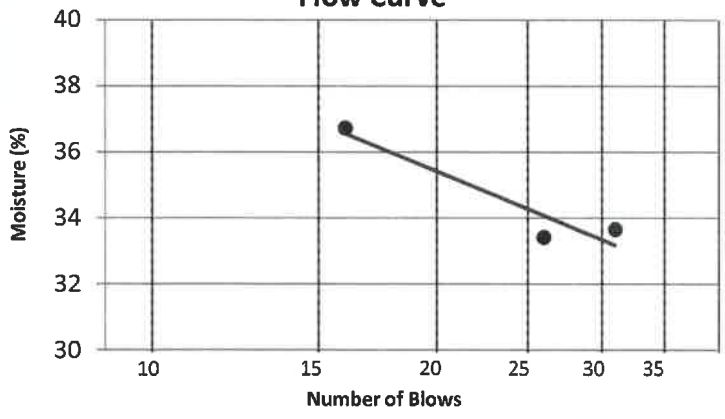
Liquid Limits

Number of Blows	16	31	26
Mass of Wet Pan and Soil (g):	8.43	9.35	8.90
Mass of Dry Pan and Soil (g):	6.46	7.28	6.95
Mass of Pan (g):	1.10	1.14	1.10
Moisture (%)	**36.7**	**33.7**	**33.4**

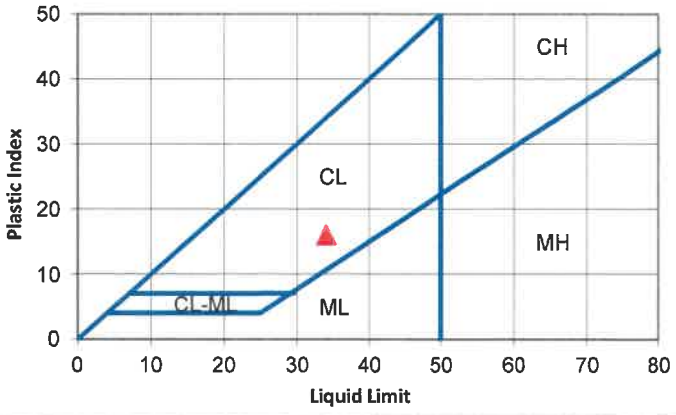
Plastic Index

Plastic Limit:	**18**	Atterberg Classification:	CL
Liquid Limit:	**34**	Method:	A
Plastic Index:	**16**		

Flow Curve



Plasticity Chart



NOTES

Data entry by:	SKS	Date:	3/13/2018
Checked by:	CHC	Date:	3/14/18
File name:	2679_118_Atterberg ASTM D4318_3.xls		

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-102
JOB NO.	2679-118	DEPTH	6.5-7.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/12/18	DESCRIPTION	--
TECHNICIAN	SKS		

Plastic Limits

Mass of Wet Pan and Soil (g):	7.05	6.89	6.81
Mass of Dry Pan and Soil (g):	6.19	6.09	6.01
Mass of Pan (g):	1.07	1.14	1.13
Moisture (%)	**16.8**	**16.3**	**16.3**

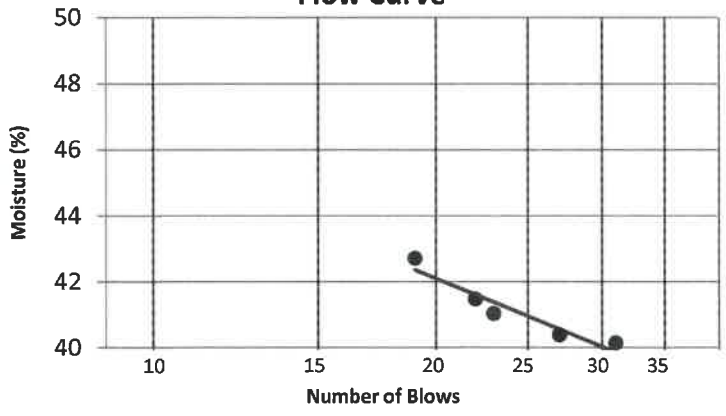
Liquid Limits

Number of Blows	19	22	23	27	31
Mass of Wet Pan and Soil (g):	12.57	13.04	13.06	13.10	13.25
Mass of Dry Pan and Soil (g):	9.15	9.55	9.59	9.66	9.78
Mass of Pan (g):	1.14	1.14	1.13	1.16	1.15
Moisture (%)	**42.7**	**41.5**	**41.0**	**40.4**	**40.2**

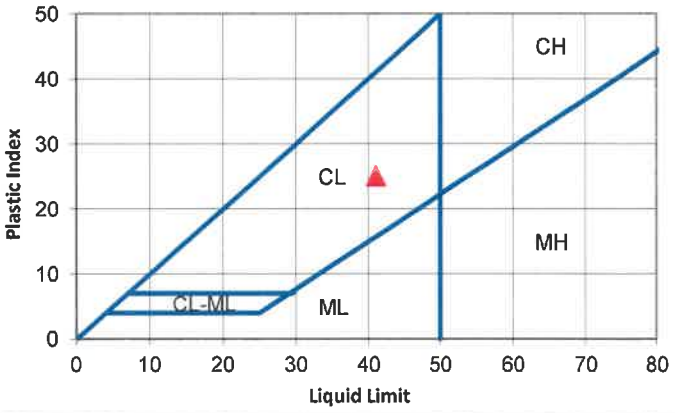
Plastic Index

Plastic Limit:	**16**	Atterberg Classification:	CL
Liquid Limit:	**41**	Method:	A
Plastic Index:	**25**		

Flow Curve



Plasticity Chart



NOTES

Data entry by: SKS Date: 3/13/2018

Checked by: CM Date: 3/15/18

File name: 2679_118_Atterberg ASTM D4318_0.xls

ADVANCED TERRA TESTING

Atterberg Limits
ASTM D 4318

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	7.5-8.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	SAMPLED BY	--
DATE TESTED	03/13/18	DESCRIPTION	--
TECHNICIAN	SKS		

Plastic Limits

Mass of Wet Pan and Soil (g):	7.57	7.38
Mass of Dry Pan and Soil (g):	6.59	6.43
Mass of Pan (g):	1.15	1.15
Moisture (%)	**17.9**	**17.9**

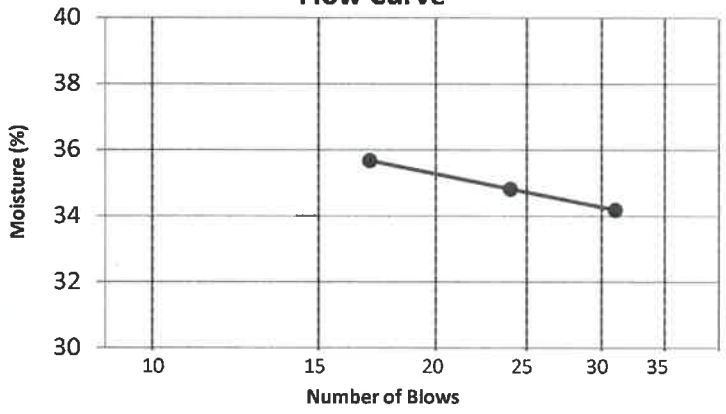
Liquid Limits

Number of Blows	17	24	31
Mass of Wet Pan and Soil (g):	13.16	11.33	13.39
Mass of Dry Pan and Soil (g):	10.00	8.69	10.26
Mass of Pan (g):	1.14	1.12	1.12
Moisture (%)	**35.7**	**34.8**	**34.2**

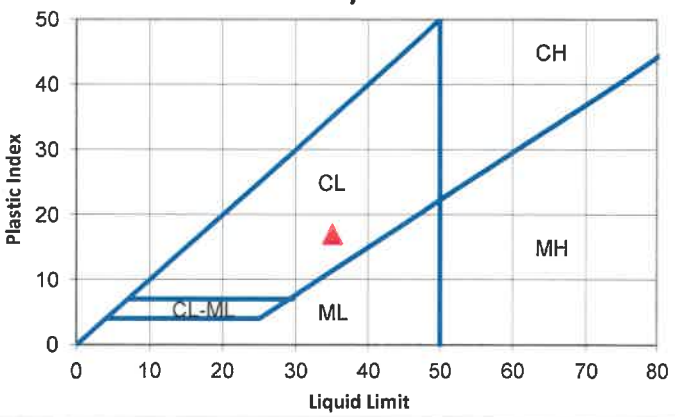
Plastic Index

Plastic Limit:	**18**	Atterberg Classification:	CL
Liquid Limit:	**35**	Method:	A
Plastic Index:	**17**		

Flow Curve



Plasticity Chart



NOTES

Data entry by: SKS Date: 3/14/2018

Checked by: CH Date: 3/15/18

File name: 2679_118_Atterberg ASTM D4318_5.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-103
JOB NO.	2679-118	DEPTH	22.5-24.0'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	S-9
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/01/18		
TECHNICIAN	BDF		

Hygroscopic Moisture

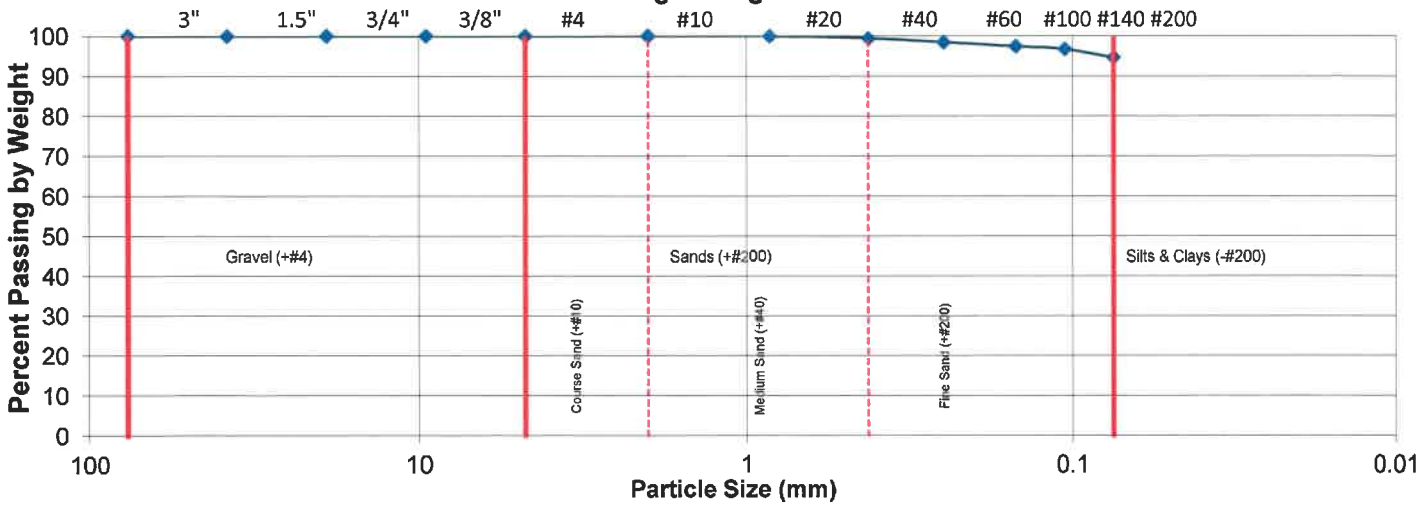
Mass Wet Pan and Soil (g): 1224.14
Mass Dry Pan and Soil (g): 1219.54
Mass of Pan (g): 1030.24
Moisture (%): **2.4**

Sample Data

Total Wet Mass of Sample (g): 193.9
Total Dry Mass of Sample (g): 189.3

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	**--**
1.5"	38.1	--	--	--	--	**--**
3/4"	19.05	--	--	--	--	**--**
3/8"	9.53	--	--	--	--	**--**
#4	4.75	--	--	--	--	**--**
#10	2.00	0.0	--	0.0	1.00	**100.0**
#20	0.850	0.1	--	0.1	1.00	**99.9**
#40	0.425	1.1	--	1.1	1.00	**99.4**
#60	0.250	1.8	--	1.8	1.00	**98.4**
#100	0.150	2.0	--	2.0	1.00	**97.4**
#140	0.106	1.3	--	1.3	1.00	**96.7**
#200	0.075	4.0	--	4.0	1.00	**94.5**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Lean Clay

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/9/2018
Checked by: CK Date: 3/12/18
File name: 2679_118_Grain Size Analysis ASTM D6913_3.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-103
JOB NO.	2679-118	DEPTH	12.5-13.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1 #2
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/08/18		
TECHNICIAN	SKS		

Hygroscopic Moisture

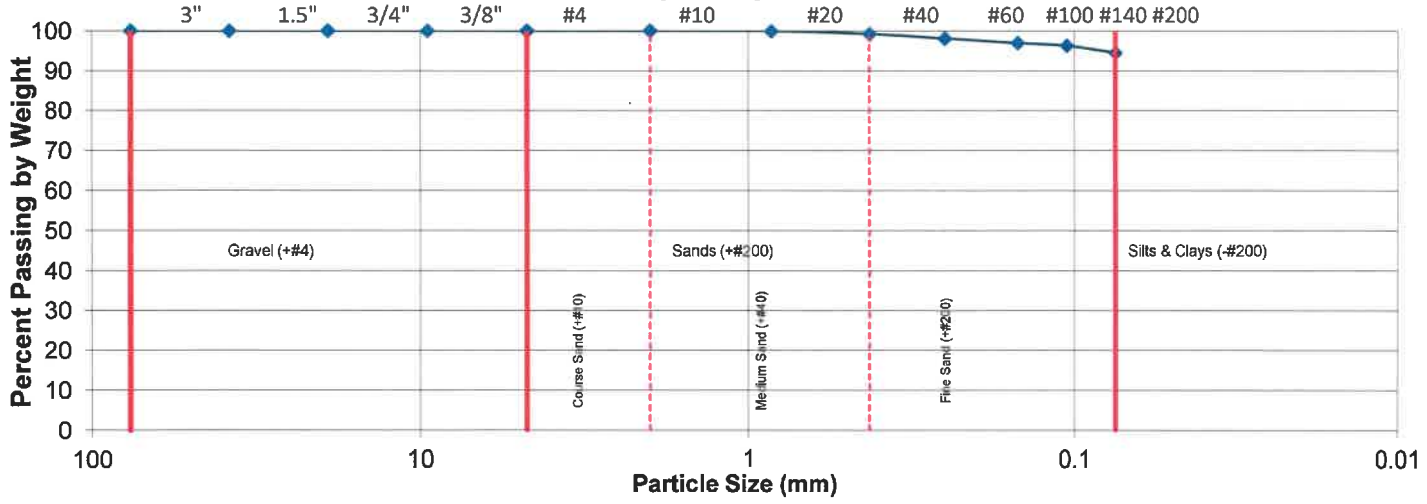
Mass Wet Pan and Soil (g): 231.70
Mass Dry Pan and Soil (g): 218.21
Mass of Pan (g): 6.75
Moisture (%): **6.4**

Sample Data

Total Wet Mass of Sample (g): 225.0
Total Dry Mass of Sample (g): 211.5

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	--
1.5"	38.1	--	--	--	--	--
3/4"	19.05	--	--	--	--	--
3/8"	9.53	--	--	--	--	--
#4	4.75	--	--	--	--	--
#10	2.00	--	--	--	--	--
#20	0.850	0.2	--	0.2	1.00	**99.9**
#40	0.425	1.5	--	1.5	1.00	**99.2**
#60	0.250	2.4	--	2.4	1.00	**98.1**
#100	0.150	2.5	--	2.5	1.00	**96.9**
#140	0.106	1.4	--	1.4	1.00	**96.2**
#200	0.075	3.8	--	3.8	1.00	**94.4**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: --
Group Symbol: --
USCS Classification: --

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/9/2018
Checked by: CH Date: 3/12/18
File name: 2679_118_Grain Size Analysis ASTM D6913_2.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	25-26'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-2
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/09/18		
TECHNICIAN	BDF		

Hygroscopic Moisture

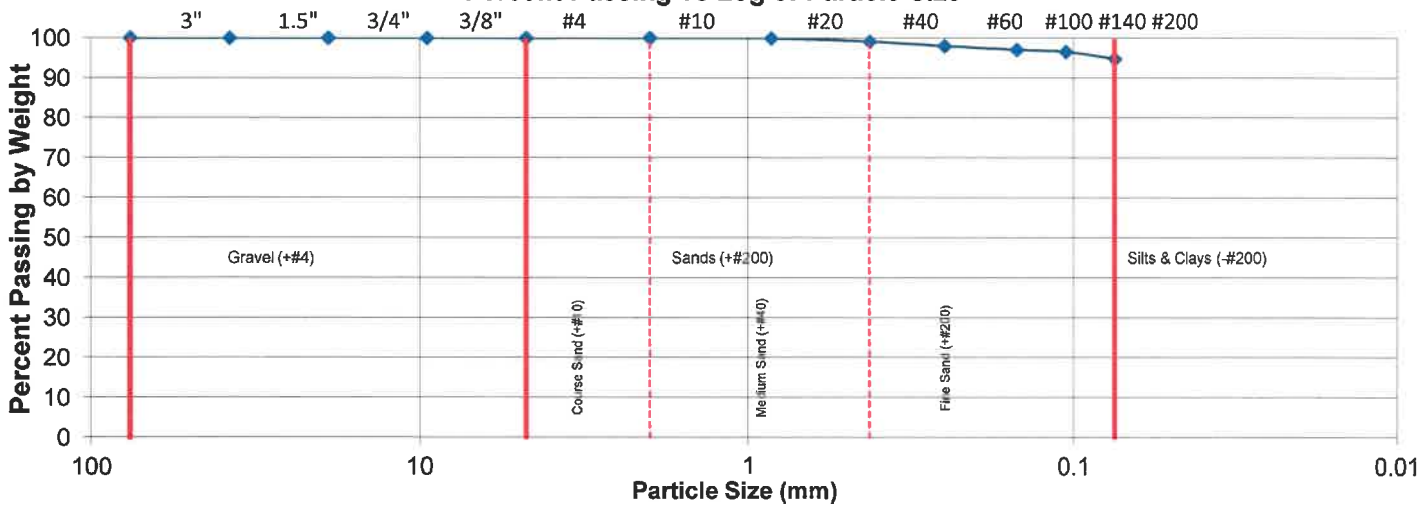
Mass Wet Pan and Soil (g): 206.83
Mass Dry Pan and Soil (g): 202.23
Mass of Pan (g): 6.59
Moisture (%): **2.4**

Sample Data

Total Wet Mass of Sample (g): 200.2
Total Dry Mass of Sample (g): 195.6

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	--
1.5"	38.1	--	--	--	--	--
3/4"	19.05	--	--	--	--	--
3/8"	9.53	--	--	--	--	--
#4	4.75	--	--	--	--	--
#10	2.00	--	--	--	--	--
#20	0.850	0.1	--	0.1	1.00	**100.0**
#40	0.425	1.6	--	1.6	1.00	**99.1**
#60	0.250	2.1	--	2.1	1.00	**98.1**
#100	0.150	1.8	--	1.8	1.00	**97.1**
#140	0.106	1.1	--	1.1	1.00	**96.5**
#200	0.075	3.5	--	3.5	1.00	**94.8**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Lean Clay

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/14/2018
Checked by: CAC Date: 3/15/18
File name: 2679_118_Grain Size Analysis ASTM D6913_5.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	16.5-18.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	U-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/07/18		
TECHNICIAN	BDF		

Hygroscopic Moisture of Fines

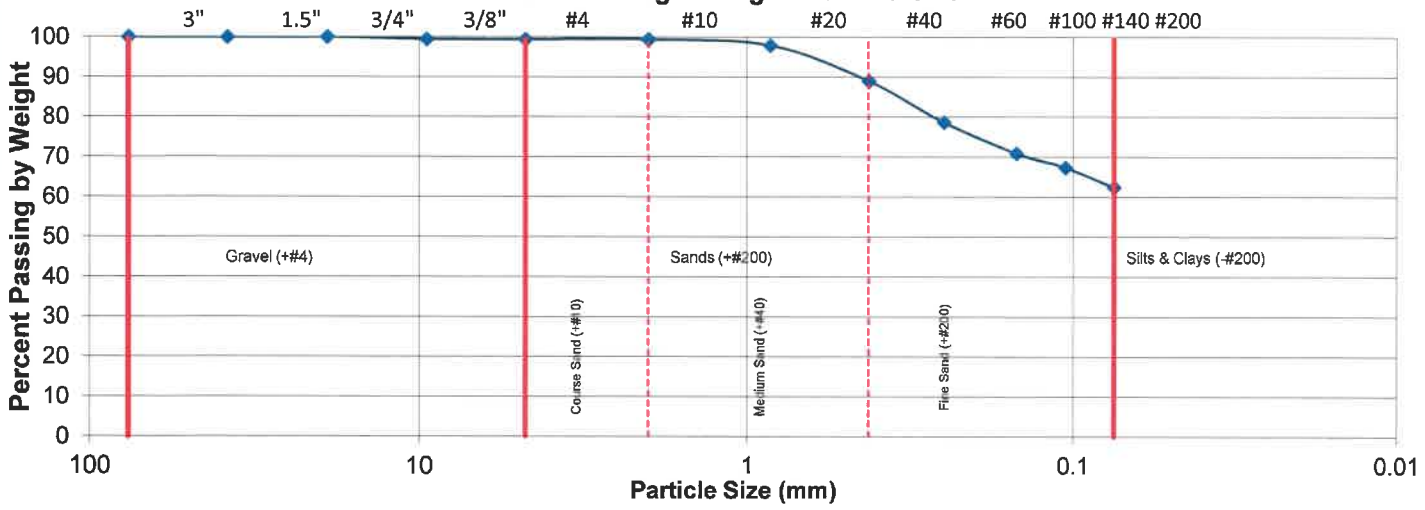
Mass Wet Pan and Soil (g): 208.63
Mass Dry Pan and Soil (g): 204.99
Mass of Pan (g): 3.16
Moisture (%): **1.8**

Sample Data

Total Wet Mass of Sample (g): 1359.6
Total Dry Mass of Sample (g): 1335.7
Split Fraction: #4
Mass of Sub-Sample Fraction (g): 204.76

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	--
1.5"	38.1	--	--	--	--	--
3/4"	19.05	--	--	--	--	--
3/8"	9.53	6.7	--	6.7	1.00	**99.5**
#4	4.75	0.7	--	0.7	1.00	**99.4**
#10	2.00	0.0	--	0.0	0.99	**99.4**
#20	0.850	3.0	--	3.0	0.99	**97.9**
#40	0.425	17.9	--	17.9	0.99	**89.1**
#60	0.250	20.9	--	20.9	0.99	**78.8**
#100	0.150	15.7	--	15.7	0.99	**71.0**
#140	0.106	7.2	--	7.2	0.99	**67.4**
#200	0.075	10.1	--	10.1	0.99	**62.4**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Sandy Lean Clay

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/8/2018
Checked by: CAC Date: 3/15/18
File name: 2679_118_Grain Size Analysis ASTM D6913_1.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-101
JOB NO.	2679-118	DEPTH	7.5-8.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/07/18		
TECHNICIAN	BDF		

Hygroscopic Moisture

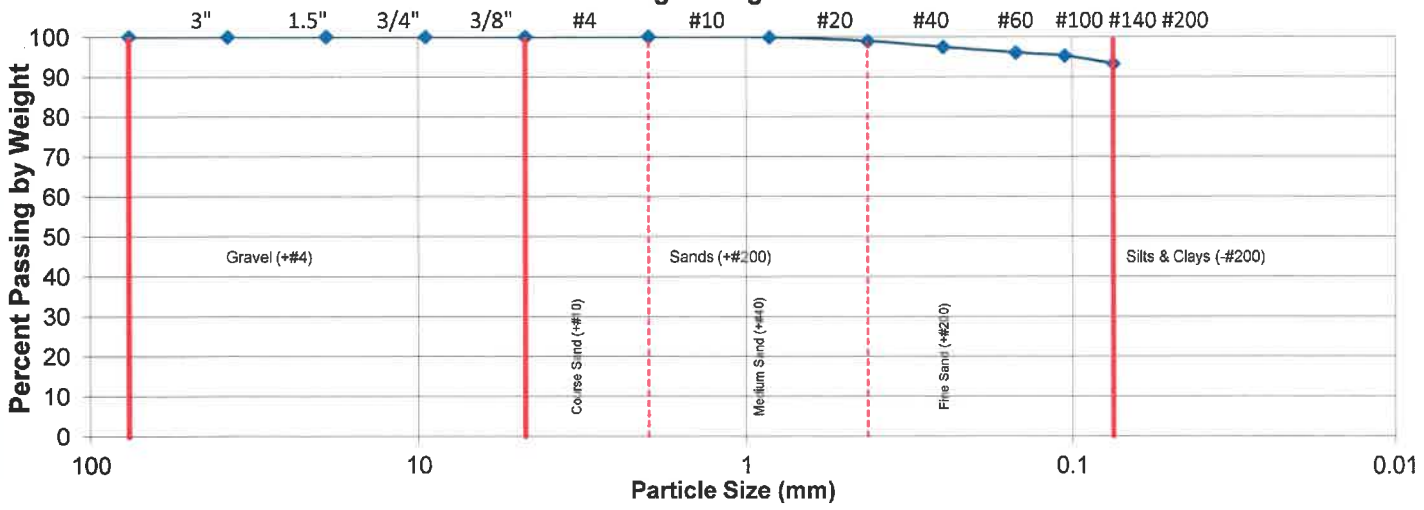
Mass Wet Pan and Soil (g): 256.87
Mass Dry Pan and Soil (g): 248.47
Mass of Pan (g): 6.72
Moisture (%): **3.5**

Sample Data

Total Wet Mass of Sample (g): 250.2
Total Dry Mass of Sample (g): 241.8

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	--
1.5"	38.1	--	--	--	--	--
3/4"	19.05	--	--	--	--	--
3/8"	9.53	--	--	--	--	--
#4	4.75	--	--	--	--	--
#10	2.00	--	--	--	--	--
#20	0.850	0.3	--	0.3	1.00	**99.9**
#40	0.425	2.3	--	2.3	1.00	**98.9**
#60	0.250	3.6	--	3.6	1.00	**97.4**
#100	0.150	3.3	--	3.3	1.00	**96.0**
#140	0.106	2.1	--	2.1	1.00	**95.2**
#200	0.075	4.7	--	4.7	1.00	**93.2**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Lean Clay

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/8/2018
Checked by: CM Date: 3/15/18
File name: 2679_118_Grain Size Analysis ASTM D6913_0.xls

ADVANCED TERRA TESTING

Grain Size Analysis
ASTM D 6913

CLIENT	RJH Consultants	BORING NO.	B-102
JOB NO.	2679-118	DEPTH	6.5-7.5'
PROJECT	Queen Dam & Reservoir	SAMPLE NO.	CA-1
PROJECT NO.	17123	DATE SAMPLED	--
LOCATION	Eads, CO	DESCRIPTION	--
DATE TESTED	03/09/18		
TECHNICIAN	BDF		

Hygroscopic Moisture

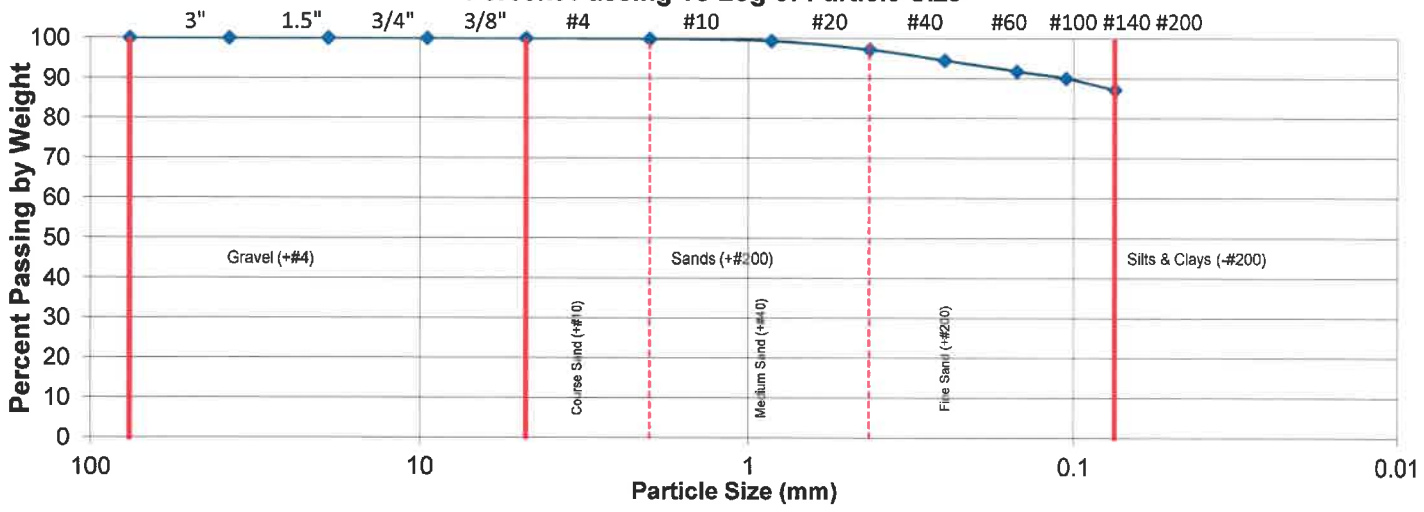
Mass Wet Pan and Soil (g): 208.19
Mass Dry Pan and Soil (g): 203.72
Mass of Pan (g): 6.64
Moisture (%): **2.3**

Sample Data

Total Wet Mass of Sample (g): 201.6
Total Dry Mass of Sample (g): 197.1

Sieve Number	Sieve Size (mm)	Mass of Pan and Soil (g)	Mass of Pan (g)	Mass of Individual Retained Soil (g)	Correction Factor	Percent Passing by Weight (%)
3"	76.2	--	--	--	--	**--**
1.5"	38.1	--	--	--	--	**--**
3/4"	19.05	--	--	--	--	**--**
3/8"	9.53	--	--	--	--	**--**
#4	4.75	--	--	--	--	**--**
#10	2.00	0.2	--	0.2	1.00	**99.9**
#20	0.850	0.9	--	0.9	1.00	**99.4**
#40	0.425	4.2	--	4.2	1.00	**97.3**
#60	0.250	5.2	--	5.2	1.00	**94.6**
#100	0.150	5.3	--	5.3	1.00	**91.9**
#140	0.106	3.6	--	3.6	1.00	**90.1**
#200	0.075	5.8	--	5.8	1.00	**87.2**

Percent Passing vs Log of Particle Size



USCS Classification ASTM D 2487

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Lean Clay

Coefficient of Curvature - C_c: --
Coefficient of Uniformity - C_u: --

Data entry by: SKS Date: 3/13/2018
Checked by: CK Date: 3/15/18
File name: 2679_118_Grain Size Analysis ASTM D6913_4.xls

Crumb Dispersion Test
USBR Method 5400

Client: RJH
Job Number: 2679-118
Location: Eads, CO
Project: Queen Dam & Reservoir
Project No.: 17123

Date Tested: 3/14/2018
Data Entered By: BDF

By: BDF
Date: 3/15/2018

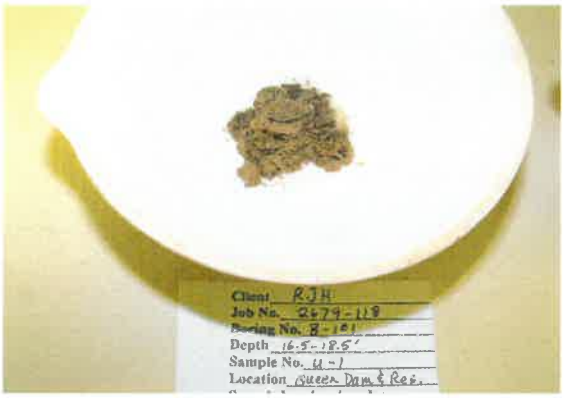
Specimen Type: Irregular
Boring No.: B-101
Depth: 16.5-18.5'
Sample No.: U-1

	Water Temp °C	Grade
2 min	21.1	1
15 min	21.2	1
*60 min	21	1
1440 min	20.8	1

Before Test Moisture Content

Weight of Wet Soil & Dish (g):	39.535
Weight of Dry Soil & Dish (g):	33.57
Weight of Water (g):	5.965
Weight of Dish (g):	3.152
Dry Weight of Soil (g):	30.418
Moisture Content:	19.61%

Grade 1: Non-Dispersive
Grade 2: Intermediate
Grade 3: Dispersive
Grade 4: Dispersive



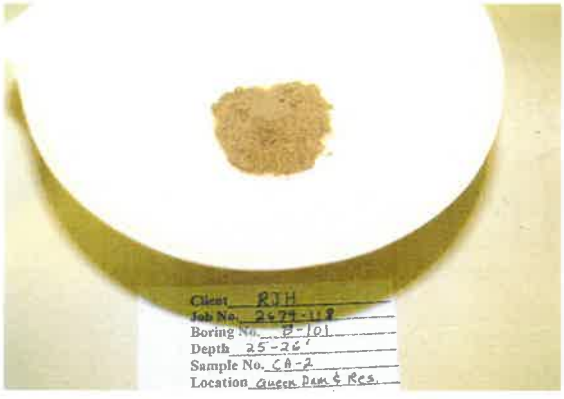
Specimen Type: Irregular
Boring No.: B-101
Depth: 25-26'
Sample No.: CA-2

	Water Temp °C	Grade
2 min	21.2	1
15 min	21.3	1
*60 min	21.1	1
1440 min	20.9	1

Before Test Moisture Content

Weight of Wet Soil & Dish (g):	40.973
Weight of Dry Soil & Dish (g):	32.271
Weight of Water (g):	8.702
Weight of Dish (g):	3.089
Dry Weight of Soil (g):	29.182
Moisture Content:	29.82%

Grade 1: Non-Dispersive
Grade 2: Intermediate
Grade 3: Dispersive
Grade 4: Dispersive



Notes: * indicates that overall grade for the sample should be taken at the 60min. reading.

File Name: 2679_118_CRUMB-USBR5400-R0_0.xls

Data Checked By: VR
Date: 3/16/18

ATT
ADVANCED TERRA TESTING

Crumb Dispersion Test
USBR Method 5400

Client: RJH
Job Number: 2679-118
Location: Eads, CO
Project: Queen Dam & Reservoir
Project No.: 17123

Date Tested: 3/14/2018
Data Entered By: BDF

By: BDF
Date: 3/15/2018

Specimen Type: Irregular
Boring No.: B-102
Depth: 6.5-7.5'
Sample No.: CA-1

	Water Temp °C	Grade
2 min	21.1	1
15 min	21.1	1
*60 min	21.2	1
1440 min	21	1

Before Test Moisture Content

Weight of Wet Soil & Dish (g):	31.4
Weight of Dry Soil & Dish (g):	25.672
Weight of Water (g):	5.728
Weight of Dish (g):	3.22
Dry Weight of Soil (g):	22.452
Moisture Content:	25.51%

Grade 1: Non-Dispersive
Grade 2: Intermediate
Grade 3: Dispersive
Grade 4: Dispersive

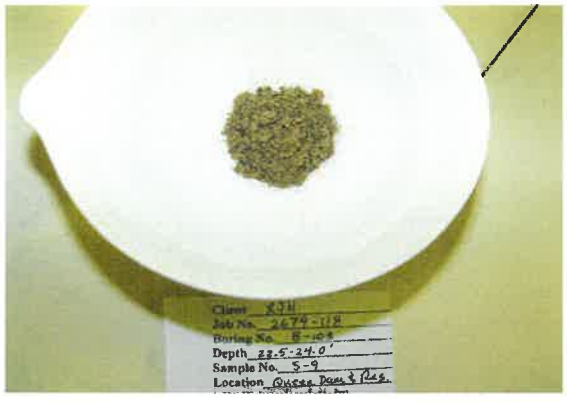
Specimen Type: Remolded
Boring No.: B-103
Depth: 22.5-24.0'
Sample No.: S-9

	Water Temp °C	Grade
2 min	21.2	1
15 min	21.3	1
*60 min	21.2	1
1440 min	21	1

Before Test Moisture Content

Weight of Wet Soil & Dish (g):	30.132
Weight of Dry Soil & Dish (g):	25.548
Weight of Water (g):	4.584
Weight of Dish (g):	3.114
Dry Weight of Soil (g):	22.434
Moisture Content:	20.43%

Grade 1: Non-Dispersive
Grade 2: Intermediate
Grade 3: Dispersive
Grade 4: Dispersive



Notes: * indicates that overall grade for the sample should be taken at the 60min. reading.

File Name: 2679_118_CRUMB-USBR5400-R0_1.xls

Data Checked By: VR
Date: 3/16/18

ATT
ADVANCED TERRA TESTING

APPENDIX C

OPINION OF PROBABLE COST AND QUANTITIES

Engineer's Opinion of Cost
Queen Reservoir
Concept #1A - Steel Pipes
Project No. 17123

Item Number	Description	Estimated Quantity [1]	Unit	Unit Price ($)	Total Cost ($)
General					
1	Stripping, Clearing, and Grubbing	1	acre	$ 4,750.00	$ 4,750
2	Erosion & Sedimentation	1	LS	$ 5,000.00	$ 5,000
3	Demolition	1	LS	$ 20,000.00	$ 20,000
4	Site Restoration	1	acre	$ 2,500.00	$ 2,500
5	General Conditions/Management	1	LS	$ 20,000.00	$ 20,000
Earthwork Construction					
6	Excavation (Embankment)	1,500	CY	$ 10.00	$ 15,000
7	Common Fill	1,500	CY	$ 12.00	$ 18,000
8	Excavation (Channel)[2]	2,600	CY	$ 10.00	$ 26,000
9	Slotted Drain Pipe with Filter Gravel	40	LF	$ 200.00	$ 8,000
Outlet Works					
10	26-inch Steel Pipe	162	LF	$ 200.00	$ 32,400
11	Grout Backfill - Casing Pipe (Includes Spacers)	3	EA	$ 10,000.00	$ 30,000
12	Concrete Pipe Encasement	50	CY	$ 500.00	$ 25,000
13	Sand Filter	40	CY	$ 100.00	$ 4,000
Stilling Basin					
14	Concrete Stilling Basin	1	EA	$ 70,000.00	$ 70,000
15	Bedding Material	4	CY	$ 200.00	$ 800
16	Riprap	12	CY	$ 150.00	$ 1,800
Base Construction Cost (BCC)					**$ 283,250**
Mobilization/Demobilization (10% of BCC)					$ 28,325
Bonds/Insurance (1.5% of BCC)					$ 4,249
Direct Construction Cost (DCC)					**$ 315,824**
Contingency and Unlisted Items (25% of DCC)					$ 78,956
Design and Engineering (15% DCC)					$ 47,374
Construction Engineering (20% of DCC)					$ 63,165
Opinion of Probable Construction Cost					**$ 505,318**

Notes:

1. All unit prices and quantities developed from Engineer's judgement and conceptual drawings.
2. Excavation and grading downstream channel.

Engineer's Opinion of Cost
Queen Reservoir
Concept #1B - HDPE Pipes
Project No. 17123

Item Number	Description	Estimated Quantity [1]	Unit	Unit Price ($)	Total Cost ($)
General					
1	Stripping, Clearing, and Grubbing	1	acre	$ 4,750.00	$ 4,750
2	Erosion & Sedimentation	1	LS	$ 5,000.00	$ 5,000
3	Demolition	1	LS	$ 20,000.00	$ 20,000
4	Site Restoration	1	acre	$ 2,500.00	$ 2,500
5	General Conditions/Management	1	LS	$ 20,000.00	$ 20,000
Earthwork Construction					
6	Excavation (Embankment)	1,500	CY	$ 10.00	$ 15,000
7	Common Fill	1,500	CY	$ 12.00	$ 18,000
8	Excavation (Channel)[2]	2,600	CY	$ 10.00	$ 26,000
9	Slotted Drain Pipe with Filter Gravel	40	LF	$ 200.00	$ 8,000
Outlet Works					
10	26-inch HDPE Pipe	162	LF	$ 165.00	$ 26,730
11	Grout Backfill - Casing Pipe (Includes Spacers)	3	EA	$ 10,000.00	$ 30,000
12	Concrete Pipe Encasement	50	CY	$ 500.00	$ 25,000
13	Sand Filter	40	CY	$ 100.00	$ 4,000
Stilling Basin					
14	Concrete Stilling Basin	1	EA	$ 70,000.00	$ 70,000
15	Bedding Material	4	CY	$ 200.00	$ 800
16	Riprap	12	CY	$ 150.00	$ 1,800
Base Construction Cost (BCC)					**$ 277,580**
Mobilization/Demobilization (10% of BCC)					$ 27,758
Bonds/Insurance (1.5% of BCC)					$ 4,164
Direct Construction Cost (DCC)					**$ 309,502**
Contingency and Unlisted Items (25% of DCC)					$ 77,375
Design and Engineering (15% DCC)					$ 46,425
Construction Engineering (20% of DCC)					$ 61,900
Opinion of Probable Construction Cost					**$ 495,203**

Notes:

1. All unit prices and quantities developed from Engineer's judgement and conceptual drawings.
2. Excavation and grading downstream channel.

Engineer's Opinion of Cost
Queen Reservoir
Concept #2 - Outlet Works Modification
Project No. 17123

Item Number	Description	Estimated Quantity [1]	Unit	Unit Price ($)	Total Cost ($)
General					
1	Stripping, Clearing, and Grubbing	1	acre	$ 4,750.00	$ 4,750
2	Erosion & Sedimentation	1	LS	$ 5,000.00	$ 5,000
3	Demolition	1	LS	$ 60,000.00	$ 60,000
4	Site Restoration	1	acre	$ 2,500.00	$ 2,500
5	General Conditions/Management	1	LS	$ 20,000.00	$ 20,000
Earthwork Construction					
6	Excavation (Embankment)	2,400	CY	$ 10.00	$ 24,000
7	Excavation - Borrow	600	CY	$ 10.00	$ 6,000
8	Common Fill	2,400	CY	$ 12.00	$ 28,800
9	Excavation (Channel)[2]	2,600	CY	$ 10.00	$ 26,000
10	Slotted Drain Pipe with Filter Gravel	60	LF	$ 200.00	$ 12,000
Discharge Piping					
11	54-inch Steel Pipe	100	LF	$ 455.00	$ 45,500
12	Concrete Pipe Encasement	100	CY	$ 500.00	$ 50,000
13	Sand Filter	70	CY	$ 100.00	$ 7,000
Gate Vault					
14	Concrete Gate Vault	1	EA	$ 40,000.00	$ 40,000
15	Piping and Fittings	1	LS	$ 24,600.00	$ 24,600
16	Gates/Valves	1	EA	$ 61,000.00	$ 61,000
Outlet Works					
17	Concrete Stilling Basin	1	EA	$ 40,000.00	$ 40,000
18	Bedding Material	4	CY	$ 200.00	$ 800
19	Riprap	12	CY	$ 100.00	$ 1,200
Intake Structure					
20	Concrete Intake Structure	1	EA	$ 60,000.00	$ 60,000
21	Trash Rack	1	EA	$ 25,000.00	$ 25,000
22	Hydraulic Slide Gate (Includes Controls)	1	EA	$ 110,000.00	$ 110,000
23	Bedding Material	4	CY	$ 60.00	$ 240
24	Riprap	12	CY	$ 75.00	$ 900
Base Construction Cost (BCC)					**$ 655,290**
Mobilization/Demobilization (5% of BCC)					$ 32,765
Bonds/Insurance (1.5% of BCC)					$ 9,829
Direct Construction Cost (DCC)					**$ 697,884**
Contingency and Unlisted Items (25% of DCC)					$ 174,471
Design and Engineering (10% DCC)					$ 69,788
Construction Engineering (12% of DCC)					$ 83,746
Opinion of Probable Construction Cost					**$ 1,025,889**

Notes:

1. All unit prices and quantities developed from Engineer's judgement and conceptual drawings.

Opinion of Probable Cost Summary			
Concept	Estimated Construction Costs	Estimated Engineering Costs[(1)]	Total Cost Range
1	$320,000 to $500,000	$130,000 to $160,000	$450,000 to $660,000
2	$800,000 to $1,100,000	$160,000 to $230,000	$960,000 to $1,330,000

Note:
1. Includes final design and construction engineering.