FINAL CONSTRUCTION REPORT
for
MACFARLANE DAM REHABILITATION PROJECT

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COLORADO DAM ID: 470202
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WATER DIVISION 6 – WATER DISTRICT 47
JACKSON COUNTY, COLORADO

Prepared for:

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Executive Summary

This report was prepared by W. W. Wheeler & Associates, Inc. (Wheeler) to document the construction of the MacFarlane Dam Rehabilitation Project and meet the final report requirements of the Colorado Division of Water Resources, Dam Safety Branch (SEO). MacFarlane Dam is a homogeneous embankment dam located south of the Arapaho National Wildlife Refuge in Jackson County, approximately 13 miles south of Walden, Colorado, in Section 29, Township 7 North, Range 79 West of the 6th Principal Meridian. MacFarlane Dam is owned and operated by the U.S. Fish and Wildlife Service (FWS) on land owned by the U.S. Department of Interior, Bureau of Land Management (BLM). Approximately half of the water rights in MacFarlane Reservoir are owned by Blaine and Judy Evans. The other half of the water rights are owned by the FWS, who has an agreement with the BLM allowing the BLM access to 30 percent of the FWS water rights. The dam is regulated by both the FWS Dam Safety Program and the SEO.

The objective of the Project was to address long-standing dam safety issues that included corrosion of the outlet works conduit; embankment seepage and stability concerns; and the lack of a cut-off in the spillway channel. Construction began at the spillway creating spillway berms and excavating for concrete cut-off control walls keyed into bedrock to protect against uncontrolled scour during major flood events. To facilitate embankment and outlet lining work MacFarlane Reservoir was drained and a temporary coffer dam and reservoir control system were installed. Embankment Work included constructing a new dual filter drainage system inside of stability berms on the downstream toe of both the Main Dam and the North Embankment. Outlet works construction included lining the existing 100-year-old steel outlet conduit with a new Cured-in-Place Pipe (CIPP) liner and rebuilding the outlet works terminal structure and the downstream plunge pool. A filter diaphragm was constructed around the downstream end of the outlet conduit to provide additional protection against piping potential failure modes. Construction elements also included installing dam instrumentation such as replacement piezometers and an air vent encasement wall to contain the air vent pipe as well as serve as the new reservoir grade beam.

Construction occurred between July 15, 2015 and November 28, 2017, with minor site work completed in May of 2018. The construction administrative services were authorized with Task Order No. F16PD0121 between the U.S. Fish & Wildlife Service (FWS) Colorado Division of Engineering Dam, Bridge, and Seismic Safety Branch, and Wheeler. Wheeler subcontracted to Kumar & Associates, Inc. (Kumar) to perform independent Government construction materials testing. Rocky Mountain Excavation (RME) was selected by the FWS as the construction contractor. RME hired C&L Water Solutions, Gordon Miller, and Guilder as the sub-contractors for the outlet lining, surveying and piezometer work, respectively.

This construction report documents that the Project was constructed in general conformance with the Specifications and Drawings that were approved by the Colorado SEO and the FWS. The report also includes representative construction photos, Change Orders, Record Drawings, construction materials testing data, a description of key stages of construction, a discussion of construction challenges, and Wheeler's key conclusions and recommendations.

MacFarlane Dam Rehabilitation Project
Final Construction Report

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1 Introduction

This is the final construction report for the MacFarlane Dam Rehabilitation Project. This report was prepared to meet Rule 10.2 of the Colorado Division of Water Resources, Dam Safety Branch (SEO) (CO DNR, 2007). MacFarlane Dam is owned and operated by the U.S. Fish & Wildlife Service (FWS) on land owned by the U.S. Department of Interior, Bureau of Land Management (BLM). Approximately half of the water rights in MacFarlane Reservoir are owned by Blaine and Judy Evans. The other half of the water rights are owned by the FWS. The BLM has an agreement with the FWS which grants the BLM access to 30 percent of the FWS water rights (15 percent of the total water rights in MacFarlane Reservoir). The dam is regulated by both the FWS Dam Safety Program and Colorado Office of the State Engineer, Dam Safety Branch. MacFarlane Dam is a homogeneous embankment dam located on Soap Creek south of the Arapaho National Wildlife Refuge (NWR) in Jackson County, approximately 13 miles south of Walden, Colorado. The dam is located on BLM land in Sections 29 & 30, T7N, R79W, 6th Principal Meridian. Construction took place between July 15, 2015 and November 28, 2017, with minor site work completed in May of 2018. As of May 22, 2018, the Project construction was considered to be complete.

1.1 Background

MacFarlane Dam was previously classified as a Low Hazard dam by the FWS, and a significant Hazard Dam by the State of Colorado, Division of Water Resources. A hazard classification re-evaluation was completed concurrently with the rehabilitation design to resolve the differences and conclude that MacFarlane Dam should be classified as a Low Hazard dam (Wheeler, 2016).

MacFarlane Dam was originally constructed around 1915 and reconstructed in 1962. The 1962 reconstruction extended the outlet works conduit, raised the dam crest by 1 foot, and added seepage cut-off collars every 20 feet along the outlet conduit and constructed a reinforced concrete terminal structure. MacFarlane Dam is 40 feet in height and includes two embankments, an approximately 600-foot-long North Embankment and an approximately 800-foot-long Main Dam. The appurtenant discharge structures include an emergency spillway and a low-level outlet. The reservoir is filled by Soap Creek as well as Howard Ditch. The dam impounds approximately 6,726 acre-feet (AF) of water that is used for irrigation purposes as well as providing waterfowl habitat to the FWS and the BLM. In 1975, a shallow slope failure occurred near the left abutment of the Main Dam and this area was repaired and a new toe drain was installed to address this issue. In 1980, the slide gate was replaced with a 36-inch-diameter sluice gate.

Discussions with Dana Miller, Colorado Division 6 Dam Safety Engineer, had indicated that the dam has had a long history of seepage and slope stability problems. The original steel outlet conduit was almost 100 years old and the CMP outlet conduit extension, installed in 1962, was more than 50 years old. A 2012 internal video inspection of the outlet works and toe drain system in the main dam indicated corrosion inside the outlet conduit and significant leakage at the upstream slide gate. The internal inspection video also showed the toe drains were locally blocked with root penetrations and other sediment and were not operating effectively. Additional Dam Safety issues documented in the 2014 Field Investigation Report (Wheeler, 2014) included wave erosion along the upstream slope of the North Embankment, inadequate seepage control in both embankments, localized slope instability in the downstream slope of both embankments, a severely deteriorated outlet works terminal structure, and lack of a cutoff in the spillway to prevent headwards erosion into the reservoir during significant spillway flows.

1.2 Objective and Scope of Work

The purpose of the MacFarlane Dam Rehabilitation Project is to improve the overall safety of the dam by addressing the current deficiencies, and thus eliminating potential concerns for future dam safety and storage restrictions. Key outlet works modifications that were intended to reduce potential failure modes along the outlet conduit and extend its service life included:

1. Lining the existing outlet conduit with a Cured-in-Place Pipe (CIPP) liner;
2. Construction of an air vent pipe that attached to the upstream inlet of the outlet conduit to prevent cavitation;
3. Modification of the existing deteriorated outlet works terminal structure;
4. Construction of a filter diaphragm at the downstream end of the outlet conduit; and
5. Construction of a new plunge pool energy dissipator.

Key embankment modifications that were intended to reduce potential failure modes along the Main Dam and North Embankment included:

1. Construction of stability berms along the downstream toe of the Main Dam and the North Embankment; and
2. Installation of a seepage collection system within the stability berms.

The stability berms were constructed to address the deficiencies in the slope stability and to control seepage. The seepage collection system constructed within the berms included a 6-inch-diameter slotted PVC pipe surrounded by a two-stage sand and gravel filter for the toe drain. The toe drain was then connected to a chimney drain which was installed along the interface of the excavated downstream slope of the embankments and within the stability berms. The toe drain and chimney drain extended beyond the stability berm and into the left and right abutments of the Main Dam and North Embankment.

Key spillway modifications addressed the lack of a cut-off wall which would prevent headwards erosion during large spillway discharges. Two concrete cut-off walls were constructed in the spillway to a depth of ten feet to eliminate the potential that the spillway could be eroded below the control section cut-off elevation. The spillway between the two cutoff walls was constructed to a slope of approximately 1 percent to ensure subcritical flow downstream of the structures. The spillway control crest was raised by about two feet to allow for the full reservoir storage as decreed by water rights. The 100-year storm was selected for the design of the reconstructed spillway based on the conclusion from the hazard classification that MacFarlane Dam is a Low Hazard dam (Wheeler, 2016). The 30-foot-wide spillway channel was designed to safely pass the aforementioned 100-year flood event, which satisfied the Colorado SEO and FWS spillway requirements for a Low Hazard dam.

1.3 Project Team

Key members of the project team involved in the construction of MacFarlane Dam included:

1. Steve Jamieson, P.E., Engineer-of-Record, W. W. Wheeler & Associates, Inc. (Wheeler)
2. John Treacy, P.E., Project Manager, Wheeler
3. Andrea Fasen, E.I., Project Engineer and Resident Engineer, Wheeler
4. Greg Monley, P.E., Geotechnical Engineer, Kumar & Associates, Inc. (Kumar)
5. Barrett Sullivan, Engineering Technician and Field Inspector, Kumar
6. Jeremy Franz, P.E., Design Review Engineer, Dam Safety Engineer, SEO
7. Dana Miller, P.E., Dam Safety Branch, Dam Safety Engineer, SEO
8. Lorri Harper, P.E. Regional Engineer, U.S. Fish and Wildlife Service, FWS
9. Jon Morse, Contracting Officer, U.S. Fish and Wildlife Service, FWS
10. Josh Roth, Arapahoe NWR Maintenance, U.S. Fish and Wildlife Service, FWS
11. Paula Belcher, U. S. Bureau of Land Management, BLM
12. Blaine and Judy Evans, Water Rights Owner, Evans Cattle Company
13. Johnathan Hernandez, Colorado Water Conservation Board (CWCB)

The construction contractor was Rocky Mountain Excavating, Inc. (RME). Key members of the RME construction management team included:

1. Jeremiah Kamp, Project Manager
2. Trent Burns, On-Site Project Manager/On-Site Supervisor
3. Sean Shelbourn, Division Manager/Cost Estimator

2 Description of Construction

The pre-construction meeting was held at the FWS Region 6 Office on June 29, 2017. Minor pre-construction work completed during the last two weeks of July 2017 included video inspection of the outlet conduit, piezometer abandonment, and arrival and initial installation of erosion control materials to the Site. Construction officially began on August 1, 2017 with the arrival of the RME crew. The majority of the construction was completed in the summer and fall of 2017. A punch-list of incomplete work items was developed during a visit by the SEO on November 1 detailing items to be completed prior to approval of winter shutdown.

Project clean-up was completed on November 20, 2017 and a substantial completion inspection of the project was held with representatives of RME, the Colorado SEO, and Wheeler on November 28, 2017. A final punch-list of incomplete work items was developed during the November 28, 2017 inspection. These punch-list items were completed in the spring of 2018 and a final completion inspection of the project was performed on May 22, 2018 with representatives from the SEO, Wheeler, RME and the FWS.

2.1 Construction Overview

Key components of the construction of the MacFarlane Dam Rehabilitation Project are summarized below and described in more detail in subsequent sections of this report. Key project components included:

1. Installation of erosion control;
2. Abandonment of two existing piezometers at the downstream toe of the Main Dam and North Embankment, respectively, prior to construction;
3. Excavation and earthwork for the spillway;
4. Installation of two reinforced concrete cutoff walls in the spillway discharge channel;
5. Installation of the temporary reservoir control system;
6. Removal of the old toe drain system in the Main Dam (where accessible without over-excavating into the embankment);
7. Construction of the toe drain and chimney drain seepage collection systems and stability berms in the Main Dam and North Embankment;
8. Installation of a Cured-in-Place Pipe (CIPP) liner in the outlet works conduit;
9. Installation of an HDPE transition pipe from the original riveted steel outlet works inlet to the CIPP liner;

10. Grouting of the annular space around the HDPE transition pipe and constructing a non-shrink grout transition from the original riveted steel inlet to create a smooth transition from the inlet to the HDPE transition pipe;
11. Installation of an air vent at the upstream outlet conduit inlet;
12. Construction of a reinforced concrete air vent encasement wall for the air vent which extended from the connection to the outlet conduit near the inlet, ran parallel to the gate operator, and terminated near the upstream crest of the main dam;
13. Installation of a grade beam in the form of a continuous angle iron embedded into the concrete air vent encasement wall starting from 8 feet above the outlet works inlet to the crest of the dam;
14. Demolition of the existing outlet works terminal structure wingwalls. The existing headwall and base remained intact and were incorporated into the new terminal structure;
15. Installation of a new reinforced concrete, outlet works terminal structure headwall downstream of the original headwall;
16. Installation of a filter diaphragm and filter diaphragm seepage collection system around the downstream end of the outlet works conduit and upstream of the new terminal structure headwall;
17. Installation of a corrugated metal pipe (CMP) extension that was encased in reinforced, backfill concrete from the terminus of the old CMP outlet to the new headwall;
18. Installation of a riprap lined plunge pool downstream of the outlet works terminal structure;
19. Installation of replacement piezometers, at the downstream toe of the Main Dam and North Embankment, respectively, in-line with the preserved existing piezometers at the dam crest;
20. Site reseeding; and
21. Repairs to the dam access road as required.

Representative construction photos are provided in Appendix A and leger-size copies of the Record Drawings are provided in Appendix B. The weekly construction activities are summarized below.

July 19 – 25, 2017:	Pre-construction Work included mobilizing equipment and erosion control materials to the Site. The BLM was on-site during the July 19 mobilization to discuss the wetland mitigation with RME and the FWS. RME installed erosion control BMP’s and obtained Embankment Fill samples from Borrow Area No. 2 for gradation testing.

Subcontractor work was completed by C&L Water Solutions (C&L) and Golder Associates. This included an internal video inspection of the existing outlet works conduit by C&L and abandoning the two existing downstream piezometers by Golder Associates.

August 1 – 5, 2017: RME continued construction set-up. RME began clearing and grubbing the Spillway, which included stockpiling the excavated soils in the Staging and Stockpile Area. RME processed Embankment Fill from Borrow Area No. 2. RME started Work on the Spillway, which included proof-rolling the foundation with the loader and placing subsequent lifts of Embankment Fill to build the left and right Spillway berms.

RME began intermittent reservoir draining by using the existing control gate and outlet works to release water into the downstream channel. Blaine Evans was also operating the gate as required to deliver water for his livestock needs.

August 6 – 12, 2017: RME continued work on constructing the left and right berms in the downstream half of the Spillway, which included foundation preparation, Embankment Fill placement and compaction. Embankment lifts were tested for moisture and compaction by Kumar. The Spillway berms were over-built for constructability and following completion of the Embankment lifts will be shaped to the final grade.

Regularly developing afternoon thunderstorms would occasionally cause a temporary construction safety stand-down due to lightning.

August 13 – 19, 2017: RME excavated both Spillway cutoff walls at ES Stations 2+20 and 5+20 with an excavation approximately 10 feet deep which penetrated approximately 2 feet into the claystone bedrock. On August 15, 2017, Steve Jamieson (Wheeler) and Jeremy Franz (SEO) were on-site on to inspect the spillway cutoff wall foundations and determined the spillway cutoff walls were adequately excavated into bedrock. Water was constantly seeping into the foundation of the downstream spillway cutoff wall to a depth of a few inches

RME constructed forms and installed the reinforcement steel for the upstream spillway cutoff wall. On Friday August 18, RME began placement of concrete in the upstream Spillway cutoff wall at ES Sta. 2+20. During the placement, the forms buckled and blew out in several locations. John Treacy terminated the placement after approximately 10 cubic yards of concrete were placed in the lower half of the cutoff wall. The remaining concrete was placed in the foundation of the downstream Spillway cutoff wall at ES Sta. 5+20 as a mud-mat in the foundation.

August 20 – 26, 2017: RME decided to mobilize an additional concrete crew to complete the remaining spillway concrete work at MacFarlane Dam, including the upper half of the Spillway cutoff wall at ES Sta. 2+20 which was unfinished from last week.

RME excavated the access road through the Spillway and continued to excavate and shape the Spillway berms. RME began clearing and grubbing the downstream toe of the Main Dam embankment in preparation for the toe drain installation. RME also started receiving deliveries of Type A Filter Sand and Type B Gravel Drain material which was stockpiled on-site in Borrow Area No. 2.

August 27 – September 2, 2017: RME began Work on the seepage collection system of the Main Dam. RME excavated in the downstream toe of the Main Dam embankment starting at Main Toe Drain (MTD) Station 2+60. The existing toe drain was removed as it was encountered.

Jeremy Franz (SEO) and Steve Jamieson (Wheeler) were on-site on Tuesday August 29, 2017 to observe the means and methods for installation of the chimney drain. Jeremy observed the exposed chimney drain foundation, the placement and compaction of the Type A Filter Sand, and the excavation into the Type A Filter Sand for the installation of the Type B Gravel Drain and slotted toe drain pipe. RME elected to overbuild the width of the Type A Filter Sand component of the seepage collection system so they could compact the Type A Filter Sand with a smooth drum roller. RME excavated for the chimney drain and filled it with Type A Filter Sand from MTD Station 2+60 to 4+00. RME started the next section of toe drain excavation from MTD Sta. 4+00 to 4+30.

September 3 – 9, 2017: RME continued Work on the seepage collection system of the Main Dam which included the following:

- Placement and Compaction of the Type A Filter Sand layer for the new toe drain from MTD Sta. 4+00 to 5+09 on the right side of the outlet works and from MTD Sta. 1+50 to 2+50 on the left side of the outlet works.

- Removal of the existing toe drain as it was exposed during excavation for the seepage collection system. Occasionally, water which was trapped in the old seepage collection system was released creating saturated foundation conditions which were mitigated as required.
- Placement of the Type B Gravel Drain and slotted drain pipe for the toe drain from MTD Sta. 2+55 to 5+09 which required excavation into the compacted Type A Filter Sand and subsequent covering of the slotted drain pipe by one foot of Type B Gravel Drain.
- Placement of the Type A Filter Sand for the top half of the toe drain from MTD Sta. 3+00 to 5+00 which covered the Type B Gravel Drain from approximate MTD Sta. 2+75 to 2+85.

A second front end loader was brought to the site on September 7 which allowed RME to begin concurrent work on the Main Dam seepage collection system, Main Dam stability berm, and start work on the North Embankment.

RME began work on the North Embankment. Because the seepage collection system was located above the existing ground surface, excavation into the existing embankment toe was not required. RME elected to build the Stability Berm to the approximate top of sand elevation for the toe drain with lifts of Embankment Fill. RME would then excavate into the Stability Berm to place the two-stage filter and drainage pipe for the chimney drain. RME prepared the foundation and began subsequent lifts of Embankment Fill for the Stability Berm.

RME began work on the Main Dam Stability Berm and chimney drain from MTD Sta. 3+00 to 4+70. Kumar was on-site to test the Stability Berm lifts at both the North Embankment and right side of the Main Dam for moisture and compaction.

September 10 – 16, 2017: RME encountered a rapidly rising layer of sandstone/claystone bedrock in the left abutment of the Main Dam at approximate MTD Station 0+40. Dana Miller (SEO) (who was on-site on Wednesday September 13 for a construction site visit), conversed via phone and e-mail with Greg Monley (Kumar) and Steve Jamieson (Wheeler) and agreed on the following:

- Excavation further to the left abutment and bedrock layer was not necessary for the seepage collection system
- The Main Dam toe drain located between MTD Sta. 0+00 and 0+50 would no longer be constructed. In place of the toe drain, a Type A Filter finger drain, 3-feet-wide and 2-feet-thick, would be constructed along the top of the current excavation from MTD Sta. 0+00 to 0+45.
- The chimney drain would terminate with the cleanout located at approximate MTD Sta. 0+45.

RME continued Work on the seepage collection system of the Main Dam which included the following:

- Placement and Compaction of the Type A Filter Sand layer for the new toe drain from MTD Sta. 0+40 to 1+75 on the left side of the outlet works. This work completed the Type A Filter Sand layer of the chimney drain base on the Main Dam.
- Removal of the existing toe drain as it was exposed during excavation for the seepage collection system.
- Placement of the Type B Gravel Drain and slotted drain pipe to the left of the outlet works from MTD Sta. 0+44 to 2+40 which required excavation into the compacted Type A Filter Sand and subsequent covering of the slotted drain pipe by one foot of Type B Gravel Drain.
- Installation of the Main Dam, right and left toe drain cleanout.

RME finished building the bottom of the Stability Berm and began work on the North Embankment seepage collection system which included the following:

- Excavation into the Stability Berm to create a trench for the two-stage filter and slotted drain pipe.
- Placement and Compaction of the Type A Filter Sand layer for the new toe drain from North Toe Drain (NTD) Sta. 0+00 to 0+20.

RME continued work on the Stability Berm and Chimney Drain along the right side of the Main Dam from MTD Sta. 3+00 to 4+50. RME began to have difficulty achieving compaction and moisture requirements in the Main Dam Stability Berm Embankment lifts with soils from Borrow Area No. 2. A possible change in material was theorized and additional Embankment Fill samples were obtained by Kumar. In the interim, RME used Embankment Fill from Borrow Area No. 1. RME began work on the Stability Berm and Chimney Drain along the embankment along the left side of the Main Dam from MTD Sta. 0+50 to 2+00.

RME received the delivery of the 20-inch-diameter HDPE liner pipe.

September 17 – 23, 2017: RME continued work on the North Embankment seepage collection system which included the following:

- Excavation into the Stability Berm to create a trench for the two-stage filter and slotted drain pipe.
- Placement and Compaction of the Type A Filter Sand layer for the new toe drain from North Toe Drain (NTD) Sta. 0+00 to 3+25.
- Excavation into the Type A Filter Sand layer for the placement of the Type B Gravel Drain and slotted drain pipe began near NTD Sta. 1+50 to 1+90 and subsequent covering of the slotted drain pipe by one foot of Type B Gravel Drain.

On Tuesday September 19, RME began constructing an access road for the Coffer Dam that was located upstream of the outlet works inlet. On Wednesday September 20, RME began construction of the Coffer Dam and installation of the two reservoir dewatering pumps.

An additional concrete crew arrived on September 20 to complete the suspended work on the upstream spillway cutoff wall and begin work on the downstream spillway cutoff wall. At the upstream spillway cutoff wall, the concrete crew completed repairs to the reinforcing steel as required and installed new formwork. At the downstream spillway cutoff wall, the concrete crew started installing the reinforcing steel and formwork.

RME continued work on the Stability Berm and Chimney Drain along the embankment along the left side of the Main Dam from MTD Sta. 0+00 to 2+00. RME also started the finger drain on top of the exposed bedrock layer from MTD Sta. 0+00 to 0+50. RME reached the maximum, 5-foot-tall height of the Stability Berm limit from MTD Sta. 0+00 to 2+00 where by the Approved Specifications RME needed to complete an internal video inspection of the toe drain before placing additional lifts. RME also completed lifts for the Stability Berm and

Chimney Drain along the embankment along the right side of the Main Dam from MTD Sta. 2+85 to 4+00.

September 24 – 30, 2017: RME continued work on the North Embankment seepage collection system which consisted of the following:

- Excavation into the Type A Filter Sand layer for the placement of the Type B Gravel Drain and slotted drain pipe continued from NTD Sta. 0+60 to 1+50.
- Covering of the slotted drain pipe with one foot of Type B Gravel Drain.
- Excavation of the North Dam Stability Berm Foundation for the placement of the Type A Filter Sand from approximate NTD Sta. 3+00 to 4+00.

RME continued work on the Stability Berm and Chimney Drain along the right side of the Main Dam from MTD Sta. 2+75 to 5+00. Once again, RME began to have difficulty achieving compaction and moisture requirements in the Main Dam Stability Berm Embankment Lifts from Borrow Area No. 2. It was observed that RME was pulling Embankment Fill directly from the native ground instead of a blended stockpile resulting in too much soil variability throughout a single lift. Additional Embankment Fill samples were obtained by Kumar and RME discontinued the use of Borrow Area No. 2.

The RME concrete crew completed the reinforcing steel installation and formwork in the downstream spillway cutoff wall and on Wednesday September 27 placed approximately 37 cubic yards of concrete in the upstream and downstream spillway cutoff walls. The concrete forms were stripped the following day and the RME concrete crew left the site.

Due to the presence of the coffer dam, RME routinely ran the reservoir dewatering pumps through the evening hours to keep the reservoir water surface low enough. Daily operation of the reservoir dewatering pumps was limited because the discharge lines, which ran over the dam crest, prevented the movement of equipment and material across the right side of the Main Dam.

C&L Water Solutions (C&L) arrived on-site September 25 and began welding the HDPE liner pipe and preparing a test pull section of the

HDPE liner pipe. The grout tubes and centralizers were installed on the test pull section of the HDPE pipe.

On September 27, an on-site, pre-grouting meeting was conducted and attended by John Treacy, Steve Jamieson and Andrea Fasen of Wheeler; Lorri Harper, Jon Morse, and Josh Roth of the FWS; Trent Burns and Jeremiah Kamp of RME; Dana Miller from the SEO; and C&L. The pre-grouting meeting discussed the HDPE slip-lining sequence, fusing the pipe, completing the test pull through the host pipe, and grouting the annular space.

On September 28 Snowbridge Inc. (Snowbridge) completed a power jetting of the outlet conduit and post-cleaning internal outlet works video inspection. Snowbridge also performed an internal video inspection of the installed left and right Main Dam seepage toe drain pipes.

On September 29, C&L started the initial test pull with a 20-foot-long, HDPE pipe test section that included the three gout tubes and centralizers spaced at the start, middle, and end of the test section. The initial test pull was terminated because one of the grout tubes and several centralizers had become dislodged, and the test section was stuck on something within the first ten feet of host pipe. The second and final test pull test section included no centralizers or grout tubes and was approximately 85 to 90 feet into the original outlet works conduit, as measured from the downstream end, when the test section became stuck within the host pipe. Based on the outlet conduit video, the material change between the corrugated metal pipe on the downstream section of the host pipe and the riveted steel on the upstream section of the host pipe is located in the area where the test section of HDPE pipe became stuck. The internal video documented that at this transition, there was a previously undetected vertical deformation of the outlet conduit. C&L terminated the test pull and removed the test pull pipe section from the outlet.

RME began backfilling around the upstream Spillway cutoff wall.

October 1 – 7, 2017: On-site construction was temporarily suspended from Monday, October 2 through Monday October 9 due to a snow storm which began on Sunday October 1 and left approximately 9 inches of snow on-site. During this week, the coffer dam overtopped due to rising reservoir levels from the snow storm. A second snow storm left approximately 3 to 4 inches of snow on-site on Sunday October 8 into Monday, October 9. The only on-site Work completed during the week was clearing of snow and re-construction of the coffer dam once site access was re-established. The new coffer dam was built to an approximate elevation of 8294.0 feet.

During the week, the challenge associated with the 20-inch-diameter HDPE liner pipe not fitting within the host pipe was discussed with Wheeler, the SEO, the FWS, C&L, and RME. C&L initiated the process to order a CIPP liner and began providing documentation for a Change Order to use an ultra-violet cured CIPP liner instead of the HDPE liner.

October 8 – 14, 2017: RME continued work on the North Embankment seepage collection system which consisted of the following:

- Excavation into the Type A Filter Sand layer for the placement of the Type B Gravel Drain and slotted drain pipe continued from NTD Sta. 0+00 to 0+60, which completed the installation of the slotted drain pipe from the left toe drain cleanout to the location of the toe drain discharge pipe at NTD Sta.1+80.
- Installation of the North Embankment, left toe drain cleanout at NTD Sta. 0+00.
- Covering of the slotted drain pipe with one foot of Type B Gravel Drain.
- Excavation of the North Dam Stability Berm Foundation for the placement of the Type A Filter Sand from approximate NTD Sta. 4+00 to 5+09 until RME ran out of stockpiled Type A Filter Sand.
- Installation of the “T-joint” for the toe drain discharge at NTD Sta. 1+80.
- Excavation into the Type A Filter Sand layer for the placement of the Type B Gravel Drain and slotted drain pipe began on the right side of the discharge location from NTD Sta. 1+80 to 2+08.

RME continued work on the Stability Berm and Chimney Drain along the right side of the Main Dam from MTD Sta. 3+00 to 5+00. Embankment Fill from Borrow Area No. 1 was used.

RME continued backfilling around the upstream and downstream spillway cutoff walls.

An on-site meeting occurred between Steve Jamieson, John Treacy and Andrea Fasen of Wheeler, and Tracy Stenger and Christopher Larson of C&L on October 10. Steve Jamieson attempted to enter the host pipe to measure the dimension of the pipe deformation at the material transition to try and determine the source of the snag with the 20-inch-diameter HDPE pipe, but after the coffer dam was overtopped during the snow storm, water flowed through the outlet conduit and now had collected in the low areas of the host pipe, which prevented access. The use of the originally designed, 20-inch-diameter HDPE slip-lined pipe was abandoned at this time.

October 15 – 21, 2017: RME continued work on the North Embankment seepage collection system which consisted of the following:

- Excavation into the Type A Filter Sand layer for the placement of the Type B Gravel Drain and slotted drain pipe continued on the right side of the discharge location from NTD Sta. 2+08 to 5+09, which was the location of the right toe drain cleanout.
- Covering of the slotted drain pipe by one foot of Type B Gravel Drain continuing from where RME left off on October 14 at NTD Sta. 2+08 up to NTD Sta. 5+09 at the right toe drain cleanout.
- Cover and compact with a plate compactor the Type B Gravel Drain from NTD Sta. 1+80 to 3+30 and 4+50 to 5+00 with the excavated Type A Filter Sand for the top sand layer of the two-stage filter.
- Installed the right toe drain cleanout.

RME continued work on the Stability Berm and Chimney Drain along the embankment on the left side of the Main Dam from MTD Sta. 0+50 to 2+25 and the right side of the Main Dam from MTD Sta. 3+25 to 5+00. Embankment Fill from Borrow Area No. 1 was used.

RME began work on the new outlet works terminal structure, which included the following:

- Created a temporary work platform in the outlet works plunge pool for the excavator.

- Removed the existing outlet structure wing walls and excavated to the left and right of the existing outlet structure for the concrete footers and filter diaphragm.
- An additional RME concrete crew was on-site to complete the concrete work for the outlet works terminal structure. The concrete crew completed the terminal structure footings, which included tying reinforcing steel and a bank placement of concrete. The concrete crew then initiated work on the new terminal structure headwall, which included tying the reinforcing steel and partial installation of the headwall forms.

On October 20, C&L was on-site to cut and load the 20-inch-diameter HDPE pipe for transportation from the site.

RME continued backfilling around the upstream and downstream spillway cutoff walls and shaping and scarifying the Spillway berms to prepare for eventual reseeding.

RME started work on the Air Vent Encasement Wall which included excavating parallel to the outlet works gate operator along the upstream slope of the Main Dam embankment.

Snow fell on-site on October 21 canceling work for the day.

October 22 – 28, 2017: RME continued work on the Main Dam Stability Berm which included the following:

- Completion of the Chimney Drain on the left and partial completion of the Chimney Drain on the right side of the outlet structure from MTD Sta. 0+50 to 2+25 and MTD Sta. 3+50 to 4+60, respectively.
- Continued work on lifts of Embankment Fill for the top of the Stability Berm.
- At this time the Chimney Drain and Stability Berm behind the outlet works terminal structure headwall from MTD Sta. 2+60 to 3+50 was not constructed and was now several feet below the top of the Stability Berm that was being completed on either side.
- Shaping from MTD Sta. 3+50 to 5+10.

RME continued work on the new outlet works terminal structure which included the following:

- Placing concrete in the new terminal structure headwall.
- Tying reinforcing steel and adding forms for the concrete encasement section located between the new terminal structure headwall and the old headwall.

RME also continued work on the Air Vent Encasement Wall on the upstream slope of the Main Dam. RME cut the air vent hole in the top of the original riveted steel outlet works conduit just upstream of where the sluice gate was in the fully open position. The air vent pipe connection was made to the original outlet works conduit and concrete was placed in the anchor section of the Air Vent Encasement Wall. The anchor section is the horizontal section from the original outlet conduit to the upstream end of the Air vent Encasement Wall. After the concrete was placed in the horizontal anchor section of the wall, RME tied the remaining reinforcing steel, installed the air vent pipe and completed concrete forms for the entire length of the wall.

Additional site work included working stockpiled material back into the slopes of the Staging and Stockpile Area.

Snowbridge re-jetted the outlet conduit on October 27 to prepare it for the CIPP lining scheduled for next week.

October 29 – November 4, 2017:

Andrea Fasen and John Treacy (Wheeler), along with Dana Miller and Jeremy Franz (SEO) completed a project-wide walk through on November 1 to create two work punch lists. The first list addressed items which needed to be completed prior to refilling the reservoir and the second list indicated what could tentatively be completed in 2018 if a winter shutdown was required.

RME continued work on the Main Dam Stability Berm which included:

- Continued work on the upper two-feet of Stability Berm from MTD Sta. 3+50 to 5+10.
- Started work on the Chimney Drain and Stability Berm behind the new outlet works terminal structure headwall from MTD Sta. 2+60 to 3+50 to bring it up to the surrounding Stability Berm on either side. The Work included removal of contamination in the Chimney Drain layer which was had been

exposed for several weeks while work was completed in the terminal structure.

RME continued work on the North Embankment seepage collection and Stability which Berm included:

- Installing the toe drain outfall at NTD Sta. 1+80.
- Finishing the placement of the Type A Filter Sand for the Chimney Drain, where required near approximate NTD Sta. 3+00 to 4+50, and placing the top two feet of Stability Berm from NTD Sta. 3+00 to 5+00.
- Finishing the two-stage seepage filter from NTD Sta. 0+50 to 1+80 and beginning Embankment Fill placement for the Stability Berm.

RME continued work at the outlet works terminal structure which included the following:

- Placing concrete for the concrete encasement section located between the new headwall and the old headwall around the CMP outlet liner extension.
- Install the Type A Filter Sand Filter Diaphragm around the outlet conduit.
- Backfilling around the new terminal structure headwall to complete the Stability Berm in this area.

RME completed the concrete placement for the Air Vent Encasement Wall.

C&L installed the CIPP outlet conduit liner on November 1. C&L removed the upper portion of the of the CIPP liner in the outlet conduit inlet transition area on November 2 and the majority of the C&L equipment was demobilized on this day. Two C&L crew members returned on November 3 to install the HDPE inlet section and downstream bulkhead between the CIPP liner and the downstream end of the HDPE extension.

At the upstream inlet transition from the original, flared riveted steel pipe inlet to the HDPE extension from the CIPP liner, RME installed the upstream bulkhead for the HDPE extension and partially grouted the annular space. RME also installed a hand-placed non-shrink grout apron in the host pipe between the upstream bulkhead and the upstream end of the inlet. Following completion of the inlet transition section, RME installed approximately 3 cubic yards of backfill concrete around the intake structure to provide some additional shoring to the inlet and to stabilize the inlet area.

November 5 – 11, 2017: RME was continuing to backfill behind the outlet works terminal structure headwall with Embankment Fill. On November 7, John Treacy inspected the grout installation inside the intake structure of the outlet pipe. RME hand placed non-shrink grout inside of the steel inlet pipe to create a smooth transition to the HDPE inlet.

On November 8, the SEO approved the request to begin a temporary reservoir fill at MacFarlane Dam. RME removed the coffer dam and the FWS started storing water in the reservoir on November 9.

Final compaction testing was completed on the North Embankment and Main Dam Stability Berms on November 9 by Kumar. The tested lifts passed compaction testing. RME completed final slope shaping and clean-up.

November 12 – 18, 2017: RME had one staff member on-site cleaning the site prior to the winter shut down.

November 19 – 25, 2017: No work was completed during this week due to snowy conditions and Thanksgiving.

November 26 – Dec 1, 2017: On November 28, a final walk-through was completed prior to the winter shut down. Dana Miller from the SEO and John Treacy of Wheeler performed the winter-shutdown inspection. From this inspection, a final completion punch list was developed that was scheduled for completion in May of 2018 by RME.

May 14 – May 22, 2018: RME mobilized to the site to complete the punch list items from the November 28 final walk-through. This work included reworking and lowering the plunge pool riprap, grading the transition between the stability berms and the existing dam slope, reworking the riprap around the air vent encasement wall, and re-vegetation of the site. Josh Roth, with the FWS, was also on-site repairing the wave erosion area in the riprap along the upstream slope of the North Embankment. Dana Miller from the SEO and John Treacy of Wheeler performed the final inspection of the Project on May 22, 2018.

3 Construction Challenges

Some of the noteworthy construction challenges and the resolution of those challenges are described in the following paragraphs.

3.1 Construction Season

Due to sensitive wildlife on the Refuge, construction could not begin until mid-summer. Construction officially began on July 17, 2017. Winter weather conditions including snow and ice began as early as October 1 and persisted throughout the remaining construction season causing delays and less favorable working conditions.

3.2 Construction Access at Refuge

Wetlands at the downstream toe of the Main Dam and North Embankment greatly reduced the contractor's access with construction equipment, especially at the North Embankment where the only path for construction machinery was along the footprint of the Stability Berm. Restricted access coupled with the equipment that was used to complete the work increased the difficulty of installing the two-stage toe drain and seepage collection piping and resulted in slow work. This work had to be watched carefully to ensure that the filter and drain materials did not become contaminated during placement.

3.3 Precipitation Events

Summer thunderstorms regularly developed in the afternoons in August and September that would occasionally force a safety stand-down during construction. Conversely, there were also periods of very dry and windy weather that started to influence the moisture content in lifts of Embankment Fill. A single lift could take hours to place, and even if the stockpile was moisture conditioned before placement, by the time compaction occurred in the lift, additional moisture was required for compaction. The first measurable snowfall at MacFarlane Dam occurred on October 1 and was quickly followed by a second snow storm on October 8. Both snow storms caused a construction shutdown that lasted for a total of 10 days and overtopped the coffer dam. The coffer dam had to be rebuilt, the outlet conduit had to be re-jetted prior to the lining operations, and site access was impaired for several days following the final snow storm. As construction continued through October and into November, freezing temperatures and winter weather persisted and began to effect Embankment Fill operations and the later concrete placements. This challenge was addressed by placing insulating cover lifts over the fill operations at night and doing earthwork later in the day during periods of warmer temperatures. During colder periods, concrete placements were protected with concrete blankets for several days after the placement.

3.4 On-Site Embankment Fill Borrow Material and Processing

The Embankment Fill excavated from the on-site borrow areas began to change, especially during the latter half of construction, which resulted in new proctor curves for compaction testing. Inconsistencies in the Embankment Fill ultimately led to several failed compaction tests, which then meant the failed lift had to be scarified, re-moisture conditioned and re-compacted, or removed altogether. Additionally, the processing of Embankment Fill was not consistent throughout construction. Sometimes the Embankment Fill was processed, moisture conditioned and stockpiled in the borrow area, other times the Embankment Fill was directly excavated from the borrow area and placed in a loose lift and moisture conditioned in-place. Failed compaction testing ultimately slowed down the earthwork process and required the reworking of several lifts of Embankment Fill so that the fill was placed in accordance with the Approved Specifications.

3.5 Availability of Type A Filter Sand

Part way through construction for a period of a several weeks, the supplier had a limited supply of Type A Filter Sand. Deliveries were either insufficient to meet the construction demand or halted all together. The lack of Type A Filter Sand complicated work on the seepage collection system for the Main Dam and North Embankment during these periods and forced RME to complete other tasks on-site.

3.6 Removal of Old Toe Drain

The old toe drain in the Main Embankment was removed as it was encountered during the excavation for the new seepage collection system. The presence of the old toe drain however, was the source of a few challenges during construction. First, the ineffective toe drain meant saturated conditions were present along areas of the old drain line. Additionally, water that was trapped in the old seepage collection system would be released upon exhuming the old pipe which would further saturate the foundation and require additional work by RME to dry the foundation for equipment access and the foundation of the new seepage collection system. In isolated areas, removal of the old drain line required over-excavation beyond what was required for the installation of the new seepage collection system. At MTD Sta. 1+70, the old seepage collection system disappeared into the upstream side of the current excavation and into the Main Dam embankment. Rather than excavate further into the embankment, Wheeler decided to use the Approved finger drain detail shown on Sheet No. 13 of the Record Drawings to collect and filter seepage from the old drain system.

3.7 Bedrock in the Main Dam Left Abutment

A rapidly rising layer of sandstone/claystone bedrock was encountered near MTD Sta. 0+35 which slowed down excavation for the last 35 feet of the seepage collection system in the Main Dam and was wearing down the teeth on the excavator. After discussing the issue with Dana Miller (SEO), Greg Monley (Kumar), John Treacy and Steve Jamieson (Wheeler), it was decided that further excavation into bedrock was not necessary for the seepage collection system. The conclusion was to classify the modification as a field fit where the Main Dam left toe drain would no longer be constructed between MTD Sta. 0+00 and 0+49, and the Chimney Drain would terminate with the cleanout located to approximate MTD Sta. 0+45. In place of the toe drain, a Type A Filter Sand finger drain, 3-feet-wide and 2-feet-thick, was constructed along the top of the current excavation from MTD Sta. 0+00 to 0+45, which represents the approximate start of the bedrock layer. The Chimney drain was then covered with the Embankment Fill to the existing grade elevation.

3.8 Outlet Conduit Host Pipe Constriction

During the test pull of the HDPE liner pipe through the existing outlet conduit on September 29, it quickly became apparent that the centralizers and grout tubes did not fit into the host pipe strapped to the HDPE liner. The first test pull was abandoned before the test section was fully pulled into the host pipe because the centralizers and grout tubes had become detached. The test section was stripped of all centralizers and grout tubes for a second test pull where the objective was to first ensure that the HDPE liner could be pulled through the entirety of the host pipe with nothing attached. The HDPE test section had been pulled approximately 85 to 90 feet into the host pipe from the downstream end, before being stuck on something within the pipe. As C&L increased the wench tension pulling the test section from the upstream side of the host pipe, the wench which was anchored to one of the trench boxes in the coffer dam, was beginning to pull out the trench box and slide along the top of the coffer dam against the footers of the wench trailer. The C&L operator indicated that even if the wench could be more securely anchored, he would not want to increase the tension in the line past the current pull of approximately 3 tons, 1300 psi according to the gage indicator.

According to the outlet conduit internal inspection video, there was a significant vertical deflection in the pipe material connection between the corrugated metal downstream pipe section and the riveted steel pipe in the original outlet works conduit. This is the location where the test section of HDPE pipe became stuck. After several conference calls between Trent Burns and Jeremiah Kamp (RME); Tracy Stenger and Christopher Larson (C&L); Lorri Harper and Jon Morse (FWS); Dana Miller (SEO); and Steve Jamieson, John Treacy and Andrea Fasen (Wheeler); and a follow-up site visit on October 10, the eventual conclusion was that the HDPE liner pipe would not fit within the host pipe and an alternative needed to be considered. C&L encouraged the use of an ultraviolet cured CIPP liner as the most time and cost efficient alternative and began the process of ordering the CIPP liner. Wheeler documented a formal Design Change Order with the SEO. Due to manufacturer lead time, the requirement of a Change Order, and how much time had elapsed in construction already, the abandonment of the HDPE liner was a significant schedule setback for the Project. Additional information on this Change Order is provided in Section 4.2 of this report.

3.9 Outlet Works Inlet and Air Vent Connection

The inlet configuration of the original outlet works pipe and air vent connection presented a multifaceted construction challenge. First, the opening of the outlet conduit measured 36 inches in diameter, but over the length of approximately 16 feet the inlet gradually reduced to 24 inches in diameter. There was also an approximately 45-degree upward bend in the inlet pipe to accommodate the sluice gate.

The original design for the 20-inch-diameter HDPE liner was to have a pre-fabricated, 45-degree steel elbow be the only final transition from the 20-inch-diameter HDPE liner to the angled inlet control gate. The pre-fabricated elbow was sized to fit within the HDPE pipe. The steel elbow was ordered in late September and delivered in mid-October, prior to Change Order Number 2 (CO#2) that changed the liner to a CIPP liner.

Due to concerns about the integrity of the CIPP liner with an unprotected leading edge, a better transition from the upstream end of the CIPP liner to the inlet gate was required. Ultimately, Wheeler developed a construction detail that included a section of the 20-inch-diameter HDPE liner that was inserted into the CIPP liner to protect the leading edge of the CIPP. Upstream and downstream bulkheads were constructed around the outside of the HDPE pipe, and the HDPE pipe section was grouted in-place between the bulkheads as shown on the Record Drawings.

The final issue was how to accommodate the air vent connection with the HDPE inlet section. The final configuration of the outlet works consists of the original 36-inch diameter steel inlet and flared section that was encased in concrete. The original steel pipe was unlined from the entrance to the start of the 20-inch HDPE liner (approximately 9 feet downstream of the inlet) was coated with non-shrink grout. The original steel pipe transitioned from 36-inch diameter to 24-inch diameter approximately 12 feet into the inlet and remained the 24-inch diameter steel pipe for approximately 155 feet before changing to a 24-inch diameter CMP pipe. The 24-inch diameter CMP was approximately 85 feet long. This 24-inch diameter CMP was extended with an additional 10-foot section as part of this project. A new 24-inch diameter CIPP liner was installed from the downstream outlet to the air vent and is approximately 250 feet long. An insignia seal was installed between the 24-inch diameter steel pipe and the 24-inch diameter CIPP pipe approximately 11 feet downstream of the air vent just beyond the HDPE transition section. The air vent was installed into the existing steel pipe approximately 8 feet downstream of the inlet entrance. The 9-foot long, 20-inch diameter HDPE transition section of pipe was installed just downstream of the air vent and into the 24-inch diameter CIPP. Bulkheads were installed at both ends of the HDPE transition section and the annular space was grouted.

4 Construction Changes

Key changes to the Colorado SEO Approved Drawings and Specifications are described below. Each of these changes was discussed with both the Colorado SEO prior to implementation. Both changes were formally submitted as Change Orders and approved by the Colorado SEO. The SEO Change Orders are documented in Appendix D.

4.1 HDPE Outlet Conduit Liner Diameter Change (SEO CO #1)

The request for a change in the Standard Dimension Ratio (SDR) of the HDPE pipe liner from SDR 15.5 to SDR 17 was requested by RME because the 20-inch-diameter SDR 17 HDPE was a more readily available pipe and obtaining the pipe could be accommodated during the short construction schedule. Changing to SDR 17 increased the inside pipe diameter from 17.265 to 17.506 inches but did not change the outlet discharge capacity and still satisfied design load calculations. Ultimately, however, this pipe was not used to line the host pipe due to SEO CO #2. An alternative to ordering a custom staff gage was also proposed where the staff gage numbers would be installed as number plates or welded to the angle iron installed into the Air Vent Encasement Wall in conjunction with a survey to determine the elevations.

4.2 Change to a CIPP Outlet Conduit Liner (SEO CO #2)

During the unsuccessful test pull of the 20-inch-diameter HDPE section, a constriction in the host pipe prevented the passing of the 20-inch-diameter HDPE test section and another outlet works conduit liner solution was required. Due to a limited 2017 construction schedule and the lead time for purchasing smaller, 18-inch-diameter HDPE pipe, the Contractor requested to change the liner from HDPE to a 24-inch-diameter CIPP liner. The 24-inch diameter CIPP liner was a more readily available product that could be installed quickly and not significantly impact the construction schedule. Calculations provided by the contractor indicated that the CIPP liner could withstand the anticipated design loads as documented in Appendix D-2.

5 Construction Observation and Testing

5.1 Concrete Testing

Concrete slump, air content, density, temperature, and compressive strength tests were performed by Kumar for the following concrete structures:

- New outlet works terminal structure;
- Air vent encasement wall; and
- Upstream and downstream spillway cutoff walls

The concrete test results are summarized in Appendix C-1. These test results document the concrete placed was in general conformance with the specifications and exceeded the specified 28-day compressive strength for structural concrete of 4,500 pounds per square inch (psi).

5.2 Earthwork Testing

Earthwork tests were completed to evaluate suitability of the Embankment Fill, Type A Filter Sand, and Type B Gravel Drain with respect to the Approved Specifications. The following earthwork tests were performed by Kumar:

- Gradation testing for Type A Filter Sand, Type B Gravel Drain and Embankment Fill;
- Compaction testing-proctor curves for Embankment Fill and Type A Filter Sand; and
- Field density and moisture content tests of the Embankment Fill and Type A Filter Sand.

The field density and moisture content test results are provided in Appendix C-3. Gradation test results are provided in Appendix C-2. The earthwork testing documented that the earthwork met the requirements of the Approved Specifications.

5.3 Interior Video Inspections

Interior video inspections of the completed outlet conduit and the toe drain pipes are provided in Appendix E. The Main Dam toe drain pipes were video inspected on September 28, 2017 and the North Embankment toe drain pipes were video inspected on November 21, 2017. An interior video inspection of the CIPP Liner was video inspected on November 2, 2017 to document the as-built condition of the liner. Before and after videos of the outlet conduit are also provided in Appendix E.

6 Reservoir Fill and Monitoring Plan

Wheeler's proposed initial fill and long-term observation and monitoring plan is summarized in Table No. 1 below. The initial fill plan includes weekly readings of the piezometers, toe drain discharge pipes, and reservoir staff gage as well as visual monitoring of the Main Dam and North Embankment. The initial fill period is recommended to extend through the end of November 2018. If the instrumentation indicates satisfactory performance after the initial fill period, the long-term monitoring plan can commence, which would include monthly monitoring.

TABLE 1: Recommended MacFarlane Dam Observation and Monitoring Plan

Instrument	Initial Filling	Long-Term Monitoring
Reservoir Staff Gage	Weekly	Monthly
Piezometers	Weekly	Monthly
Toe Drain Discharge Pipes	Weekly	Monthly
Visual Observations	Weekly	Monthly

It is recommended that the reservoir be filled at a rate that does not exceed an increase in reservoir water surface elevation of more than 0.5-foot per day during the initial filling period. Visual observations should include observations of the upstream slope, crest, downstream slope, stability berm and downstream toe of the Main Dam and the North Dam for signs of seepage, movement or distress. If any unusual observations are noticed, the FWS Region 6 Dam Safety Office or Regional Engineer should be notified immediately. The FWS Division of Engineering should then consider notifying the Colorado Dam Safety Branch Division 6 Dam Safety Engineer.

7 Conclusions and Recommendations

As a result of the project construction observations and testing performed by Wheeler and Kumar personnel, Wheeler offers the following post-construction conclusions and recommendations regarding the MacFarlane Dam Rehabilitation Project.

1. The project was constructed in general conformance with the Approved Drawings and Specifications that were approved by the Colorado Dam Safety Branch. Significant changes to the approved design include the use of a CIPP outlet conduit liner in place of a grouted in-place, slip-lined HDPE pipe.
2. During construction, two existing piezometers were abandoned and two new piezometers were installed as replacements, one at the downstream toe of the Main Dam and one at the downstream toe of the North Embankment. The total number of piezometers at MacFarlane Dam is four as summarized below:
    a. Piezometer P-1 near the crest of the North Embankment near Station 3+00;
    b. Piezometer P-4 near the crest of the Main Dam near Station 9+60;
    c. Piezometer P-6 near the toe of the North Embankment near Station 3+50; and
    d. Piezometer P-9 near the toe of the Main Dam bear Station 9+50.

8 Limitations

The construction engineering documentation provided in this report is based on representative material tests and observations of the Wheeler construction engineering team during construction of the MacFarlane Dam Rehabilitation Project. The information in this report is based on our best knowledge and judgment and, in part, from information provided by others. Our design and construction engineering services were conducted in accordance with generally accepted dam engineering practices. Variations can and do occur in foundation soils and rock, geologic materials, concrete materials, and earthwork materials used for the project. Every hydraulic structure leaks, settles, and cracks to some degree and the objective of our work was to minimize these performance issues to the extent practical. As a result, there is no expressed or implied warranty or guarantee of the performance of this Project. The members of the Wheeler engineering team are also not responsible for the liability associated with the interpretation of the information presented in this report by others.

9 References

1. Colorado Division of Water Resources, Department of Natural Resources (CO DNR, 2007) *Rules and Regulations for Dam Safety and Dam Construction,* January 1, 2007.
2. Kumar & Associates, Inc. (Kumar, 2015) *Final Geotechnical Design Report, MacFarlane Dam Rehabilitation,* October 8, *2015.*
3. Landmark Consultants, Inc. (Landmark, 2014) *Topographic Survey of MacFarlane Dam*, November 2014.
4. W. W. Wheeler & Associates, Inc. (Wheeler, 2014), *Title I MacFarlane Dam Field Investigation Report,* December 22, 2014.
5. W. W. Wheeler & Associates, Inc. (Wheeler, 2016), *Final Hazard Classification Evaluation, MacFarlane Dam, Arapaho National Wildlife Refuge*, February 2016*.*

APPENDIX A

CONSTRUCTION PHOTOS

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

Photo 1. Erosion control wattles staked down at the toe of the North Embankment. View looking left along the toe of the North Embankment. August 1, 2017.

Photo 2. Erosion control wattles staked down at the toe of the Main Dam Embankment. View looking left along the toe of the Main Dam Embankment. August 1, 2017.

Photo 3. View looking upstream along the left side of the spillway channel at the clearing and grubbing work and the installed erosion control. Aug. 1, 2017.

Photo 4. View looking upstream at the cleared and grubbed spillway from ES Station 2+75. Aug. 2, 2017.

Photo 5. View of the spillway proof-rolling from approximate ES Stations 4+50 to 6+50. Aug. 3, 2017.

Photo 6. Placement of Embankment Fill for the first lift of the right spillway berm between ES Stations 5+50 and 6+50. Aug. 4, 2017.

Photo 7. View looking downstream from ES Sta. 2+00 of soil placement and moisture conditioning on the left and right spillway berms. Aug. 7, 2017.

Photo 8. View from ES Sta. 5+00 looking right at the right spillway berm being shaped using the excavator. Aug. 9, 2017.

Photo 9. View from ES Sta. 3+00 looking downstream along the right spillway berm toe of RME shaping the right spillway berm. Aug. 10, 2017.

Photo 10. View from ES Sta. 3+00 looking downstream along the completed right spillway berm. Aug 11, 2017.

Photo 11. View of compaction of the right spillway berm from ES Sta. 1+00 to 3+00. Aug. 11, 2017.

Photo 12. View looking right of the excavated foundation for the upstream spillway cutoff wall at ES Sta. 2+20. Aug. 14, 2017

Photo 13. View looking right at the foundation preparation of the upstream cutoff spillway at ES Sta. 2+20. Aug. 14, 2017.

Photo 14. View looking downstream from ES Sta. 4+00 at the shaped and compacted right spillway berm and spillway discharge channel prior to excavation of the downstream cutoff wall at ES Sta. 5+20.

Photo 15. View looking left at the foundation excavation of the downstream spillway cutoff wall at ES Sta. 5+20. Note the seepage in the excavated foundation. Aug. 14, 2017

Photo 16. View of the formwork and rebar installation for the upstream spillway cutoff wall at ES Sta. 2+20. Aug. 15, 2017.

Photo 17. View of the formwork and rebar installation for the upstream spillway cutoff wall at ES Sta. 2+20. Aug. 16, 2017.

Photo 18. View of the completed formwork for the upstream spillway cutoff wall at ES Sta. 2+20. Aug. 18, 2017.

Photo 19. View looking at the form work blowout on the downstream side of the upstream spillway cutoff wall at ES Sta. 2+20. Aug. 18, 2017.

Photo 20. View looking left of the mud-mat placement in the foundation of the downstream spillway cutoff wall at ES Sta. 5+20. Aug. 18, 2017.

Photo 21. View looking upstream of the left spillway berm shaping and grading from ES Station 5+50. Aug. 22, 2017.

Photo 22. View looking downstream from ES Sta. 2+50 of the smooth drum rolling of the left downstream spillway berm. Aug. 24, 2017.

Photo 23. View looking from the left side of the spillway at the right spillway berm and new access road alignment through the spillway between the upstream and downstream cutoff walls. Aug. 24, 2017.

Photo 24. View looking left from approximate MTD Sta. 2+50 at the previous toe drain encountered during excavation of chimney drain. Aug. 28, 2017.

Photo 25. Representative view of the completed excavation and placement and compaction of Type A Filter Sand in the chimney drain at MTD Sta. 2+50 to 2+70. Aug. 28, 2017.

Photo 26. View looking right from MTD Sta. 2+45 at the compacted Type A Filter Sand and the start of the excavation for the Type B Gravel Drain for the chimney drain. Aug. 29, 2017.

Photo 27. View looking right from MTD Sta. 2+50 and the first section of chimney drain and seepage collection pipe placed from MTD Sta. 2+55 to 2+70. Aug. 29, 2017.

Photo 28. View looking downstream at the exposed, previous seepage collection system at approximate MTD Sta. 2+90. This pipe was removed during excavation of the chimney drain. Aug. 29, 2017.

Photo 29. View looking downstream at the smooth drum roller compacting the Type A Filter Sand. Aug. 29, 2017.

Photo 30. Representative view of the chimney drain installation work between MTD Sta. 2+55 and 3+20. Aug 29, 2017.

Photo 31. View looking right from MTD Sta. 3+50 at continued excavation into the Main Dam toe for the seepage collection system. The excavation is from MTD Sta. 4+00 to 4+30. Aug. 31, 2017.

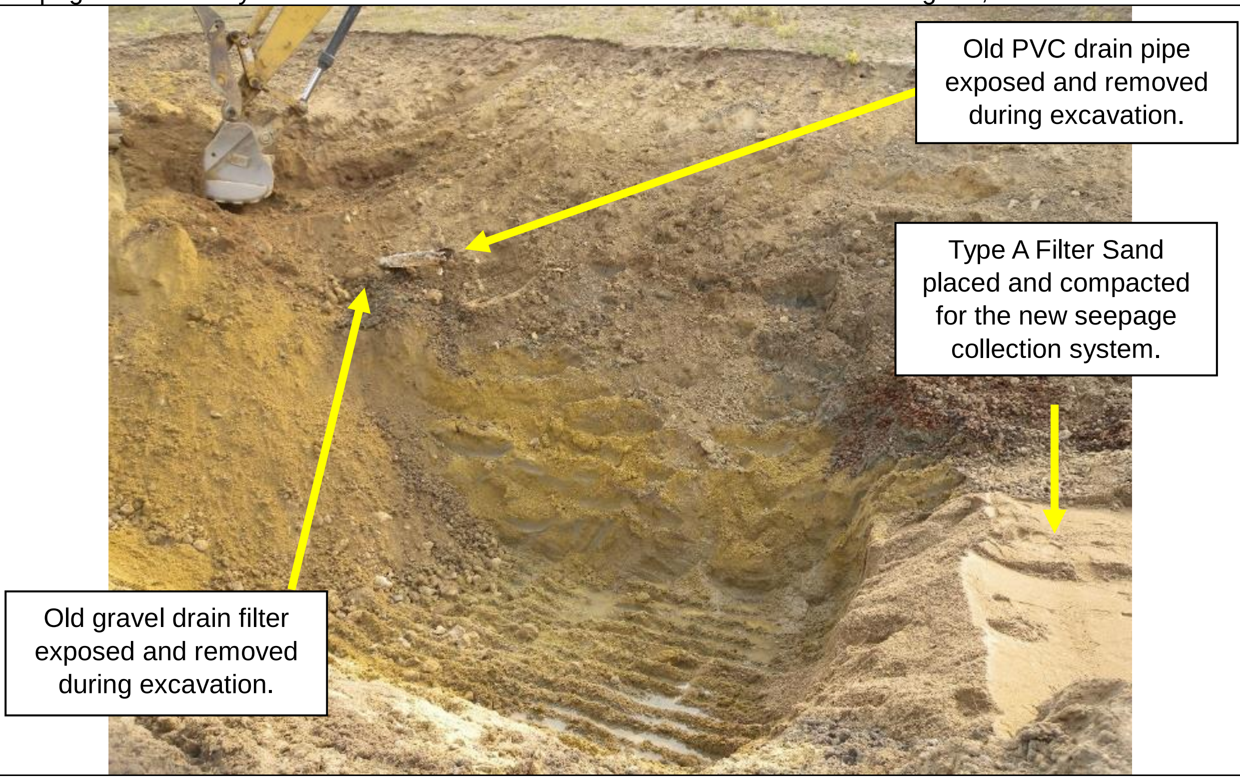


Photo 32. View looking upstream at the toe of the Main Dam during excavation and removal of the old drain line. Sept. 5, 2017.

Photo 33. View looking right from MTD Sta. 2+50 at the start of placement of the slotted drain pipe. The excavator was used to dig into the compacted layer of Type A Filter Sand, Type B Gravel Drain was placed at the bottom of the excavation to the invert of the slotted drain pipe and the drain pipe was then added and buried with 1-foot of Type B Gravel Drain. Sept. 7, 2017.

Photo 34. Representative view of the installation of the Type B Gravel Drain surrounding the slotted drain pipe. Sept. 7, 2017.

Photo 35. View looking upstream and left from approximate Sta. 4+50 at the foundation preparation work for the North Embankment Stability Berm, which included hauling and placing Embankment Fill along the North Embankment downstream toe. Sept 7, 2017.

Photo 36. View looking left from approximate MTD Sta. 5+15 at the plastic cover over the location of where the Main Dam, Right Toe Drain clean-out will be located, and the compaction of a lift of Type A Filter Sand. Sept. 8, 2017.

Photo 37. Looking downstream from approximate MTD Sta. 2+40 at the start of the seepage collection system for the left side of the Main Dam. Representative work included excavation into the toe of the Main Dam, removal of the old toe drain pipe, and placement, moisture conditioning and compaction of Type A Filter Sand shown above. Sept. 8, 2017.

Photo 38. View looking left at the outlet works inlet and closed slide gate. Reservoir draining operations have resulted in the reservoir pool at the level of the upstream slide gate. Sept 8, 2017.

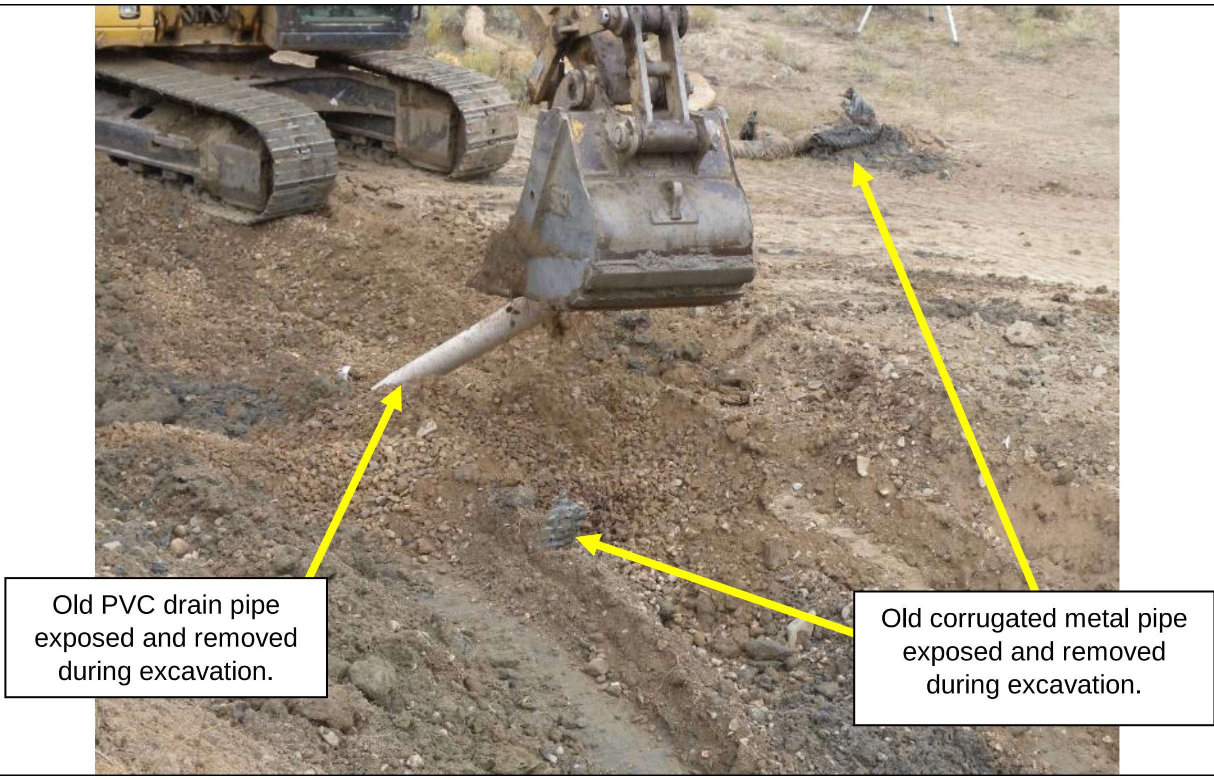


Photo 39. View looking left and downstream at the excavation of the left side of the Main Dam toe near MTD Sta. 1+25 at the installation of the seepage collection system. Note that two types of previously installed slotted drain pipe were removed, a white PVC and a corrugated metal pipe. Sept. 11, 2017.

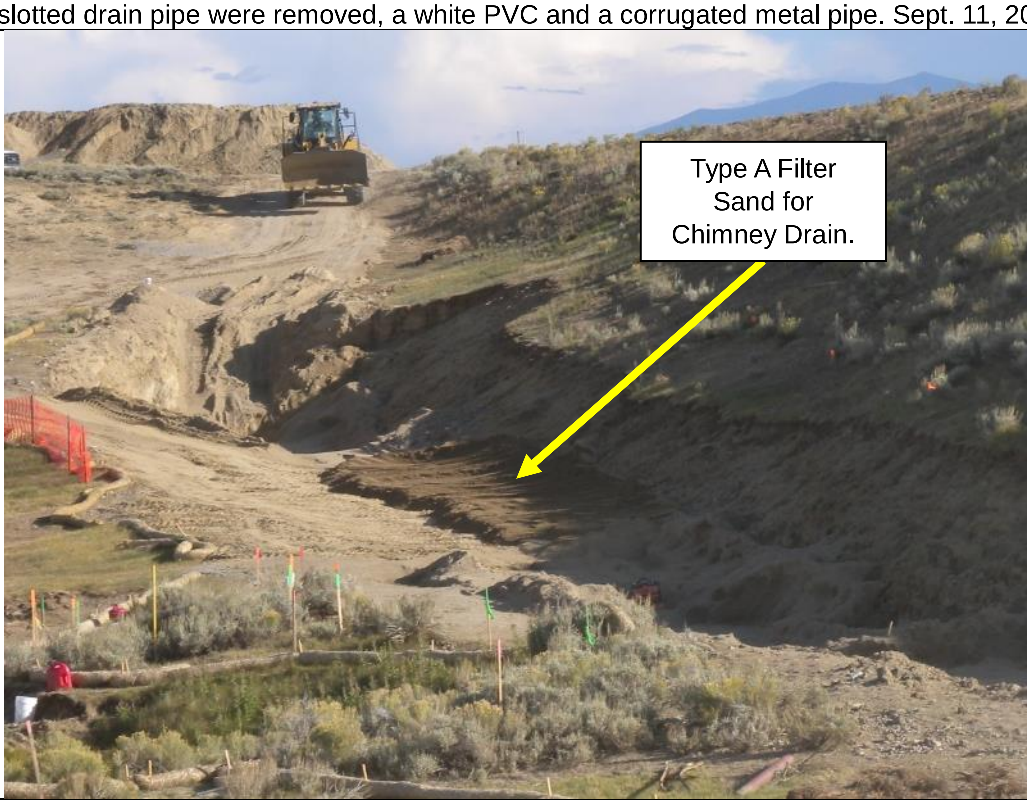


Photo 40. View looking right at the first lift of Type A Filter Sand that represents the start of the chimney drain from MTD Sta. 3+00 to 4+50. Sept. 12, 2017.

Photo 41. View looking downstream at the excavation from MTD Sta. 0+35 to 0+50. The excavator shown above was trying to cut into a rapidly rising layer of sandstone/claystone bedrock that appeared near MTD Sta. 0+35. It was decided after discussions with the SEO, Kumar and Wheeler to end the toe drain at MTD Sta. 0+50 instead of 0+00 and place the toe drain cleanout at MTD Sta. 0+45. Sep. 13, 2017.

Photo 42. View looking left from MTD Sta. 2+45 at the placement of the first section of slotted drain pipe for the left side of the Main Dam seepage collection system from MTD Sta. 2+40 to 2+26. Sept. 13, 2017

Photo 43. View looking right from approximate MTD Sta. 0+50 at a representative view of the Main Dam, right Chimney Drain installation and placement of the Embankment Fill Lift from MTD Sta. 3+00 to 4+00. Sept. 14, 2017.

Photo 44. View looking right along the toe of the Main Dam at the compaction of the first layer of Type A Filter Sand covering the Type B Gravel Drain on the left side of the dam, and the chimney drain and start of stability berm on the right side of the Main Dam. Sept. 14, 2017.

Photo 45. View from MTD Sta. 5+05 looking downstream at toe drain cleanout and special compaction of the Type A Filter Sand around the cleanout riser pipe. Sept. 14, 2017.

Photo 46. View from MTD Sta. 0+60 looking upstream at toe drain cleanout and placement of the Type A Filter Sand around the cleanout riser pipe. Sept. 14, 2017.

Photo 47. View looking right from the left abutment of the Main Dam at the continuation of the chimney drain and stability berm on the left and right side of the Main Dam outlet works. Note that the toe drain pipe sections at the location of the outlet works were left open. Sept. 15, 2017.

Photo 48. View looking left and upstream at the base of the North Embankment Stability Berm which was first constructed as shown above so the seepage collection system could then be constructed within the base of the berm. Shown above is the start of the excavation at NTD Sta. 0+00 and hauling of Type A Filter Sand for the placement of the seepage collection system Sept. 15, 2017.

Photo 49. View looking downstream from NTD Sta. 0+00 at the excavation down to the base of the seepage collection system at the left toe drain cleanout. Sept. 15, 2017.

Photo 50. View of the excavation of the stability berm and installation and compaction of the Type A Filter Sand in the North Dam chimney drain near NTD Sta. 0+00 to 0+80. Sept. 19, 2017.

Photo 51. View looking upstream from Sta. 9+90 at the start of the coffer dam construction. Sept. 20, 2017.

Photo 52. View looking upstream from Sta. 10+50 at the trench boxes and work on the coffer dam as well as construction of the temporary access road and platforms for the dewatering pumps on the upstream side of the reservoir. Sept. 20, 2017.

Photo 53. View looking downstream from the top of the coffer dam at the dewatered outlet inlet. Sept. 20, 2017.

Photo 54. View looking right from the top of the coffer dam at the two reservoir dewatering pumps placed on the upstream side of the Main Dam Embankment near Sta. 11+00. Sept. 20, 2017.

Photo 55. View looking right from approximate MTD Sta 0+00 at the Work in progress on the Main Dam which included placement of the chimney drain and lifts of Embankment Fill from MTD Sta 0+50 to 2+00. Sept 21, 2017.

Photo 56. View looking right and downstream at NTD Sta. 1+50 to 1+75 at the excavation into the stability berm and construction of the Type A Filter Sand layer of the seepage collection system. Sept. 21, 2017.

Photo 57. Representative view of the work completed by the concrete crew who added form ties and additional support to the upstream spillway cutoff wall at ES Sta. 2+20. Sept. 22, 2017.

Photo 58. View of the formwork and rebar installation for the downstream spillway cutoff wall located at ES Station 5+20. Sept. 22, 2017.

Photo 59. View looking left from NTD Sta. 0+80 at the installation of the slotted drain pipe and Type B Gravel Drain. Sept. 25, 2017.

Photo 60. C&L arrived on-site and began setting up their operations in the staging and stockpile area to the left of the outlet works. Sept. 25, 2017.

Photo 61. View looking downstream from approximate MTD Sta. 3+75 of the Embankment Fill placement in the Stability Berm. Sept. 26, 2017.

Photo 62. View of C&L fusing the 20-inch-diameter HDPE pipe. Sept. 26, 2017

Photo 63. View of the concrete placement and concrete testing for the upstream spillway cutoff wall located at ES Sta. 2+20. Sept. 27, 2017

Photo 64. View of Snowbridge Inc. water jetting the outlet works conduit. Sept. 28, 2017

Photo 65. View looking at the upstream side of the upstream concrete cutoff wall after the forms were stripped. September 28, 2017.

Photo 66. View of the 20-foot-long test section of HDPE pipe during the test pull which became stuck approximately 10-feet into the host pipe. Sept. 29, 2017.

Photo 65. View of the test section after being pulled into the host pipe approximately 85 to 90 feet with no centralizers or grout tubes attached. Note the scratches around the exterior of the pipe. This bare test pull was also abandoned because the test section became stuck on an unknown obstacle approximately 90 feet up the host pipe from the downstream end. Sept. 29, 2017.

Photo 66. View of the special compaction around the upstream spillway cutoff wall during the backfilling process. Sept. 30, 2017.

Note, on-site construction was temporarily suspended due to inclement conditions from Monday, October 2 through Monday October 9. A snow storm arrived on Sunday, October 1 which left approximately 9 inches of snow on–site. The only on-site Work which was completed during the following week was clearing of snow and re-construction of the coffer dam once site access was reestablished. The new coffer dam was built to an approximate elevation of 8294.0 feet. A second snow storm left approximately 3 to 4 inches of snow on-site on Sunday October 8 into Monday, October 9.

Photo 67. View looking right from the top of the Staging and Stock Pile Area looking at the Main Dam covered in snow from the second snow storm which occurred overnight Sunday October 8 into Monday October 9. Oct. 10, 2017.

Photo 68. View of the top of the re-constructed coffer dam. The original coffer dam was washed out following the rising reservoir levels associated with the snow storm from October 1. Oct. 10, 2017.

Photo 69. View looking upstream from the downstream end of the outlet works conduit at ponded water in the conduit due to overtopping of the coffer dam. The approximate depth of water was in excess of 4 inches in some areas. Oct. 10, 2017.

Photo 70. View looking left at the North Embankment seepage collection system from NTD Sta. -0+10. Snow is currently covering the top layer of Type A Filter Sand. Oct. 10, 2017.

Photo 71. View looking left at upstream side of the downstream Spillway cutoff wall. RME used the roller to compact the majority of the lift and the Jumping Jack to compact along the cutoff wall. Oct. 11, 2017.

Photo 72. View looking left from NTD Sta. 1+85 at the installation of the slotted drain pipe and toe drain cleanout for the left side of the North Dam seepage collection system. Oct. 13, 2017.

Photo 73. View looking right from approximate NTD Sta. 4+25 at the short lift of Type A Filter Sand placed from approximate NTD Sta. 4+50 to 5+10. Oct. 13, 2017.

Photo 74. View of the method to install the toe drain on the North Embankment due to restricted access by construction equipment. The excavator used the bucket to obtain Type B Gravel Drain from the loader and place it into the trench and surround the slotted drain pipe. Oct. 16, 2017.

Photo 75. View looking left from NTD Sta. 5+15 at work on the North Dam Seepage Collection System including installing the slotted drain pipe, Type B Gravel drain in the Type A Filter Sand, and the Toe Drain cleanout. From approximate NTD Sta. 3+34 to 4+50, the Type A Filter Sand layer stopped at a lower elevation than elsewhere along the seepage collection system, which meant that RME had mound the Type B gravel over the slotted pipe for the required 1-foot of coverage. Oct. 17, 2017.

Photo 76. View looking downstream at the excavation around the existing outlet works headwall for the filter collar, which included the removal of the old toe drain discharge pipes, and the temporarily filled in section of the outlet plunge pool required for construction access. Oct. 17, 2017.

Photo 77. View looking upstream from the temporarily filled in outlet plunge pool at the demolition of the existing outlet structure wing walls. Oct. 17, 2017.

Photo 78. View looking right across the upstream spillway cutoff wall which has been backfilled. Oct. 17, 2017.

Photo 79. View looking left across the downstream spillway cutoff wall which has been backfilled. Oct. 17, 2017.

Photo 76. View looking left across the outlet works terminal structure at the left and right wingwall foundation rebar and head wall risers which were tied and in-place prior to the concrete bank pour.

Photo 77. View looking right at the trowel finished surface of the bank poured left and right wingwall foundations. Note the test cylinders which are curing in the red cooler at the base of the old outlet works terminal structure. Oct. 18, 2017.

Photo 76. View looking upstream along the upstream slope from the coffer dam at the start of the excavation for the Air Vent encasement wall. Oct. 18, 2017.

Photo 77. View looking down at the #8 rebar rising from within the wing wall foundation which was then tied to the vertical #8 rebar for the new outlet works terminal structure headwall. Oct. 19, 2017.

Photo 76. View looking left from approximate MTD Sta. 2+60 at the CMP extension and downstream side of the headwall form.

Photo 77. View looking right from behind the headwall form at the 90-degree-bend rebar which will exit from the new concrete headwall and attach into what will be the concrete encasement around the CMP extension. Oct. 20, 2017.

Photo 78. Photo of C&L cutting and removing the HDPE liner pipe from the Staging and Stock Pile Area. The HDPE pipe was loaded onto a trailer and removed from the site. Oct. 20, 2017.

Photo 79. View looking left from NTD Sta. 5+15 at the top layer of Type A Filter Sand being placed and spread by the excavator which represents the top of sand layer for the North Dam Toe Drain. Oct. 20, 2017.

Photo 80. View looking right along the right side of the Main Dam seepage collection system from MTD Sta. 0+00 where the chimney drain and stability berm is still being constructed. Oct. 20, 2017.

Photo 81. View looking upstream from the left of the Spillway at the Main Dam which was covered in approximately 1-inch of snow following a rain/ice/snow storm that hit over night. Work was cancelled for the day. Oct. 21, 2017.

Photo 80. View looking downstream along the excavation for the Air Vent Encasement Wall and RME establishing the final required bottom grade. Oct. 22, 2017.

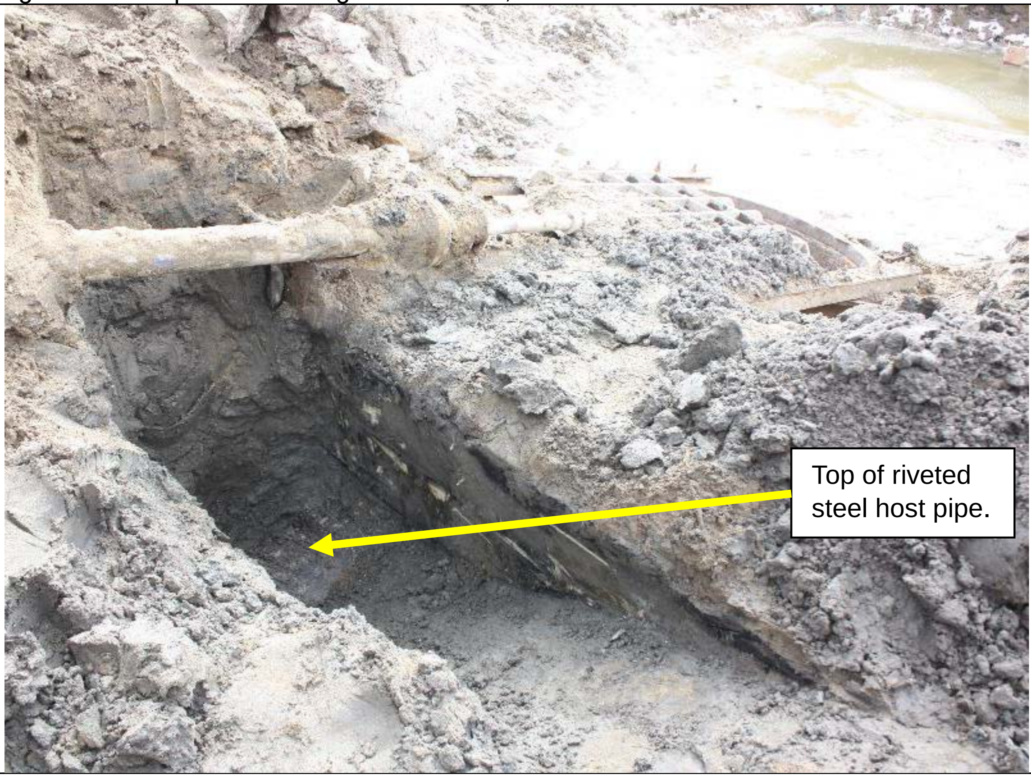


Photo 81. View looking upstream at the gate stem, slide gate, original outlet inlet headwall and excavation to the top of the riveted steel host pipe where the air vent connection was made. Oct. 22, 2017.

Photo 82. View looking right from the left side of the new outlet works terminal structure headwall at the concrete being placed from the pump truck. Oct. 23, 2017.

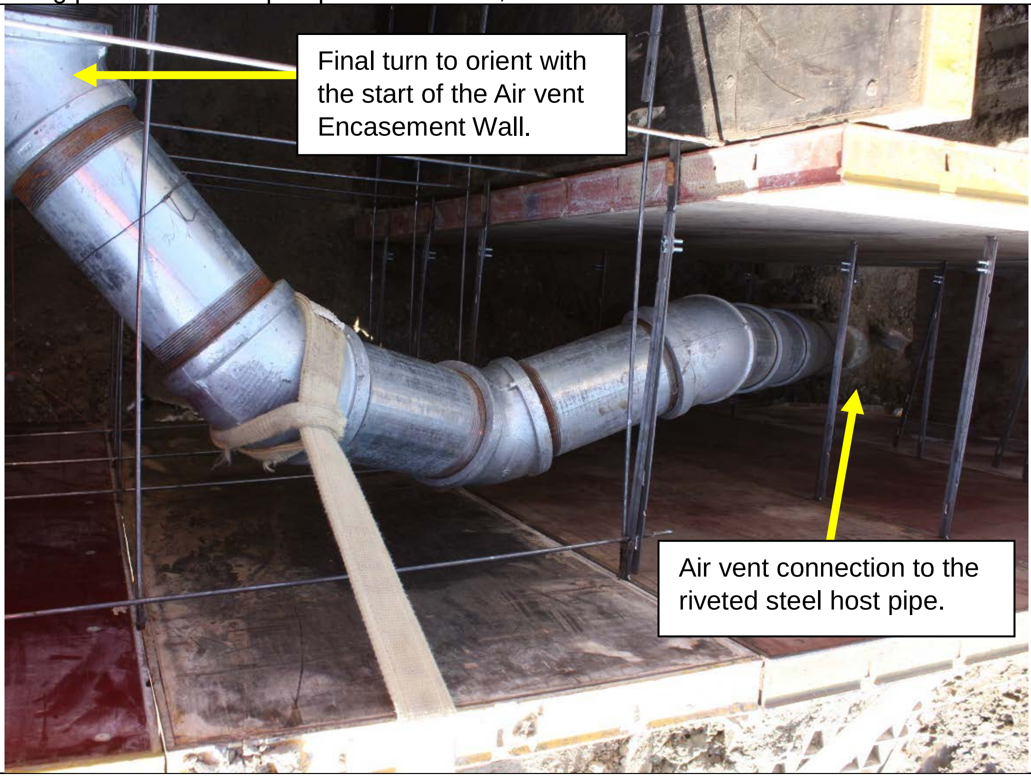


Photo 83. View looking down at the assembled air vent riser section of the air vent pipe in the anchor section of the Air Vent Encasement Wall. Oct. 23, 2017.

Photo 84. Close-up view of the Air Vent Pipe which was inserted into the original riveted steel outlet works conduit. Oct. 23, 2017.

Photo 85. View from the coffer dam looking downstream at the riser section of the Air Vent encasement wall which extends from the attachment to the original riveted steel outlet works conduit to the start of the air vent pipe encasement wall. Oct. 23, 2017.

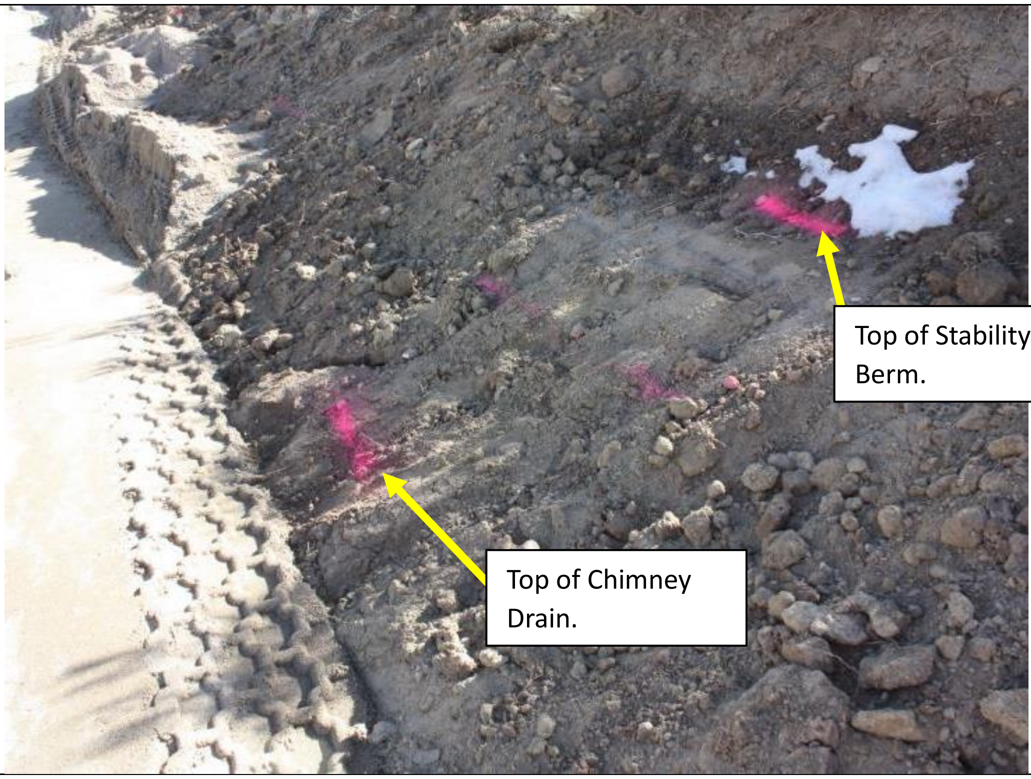


Photo 84. View of the Main Dam Stability Berm to the right of the outlet works which was approximately 2 feet below the final top of berm elevation. Oct. 24, 2014.

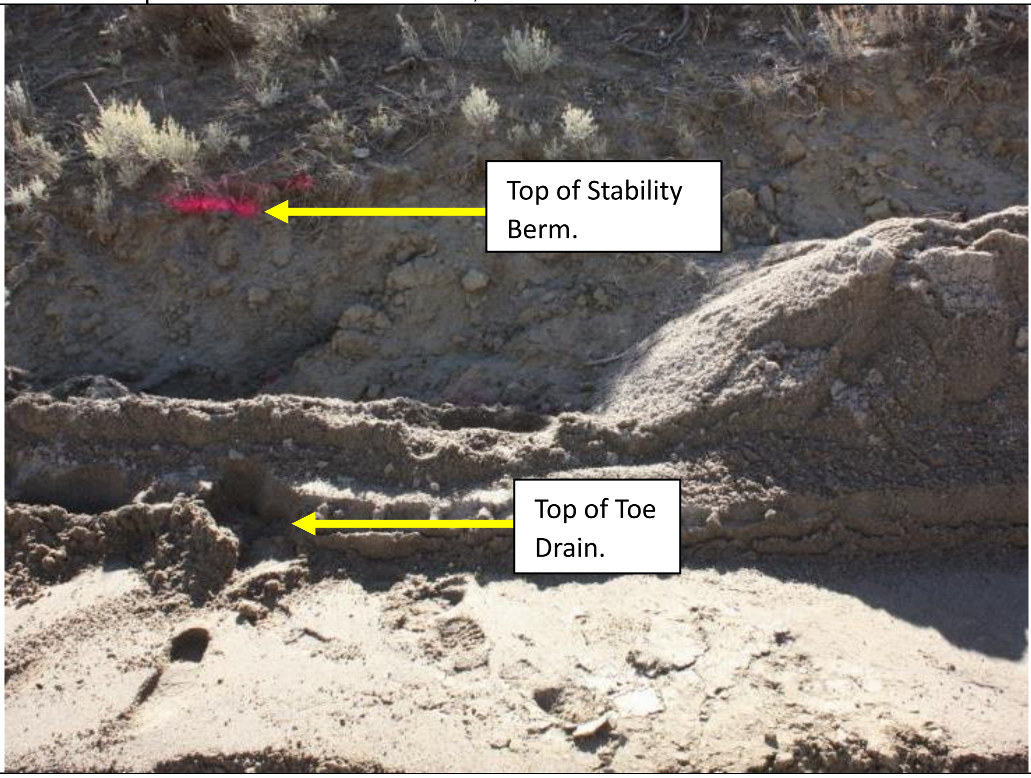


Photo 85. View at the North Embankment stability berm where the top of the Toe Drain two-stage filter was overbuilt, and the Type A Filter Sand was already at 2 feet below the top of berm elevation. As a result, no chimney drain was installed in this area. This was the case for the entire right side of the North Dam Toe Drain (NTD Sta. 1+85 to 5+10) except for NTD Sta. 3+00 to 4+50 which still needed additional Type A Filter Sand for the Chimney Drain. Oct. 24, 2017.

Photo 86. View of the concrete placement for the Air Vent Riser section and Air Vent Encasement Wall anchor section. Oct 24, 2017.

Photo 87. View looking downstream at the installation of the galvanized steel Air Vent pipe and partial rebar and formwork for the Air Vent Encasement Wall. Oct. 25, 2017.

Photo 88. Close-up view of the angle iron, which to accommodate the form ties had a notch cut into the bottom portion. The angle iron was embedded into the concrete for the reservoir staff gage. Oct. 25, 2017.

Photo 89. View looking downstream along the top of the Air Vent Encasement Wall extending parallel the gate operator along the upstream slope of the main dam. Oct. 30, 2017.

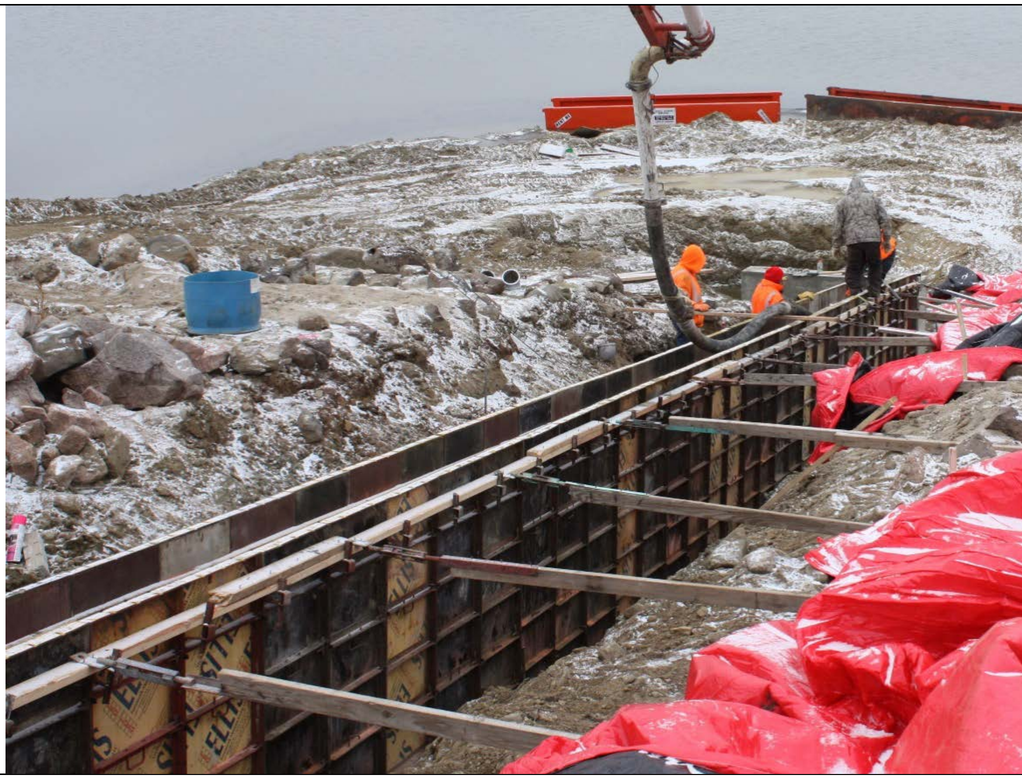


Photo 90. View looking upstream from near the dam crest at the placement of concrete by the pump truck into the Air Vent Encasement Wall. Oct. 30, 2017.

Photo 91. View looking downstream at the placement of concrete by the pump truck into the CMP outlet works conduit extension encasement section. Oct. 30, 2017.

Photo 92. View looking upstream at the downstream side of the upstream spillway cutoff wall where RME patched the concrete from the initial partial concrete pour. Oct. 31, 2017.

Photo 93. View looking downstream from NTD Sta. 1+75 at the North Embankment Toe Drain Outfall after installation of the discharge pipe and steel plate. Nov. 1, 2017.

Photo 94. View looking left and downstream from approximate NTD Sta. 2+00 at the buried toe drain discharge pipe and galvanized steel plate, and the Work by RME to cover the Type B Gravel of the toe drain system. Nov. 1, 2017.

Photo 95. View of the protective liner which was pulled through the original outlet works conduit prior to pulling through the CIPP liner. This base material covered the bottom half of the host pipe and provided a smooth surface and protection for when the CIPP liner was subsequently pulled through the conduit. Nov. 1, 2017.

Photo 96. View looking at the CIPP liner being installed from the downstream end of the outlet works conduit. Note, a jean-skirt surrounds the CIPP liner for UV protection and to prevent over-expansion of the CIPP liner during inflation which was required for the upstream inlet transition section from 24 inches to 36 inches in diameter. Nov. 1, 2017.

Photo 97. View looking downstream from the upstream inlet at the sealed upstream start of the CIPP liner. Nov. 1, 2017.

Photo 98. View looking upstream from the downstream end of the outlet works conduit at the roller device which houses the UV lamps and was now inserted into the partially inflated, downstream end of the pipe. Nov. 1, 2017.

Photo 99. View looking right from the left side of the downstream end of the outlet conduit at the sealed end of the CIPP liner during inflation. C&L slowly raised the pressure within the CIPP liner to 450 mbar (6.2 psi) to expand the liner to fill the host pipe. Nov. 1, 2017.

Photo 100. Once the internal pressure in the CIPP was achieved, C&L pulled the roller device which houses the UV lamps from the downstream side to the upstream side of the outlet pipe. During this time, C&L used an attached video camera to observe the condition of the CIPP. No issues were found within the inflated CIPP liner, so C&L then turned on the UV lamps to cure the CIPP pipe. The curing process lasted approximately 2.5 hours. Nov. 1, 2017.

Photo 101. View looking right from NTD Sta. -0+15 at the Type A Filter Sand which is at the top of the toe drain elevation and ready to be covered with Embankment Fill. Nov. 2, 2017.

Photo 102. View looking downstream at the right side of the outlet works terminal structure headwall. The filter diaphragm slotted drain pipe was being installed and buried by Type B Gravel Drain. Nov. 2, 2017.

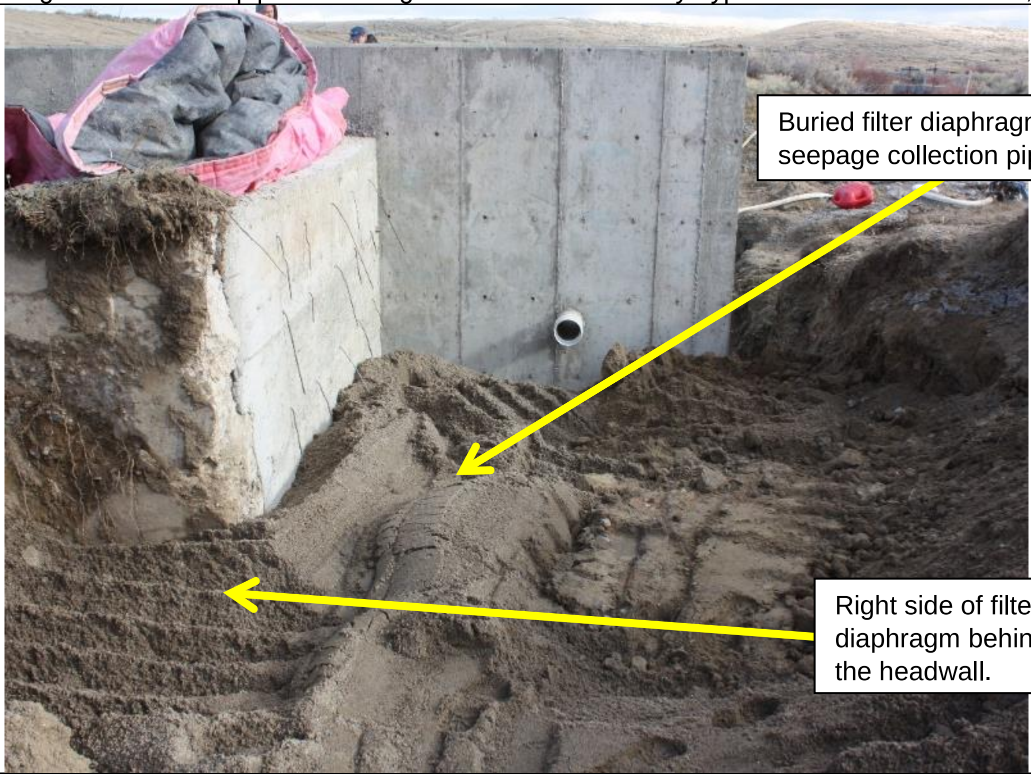


Photo 103. View looking downstream at the right side of the outlet works terminal structure headwall. The filter diaphragm slotted drain pipe was now buried by Type A Filter Sand, and the filter diaphragm was starting behind the old terminal structure headwall. Nov. 2, 2017.

Photo 104. View looking upstream from the Staging and Stockpile Area at the backfill area behind the outlet works terminal structure headwall. Nov. 4, 2017.

Photo 105. View looking downstream from the coffer dam at the concrete placed yesterday around the outlet conduit inlet. Nov. 4, 2017.

Photo 106. View looking downstream from the outlet works inlet where the HDPE liner section had been inserted into the CIPP liner at the riveted steel pipe diameter transition section. Decking was used to shim-up the base of the HDPE liner to achieve consistent annular space. Nov. 3, 2017.

Photo 107. View looking downstream into the inlet of the outlet conduit at the original riveted steel host pipe transition section which had been filled in along the bottom up to the invert of the HDPE liner pipe with concrete. Nov. 4, 2017.

Photo 108. View looking downstream at the upper half of the bulkhead which was built after grouting the bottom half of the HDPE annular space. Note the 4-inch-diameter flexible hose was encased in the bulkhead and was used to finalize the annular space grouting once the bulkhead was set. Nov. 4, 2017.

Photo 109. View looking downstream from the outlet conduit inlet gate at the non-shrink grout coating being installed in the invert and around the perimeter of the existing riveted steel outlet works pipe. Note, additional non-shrink grout was placed along the top of the existing riveted steel outlet works pipe after this picture was taken. Nov. 7, 2017.

Photo 110. View looking down at the top of the air vent encasement wall containing the staff gage grade beam which had now been backfilled. RME completed the outlet works work and was preparing to start removing the cofferdam and begin re-filling the reservoir once permission to fill was granted by the Colorado Division of Water Resources. Nov. 7, 2017.

Photo 111. View looking right from Station 2+50 MTD at the final Embankment Fill lifts being installed prior to compaction along the Main Dam. Nov. 7, 2017.

Photo 112. View looking right of the newly drilled replacement piezometer on the toe of the North Embankment. Nov. 7, 2018.

Photo 113. View looking down at the newly drilled replacement piezometer on the toe of the Main Dam, to the left of the outlet works. Nov. 7, 2018.

Photo 114. View looking right from Station 10+00 at the access road removal and upstream slope grading. Nov. 9, 2017.

Photo 115. View looking upstream at the emergency spillway control sill located at Station ES 2+20. Note that the bedding and riprap has been installed downstream of the cutoff structure. Nov. 9, 2017.

Photo 116. View looking left from Station 2+00 MTD of the final lift of Embankment Fill on the Main Dam Stability Berm. Nov. 9, 2017.

Photo 117. View looking right from Station 2+50 MTD of the final compacted Embankment Fill lift of the Main Dam Stability Berm. Nov. 9, 2017.

Photo 116. View looking down the air vent grade beam and staff gage. Note that the staff gage numbers are welded on the angle iron at 0.5-foot intervals. Note the additional grading and riprap that needs to be installed prior to completion. Nov. 13, 2017.

Photo 117. View looking left across the downstream terminal structure plunge pool. Note that the approximate invert elevation of the outlet pipe measured relative to the headwall is at Elevation 8281.2, which is 0.8 feet lower than the design elevation, and currently submerged by approximately 0.3 feet of water. The plunge pool was lowered in the spring of 2018. Nov. 14, 2017.

Photo 118. View looking left along the North Dam finished Stability Berm from approximate NTD Sta. 2+75 which has been shaped and scarified. Also shown is the downstream piezometer located to the right of the toe drain discharge outfall. Nov. 14, 2017.

Photo 119. View looking right along the North Dam finished Stability Berm from approximate NTD Sta. 2+75 which has been shaped and scarified. Nov. 14, 2017.

Photo 118. View looking left along the Main Dam finished Stability Berm from approximate MTD Sta. 2+50 which has been shaped and scarified. Nov. 14, 2017.

Photo 119. View looking right along the Main Dam finished Stability Berm from approximate NTD Sta. 2+50 which has been shaped and scarified. Nov. 14, 2017.

Photo 118. View looking right across the access road of the Emergency Spillway with basecourse placed on the road. Nov. 28, 2017.

Photo 119. View looking at the North Dam toe drain discharge pipe noting that the riprap has been installed. Nov. 28, 2017.

Photo 120. View looking right across the completed North Dam stability berm prior to reseeding. May. 17, 2018.

Photo 121. View looking left across the completed Main Dam Stability berm. Note that the berm and main dam slope transition was graded as per the SEO substantial completion comments. May 17, 2018.

Photo 122. View of the terminal structure and plunge pool. Plunge pool was reworked and the water level lowered. Additional riprap armoring was installed on the right and left side of the headwall. May 17, 2018.

Photo 123. View looking downstream from ES Station 2+20 of the completed emergency spillway. May 17, 2018.

Photo 124. View of the air vent grade beam and staff gage. Note the riprap that was installed on both sides of the grade beam and the slope between the operator and grade beam was better graded. May 22, 2018.

Photo 125. View looking left from the outlet works operator at the North upstream slope riprap repair being completed by the FWS maintenance crew. May 22, 2018.

APPENDIX B

RECORD DRAWINGS

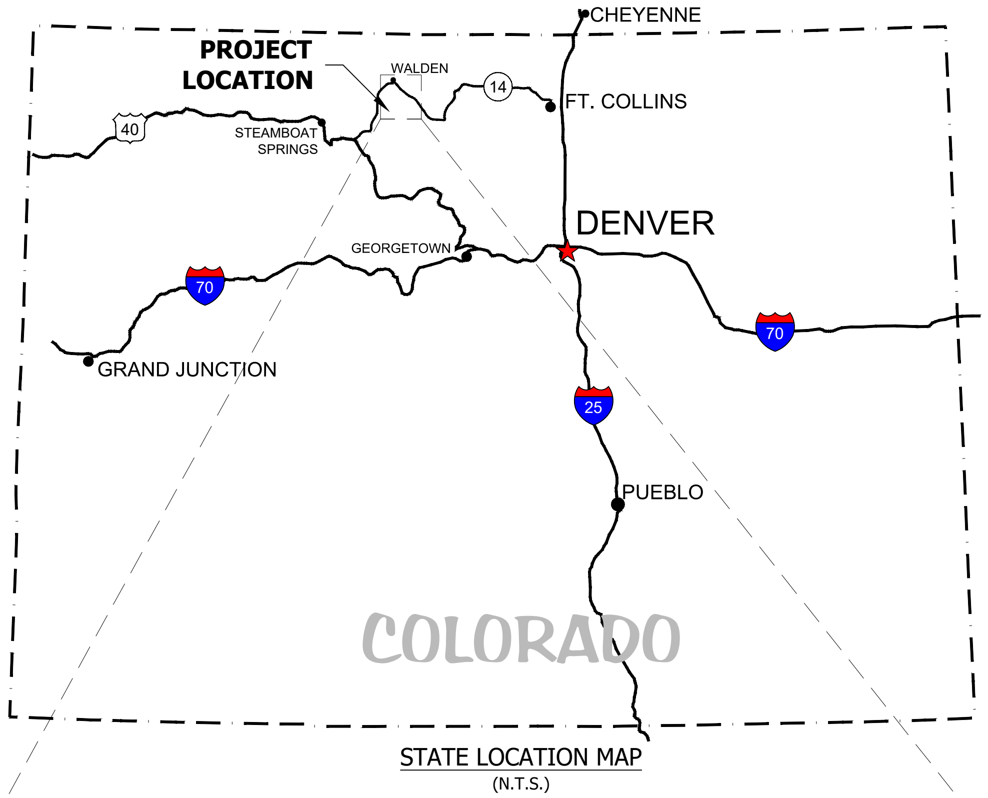
W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

MACFARLANE DAM REHABILITATION

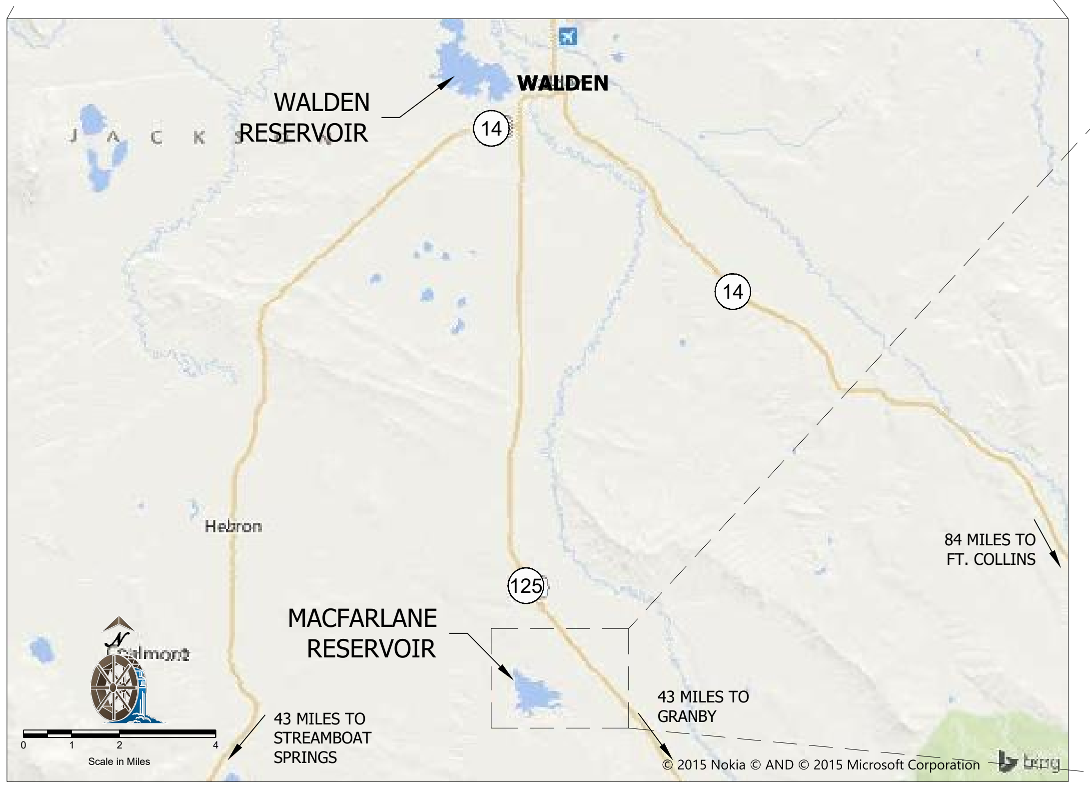
DAM ID: 470202, NID: CO-00997
JACKSON COUNTY, COLORADO
C-1031B

PREPARED FOR:
UNITED STATES FISH AND WILDLIFE SERVICE
DIVISION OF ENGINEERING
REGION 6 - MOUNTAIN PRAIRIE REGION
LAKEWOOD, COLORADO

PREPARED BY:
W. W. WHEELER AND ASSOCIATES, INC.
IN ASSOCIATION WITH:
KUMAR & ASSOCIATES, INC.



STATE LOCATION MAP
(N.T.S.)



DAM LOCATION MAP

DAM SITE ACCESS

MACFARLANE DAM REHABILITATION
C-1031B
WATER DIVISION 6 - WATER DISTRICT 47
JACKSON COUNTY, COLORADO
SECTION 29, TOWNSHIP 7 NORTH,
RANGE 79 WEST OF THE 6TH PRINCIPAL MERIDIAN

I HEREBY DECLARE THAT THESE PLANS FOR THE CONSTRUCTION OF THE MACFARLANE DAM REHABILITATION WERE PREPARED UNDER MY DIRECT SUPERVISION.

RESPONSIBLE DESIGN ENGINEER:
W. W. WHEELER & ASSOCIATES, INC.

COLO. PE NO. 25028
STEPHEN L. JAMIESON, P.E.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

STATE ENGINEER APPROVAL:
APPROVED ON THE 9th DAY OF March, 2016.

Dick Wolfe
STATE ENGINEER

BY:
WILLIAM T MCCORMICK III
CHIEF - DAM SAFETY BRANCH
COLO. PE NO. 29127

STATE ENGINEER OF COLORADO

THESE PLANS REPRESENT THE AS-CONSTRUCTED CONDITIONS OF THE MACFARLANE DAM REHABILITATION TO THE BEST OF OUR KNOWLEDGE AND JUDGMENT, BASED IN PART ON INFORMATION FURNISHED BY OTHERS AS OF THE 31st DAY OF JULY, 2018.

COLO. PE NO. 25028
STEPHEN L. JAMIESON, P.E.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JTT

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
REGION 6, DIVISION OF ENGINEERING
LAKEWOOD, COLORADO

PROJECT MANAGER — DATE 02/26/2016
REGIONAL ENGINEER — DATE 02/26/2016
REFUGE FMC — DATE 02/26/2016

ARAPAHO
NATIONAL WILDLIFE REFUGE

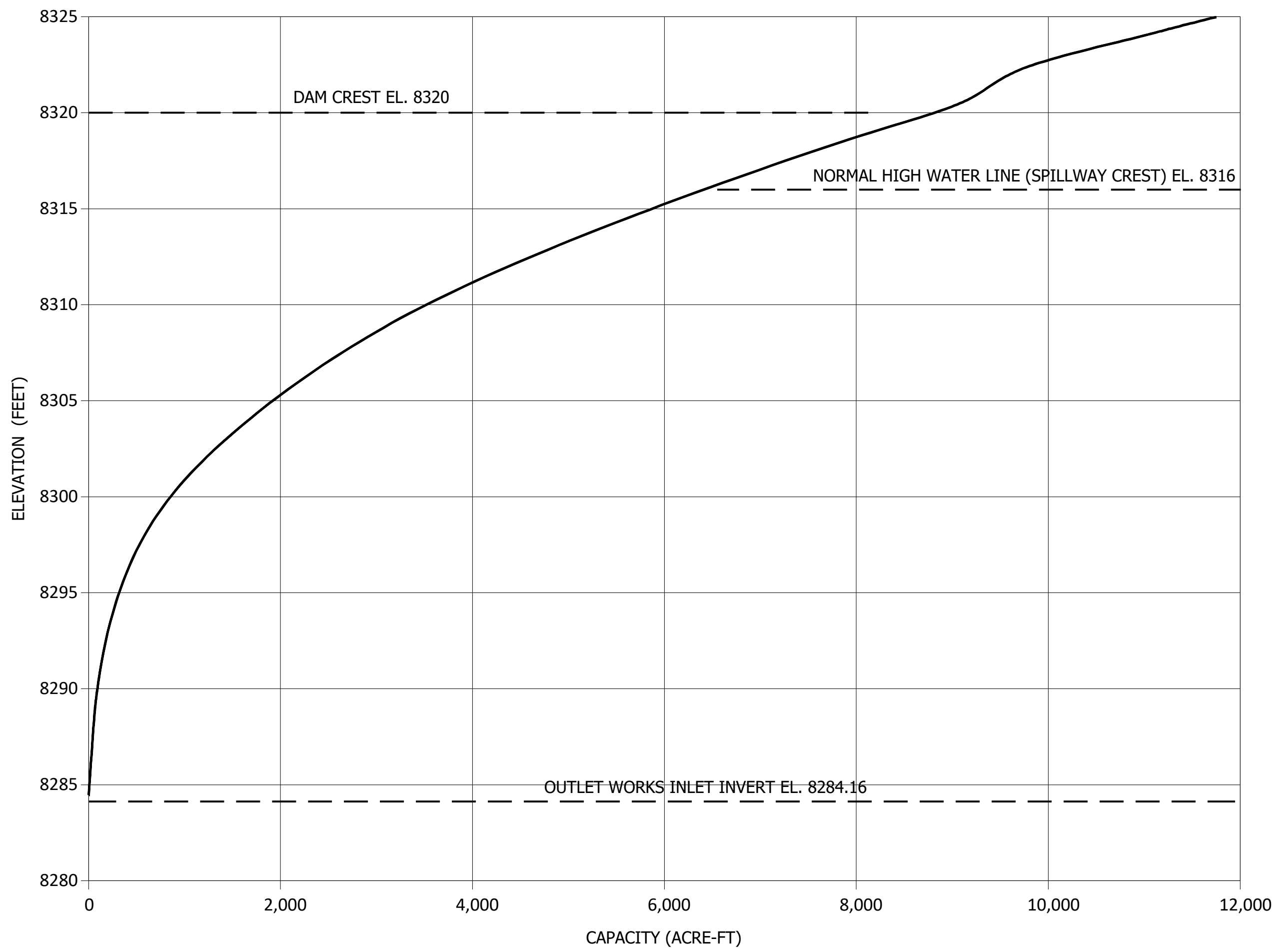
MACFARLANE DAM REHABILITATION
COVER SHEET
AND LOCATION MAPS

G1.0

JACKSON COUNTY — COLORADO

SURVEYED	DESIGNED	DRAWN	CHECKED
	JJT	SAA	SLJ

DATE: 2-26-2016
SHEET NO.: 1 OF 21



MACFARLANE RESERVOIR STORAGE CAPACITY TABLE

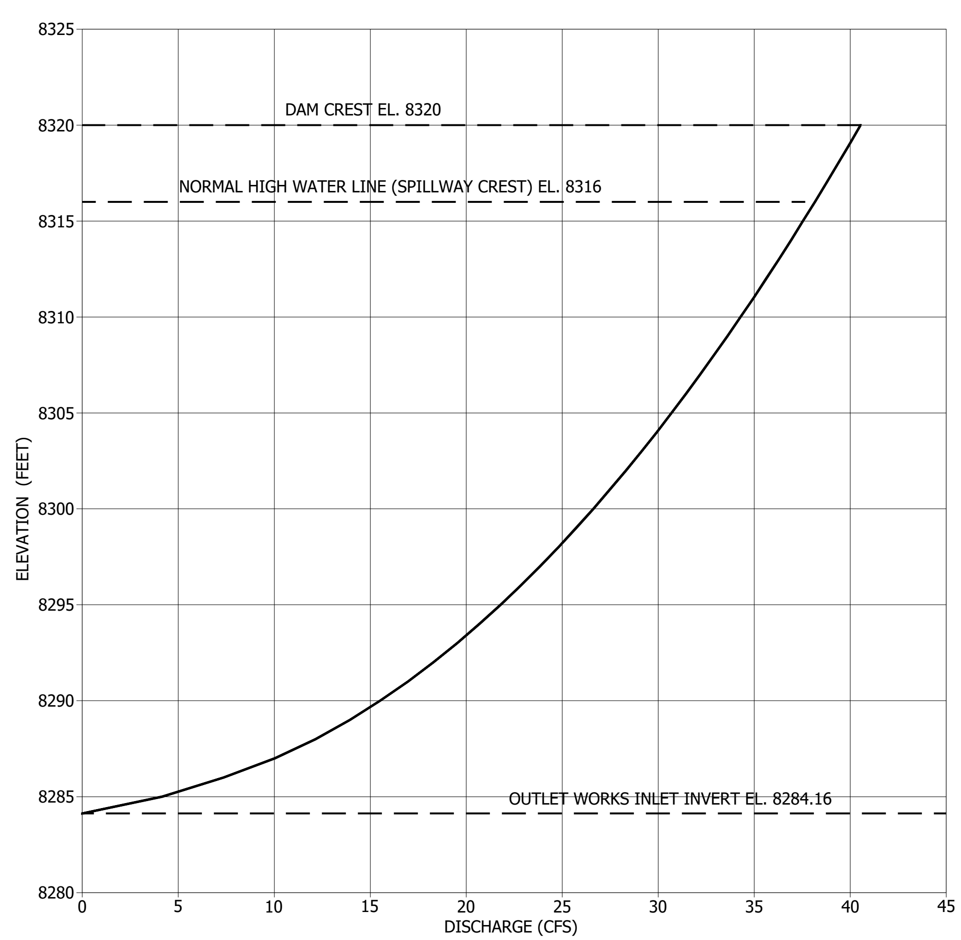
WATER SURFACE ELEVATION	RESERVOIR CAPACITY	GAGE HEIGHT	NOTES
(Feet)	(Acre-Feet)	(Feet)	
8284.16	0	0	OUTLET WORKS INLET
8288.16	5	4.0	
8290.16	30	6.0	
8292.16	84	8.0	
8294.16	181	10.0	
8296.16	327	12.0	
8298.16	549	14.0	
8300.16	864	16.0	
8302.16	1,275	18.0	
8304.16	1,764	20.0	
8306.16	2,331	22.0	
8308.16	2,999	24.0	
8310.16	3,806	26.0	
8312.16	4,710	28.0	
8314.16	5,688	30.0	
8316.00	6,726	31.9	SPILLWAY CREST
8318.16	7,821	34.0	
8320.00	8,968	35.9	DAM CREST
8322.16	9,654	38.0	
8324.16	10,982	40.0	
8325.16	11,671	41.0	

NOTE:
RESERVOIR CAPACITY BASED ON THE 2015 BATHYMETRIC SURVEY PERFORMED BY THE U. S. FISH & WILDLIFE SERVICE. RESERVOIR CAPACITY ABOVE EL 8320 WAS ESTIMATED USING 10-METER DEM DATA.

DRAWING INDEX

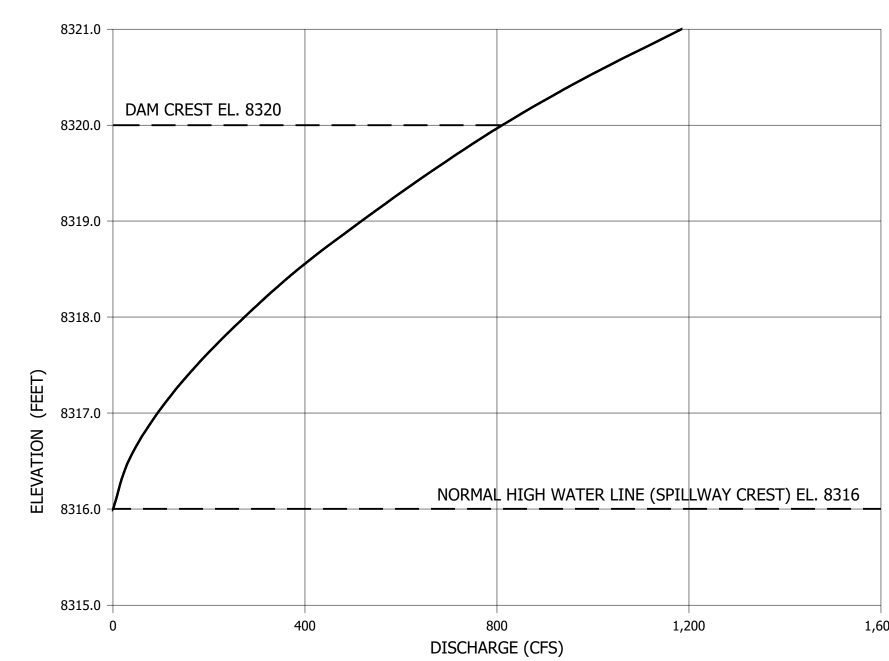
SHEET NO.	DWG. NO.	DRAWING TITLE
		GENERAL
1	G1	COVER SHEET AND LOCATION MAPS
2	G2	DRAWING INDEX AND CAPACITY CURVES
3	G3	PROJECT LIMIT OF SITE DISTURBANCE
4	G4	PRE-CONSTRUCTION SITE PLAN
5	G5	SUBSURFACE BORING LOGS
6	G6	TEST PIT LOGS
7	G7	GENERAL PLAN OF MODIFICATIONS
		CIVIL
8	C1	TEMPORARY RESERVOIR CONTROL PLAN
9	C2	EROSION CONTROL PLAN AND DETAILS
10	C3	SPILLWAY - PLAN, PROFILE AND SECTIONS
11	C4	NORTH EMBANKMENT - PLAN AND PROFILE
12	C5	MAIN DAM - PLAN AND PROFILE
13	C6	EARTHWORK AND TOE DRAIN - SECTIONS AND DETAILS
14	C7	TOE DRAIN - PROFILES AND DETAILS
15	C8	OUTLET CONDUIT LINING - PLAN AND PROFILE
	C9	OUTLET CONDUIT LINING - DETAILS
16	C10	PLUNGE POOL - PLAN AND SECTIONS
17	C11	FILTER DIAPHRAGM - PLAN, SECTIONS AND DETAILS
18	C12	ACCESS ROAD IMPROVEMENTS - PLAN AND DETAILS
19	C13	MISCELLANEOUS DETAILS 1
20	C14	MISCELLANEOUS DETAILS 2
		STRUCTURAL
21	S1	TERMINAL STRUCTURE, STRUCTURAL SECTIONS AND DETAILS

NOTE:
DRAWING C9 WAS REMOVED FROM THE AS-CONSTRUCTED DRAWINGS AS THE INFORMATION ON SHEET C9 WAS NOT USED FOR CONSTRUCTION.



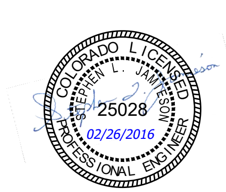
MACFARLANE DAM OUTLET WORKS DISCHARGE CAPACITY TABLE

RESERVOIR ELEVATION	GAGE HEIGHT	DISCHARGE	NOTES
(Feet)	(Feet)	(cfs)	
8284.16	0	0	OUTLET WORKS INLET
8286.16	2	6	
8288.16	4	10.8	
8290.16	6	14	
8292.16	8	16.6	
8294.16	10	18.9	
8296.16	12	20.9	
8298.16	14	22.8	
8300.16	16	24.5	
8302.16	18	26.1	
8304.16	20	27.6	
8306.16	22	29	
8308.16	24	30.4	
8310.16	26	31.7	
8312.16	28	32.9	
8314.16	30	34.1	
8316.00	31.9	35.3	SPILLWAY CREST
8318.16	34	36.4	
8320.00	35.9	37.5	DAM CREST



MACFARLANE DAM SPILLWAY CAPACITY TABLE

ELEVATION	GAGE HEIGHT	FLOW	NOTES
(Feet)	(Feet)	(cfs)	
8316.00	31.9	0	SPILLWAY CREST
8316.50	32.4	32	
8317.00	32.9	93	
8317.50	33.4	175	
8318.00	33.9	274	
8318.50	34.4	386	
8319.00	34.9	517	
8319.50	35.4	658	
8320.00	35.9	811	DAM CREST
8320.50	36.4	986	
8321.00	36.9	1,184	



C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

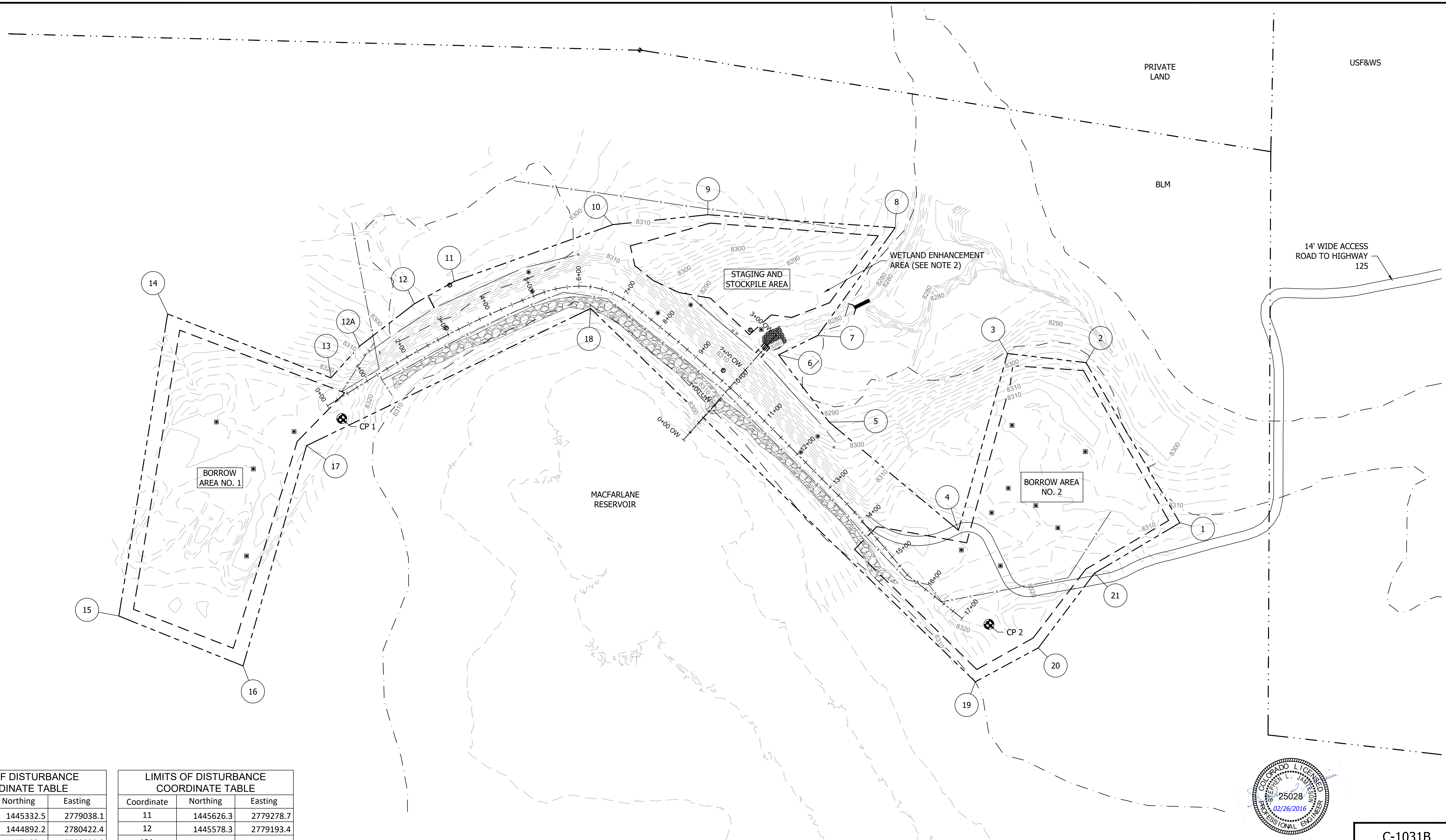
ARAPAHO N.W.R.

G2.0

MACFARLANE DAM REHABILITATION
DRAWING INDEX AND CAPACITY CURVES

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	2 OF 21

R:\1700\1772\1772.11.01_MacFarlaneDesign\Drawings\RECORD DRAWINGS\17721101-001 8-02-18 04:46pm Scott XREFS: Jamieson PE Stamp Aerial_Disturbance; Aerial_Image_C11; Colorado; CWH; LAH; o40106e3_fut; SEO_1; SEO_2; SLJ; SLJ2;



LIMITS OF DISTURBANCE COORDINATE TABLE		
Coordinate	Northing	Easting
CP 1	1445332.5	2779038.1
CP 2	1444892.2	2780422.4
1	1445109.4	2780830.9
2	1445452.4	2780630.2
3	1445471.9	2780462.1
4	1445093.4	2780357.3
5	1445325.0	2780080.8
6	1445469.1	2779972.6
7	1445510.8	2780056.6
8	1445741.3	2780221.9
9	1445769.1	2779821.2
10	1445747.8	2779617.8

LIMITS OF DISTURBANCE COORDINATE TABLE		
Coordinate	Northing	Easting
11	1445626.3	2779278.7
12	1445578.3	2779193.4
12A	1445487.644	2779076.089
13	1445419.8	2779014.9
14	1445556.6	2778665.6
15	1444909.9	2778561.4
16	1444803.1	2778827.0
17	1445274.7	2778962.8
18	1445568.4	2779570.5
19	1444769.1	2780393.4
20	1444841.8	2780528.2
21	1445001.5	2780648.2

LEGEND

- CONTROL POINT
- ACCESS ROAD
- PROPERTY BOUNDARY
- EXISTING FENCE
- BORROW AND STAGING AREAS
- LIMIT OF DISTURBANCE
- WATER/WETLAND BOUNDARY
- BORINGS DRILLED FOR SUPPLEMENTAL SEEPAGE ANALYSIS STUDY BY KUMAR & ASSOCIATES
- PITS EXCAVATED FOR SUPPLEMENTAL GEOTECHNICAL ANALYSIS BY KUMAR & ASSOCIATES

NOTES:

1. BASEMAP BASED ON OCTOBER 2014 SURVEY BY LANDMARK CONSULTANTS, INC.
2. A 0.2 ACRE WETLAND ENHANCEMENT TO BE COMPLETED BY THE GOVERNMENT.
3. SUBTRACT 0.55 FEET TO CONVERT PROJECT ELEVATIONS TO NAVD 88 ELEVATIONS.
4. ADD 1.38 FEET TO CONVERT PROJECT NORTHINGS TO COLORADO STATE PLANE NORTHINGS.
5. ADD 11.81 FEET TO CONVERT PROJECT EASTINGS TO COLORADO STATE PLANE EASTINGS.

0 50 100 200 300
Scale in Feet

C-1031B

REV.	DATE	DESCRIPTION	BY
1	4-2-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R.

G3.0

MACFARLANE DAM REHABILITATION
PROJECT LIMIT OF SITE DISTURBANCE

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	3 OF 21

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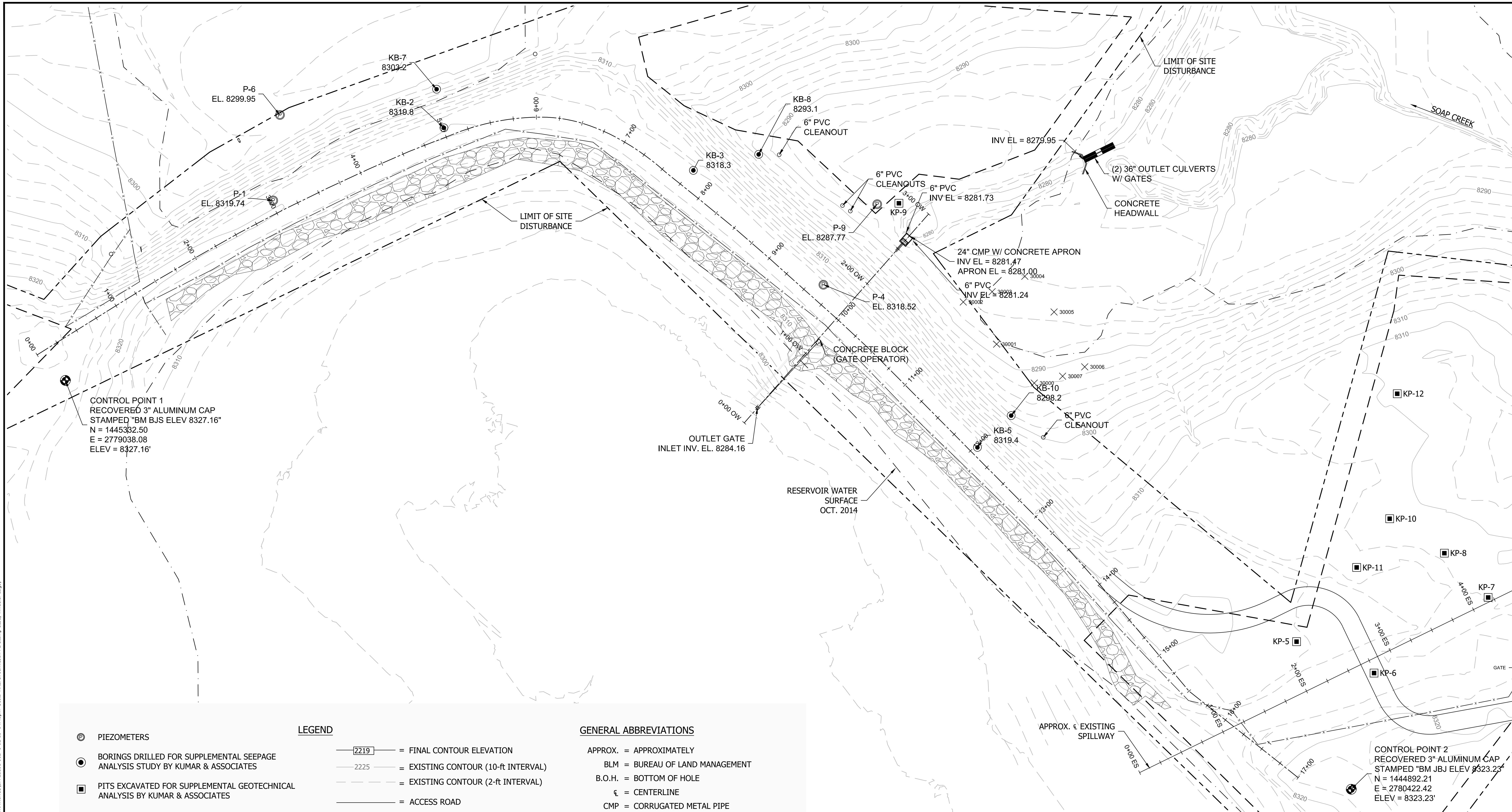


LEGEND

- Ⓟ PIEZOMETERS
- BORINGS DRILLED FOR SUPPLEMENTAL SEEPAGE ANALYSIS STUDY BY KUMAR & ASSOCIATES
- PITS EXCAVATED FOR SUPPLEMENTAL GEOTECHNICAL ANALYSIS BY KUMAR & ASSOCIATES
- = CONTROL POINT
- = HIGH WATER LINE
- = PROPERTY BOUNDARY
- = LIMITS OF SITE DISTURBANCE
- = WATER/WETLAND BOUNDARY
- = BARBED WIRE FENCING
- = BORROW AREA BOUNDARY
- 2219 = FINAL CONTOUR ELEVATION
- 2225 = EXISTING CONTOUR (10-ft INTERVAL)
- = EXISTING CONTOUR (2-ft INTERVAL)
- = ACCESS ROAD
- = BASE COURSE
- = CONCRETE
- = EXISTING RIPRAP
- = NEW RIPRAP
- = SLOPING SURFACE
- = BEDROCK
- = FILTER SAND

SECTION LETTER — A — SHEET WHERE SECTION IS TAKEN (2) / SHEET WHERE SECTION IS SHOWN (2)

DETAIL NUMBER — 1 — SHEET WHERE DETAIL IS TAKEN (2) / SHEET WHERE DETAIL IS SHOWN (2)

GENERAL ABBREVIATIONS

- APPROX. = APPROXIMATELY
- BLM = BUREAU OF LAND MANAGEMENT
- B.O.H. = BOTTOM OF HOLE
- ℄ = CENTERLINE
- CMP = CORRUGATED METAL PIPE
- DIA. = DIAMETER
- EJ = EXPANSION JOINT
- EL. = ELEVATION
- I.E. = INVERT ELEVATION
- T.O. = TOP OF
- TYP. = TYPICAL
- USF&WS = U. S. FISH & WILDLIFE SERVICE

NOTES:

1. BASEMAP BASED ON OCTOBER 2014 SURVEY BY LANDMARK CONSULTANTS, INC.

0 20 50 100 150
Scale in Feet

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

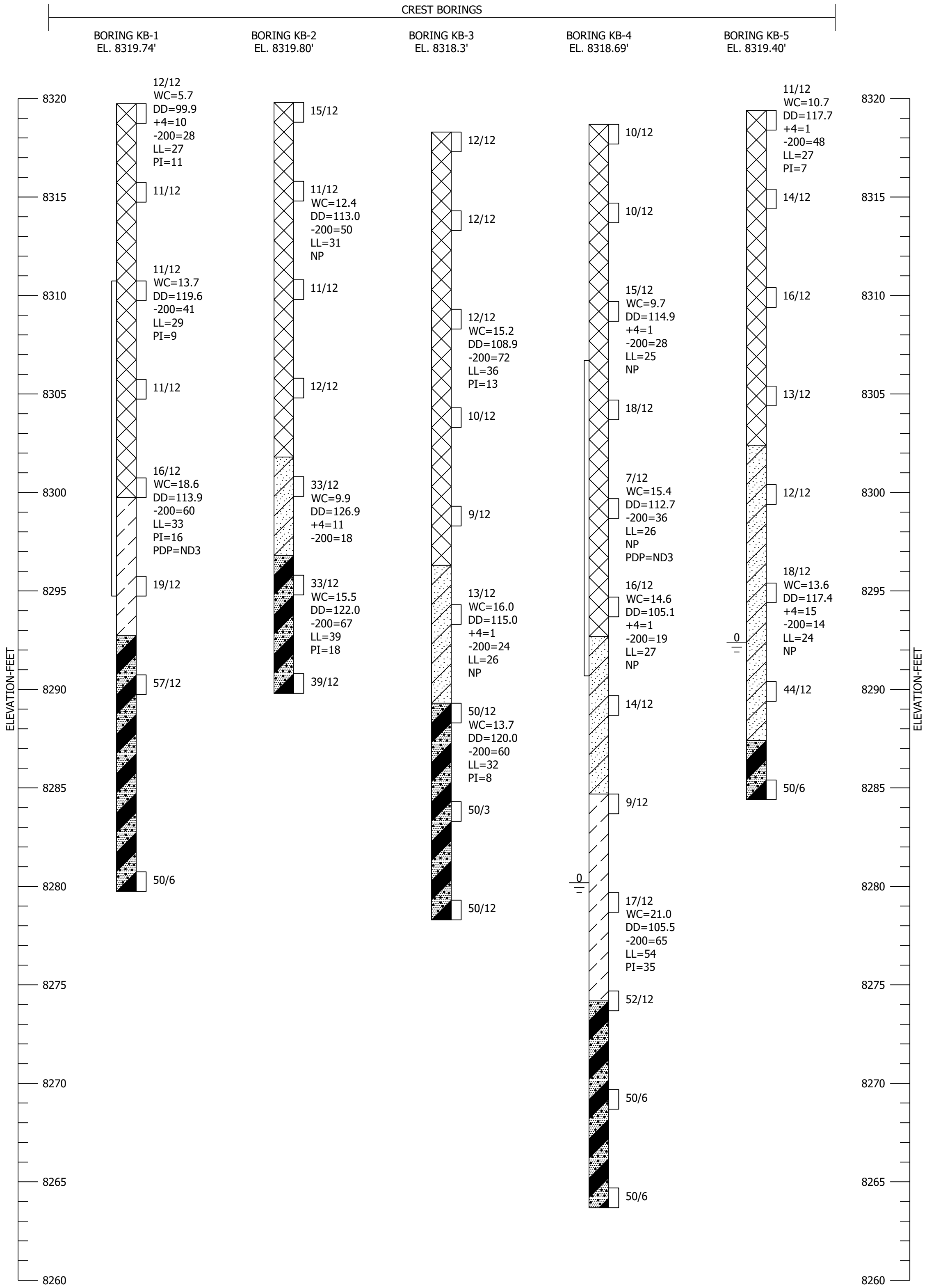
C-1031B

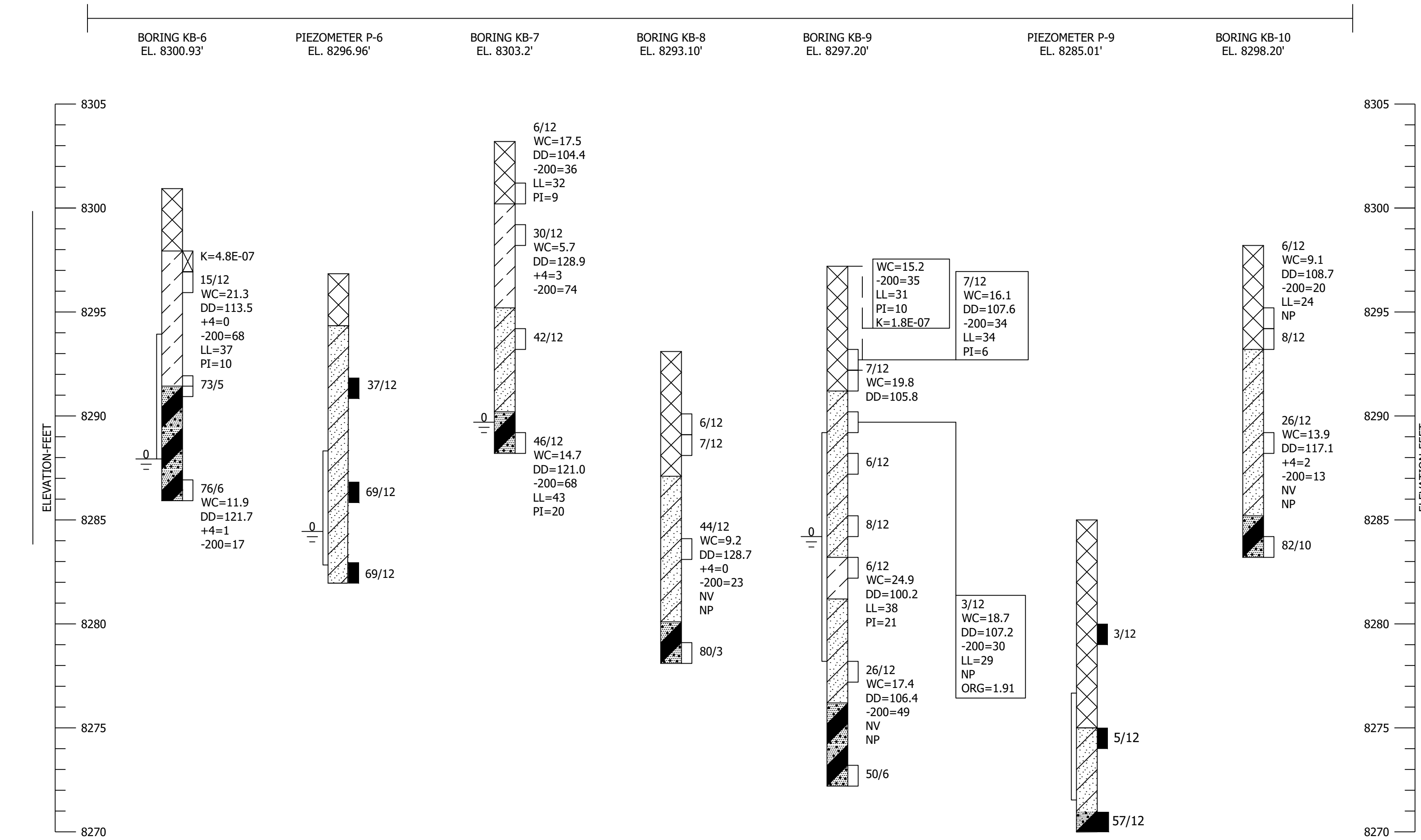
REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R. — G4.0

MACFARLANE DAM REHABILITATION
PRE-CONSTRUCTION SITE PLAN

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	4 OF 21





LEGEND

TOPSOIL.

FILL: SILTY SAND (SM), CLAYEY SAND (SC), SILTY TO CLAYEY SAND (SM-SC), SANDY SILT (ML), LEAN CLAY WITH SAND (CL), AND SANDY LEAN CLAY (CL), APPARENT LOOSE TO MEDIUM DENSE AND STIFF TO VERY STIFF CONSISTENCY BASED ON BLOW COUNTS, MOIST, TAN TO DARK BROWN.

SANDY LEAN CLAY (CL) AND LEAN CLAY WITH SAND (CL), STIFF TO VERY STIFF, MOIST, BROWN-GRAY AND GREEN-GRAY.

FAT CLAY (CH), MOIST, BROWN TO DARK GRAY.

SILTY SAND (SM), VERY LOOSE TO VERY DENSE, FINE TO COARSE SAND WITH VARYING GRAVEL, MOIST, BROWN TO GREEN-BROWN, OCCASIONAL CLAY INTERBEDS.

(APPARENT COALMONT FORMATION), INTERBEDDED CLAYSTONE/SANDSTONE, UNCEMENTED TO SLIGHTLY CEMENTED SANDSTONE, DECOMPOSED TO SEVERELY WEATHERED CLAYSTONE, SOFT, SANDSTONE VARYING FROM FINE-GRAINED TO CONGLOMERITIC, ARKOSIC.

SANDSTONE BEDROCK, LAYER WITHIN THE COALMONT FORMATION, DECOMPOSED TO SEVERELY WEATHERED ARKASIC SANDSTONE, GREENISH BROWN TO LIGHT BROWN, NON- TO WEAKLY CEMENTED.

CLAYSTONE BEDROCK, LAYER WITHIN THE COALMONT FORMATION, DECOMPOSED TO SEVERELY WEATHERED CLAYSTONE, GRAY TO GREENISH BROWN.

SILSTONE BEDROCK, LAYER WITHIN THE COALMONT FORMATION, DECOMPOSED TO SEVERELY WEATHERED SILSTONE BEDROCK, GRAY TO GREENISH BROWN.

DRIVE SAMPLE, 2-INCH I.D. CALIFORNIA LINER SAMPLE.

DRIVE SAMPLE, 1.75-INCH I.D. SPLIT SPOON STANDARD PENETRATION TEST.

SHELBY TUBE SAMPLE.

INDICATES SCREEN SECTION OF PERMANENT PIEZOMETER CONSTRUCTED IN BORING AFTER EXPLORATION DRILLING.

12/12 DRIVE SAMPLE BLOW COUNT. INDICATES THAT 12 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE THE SAMPLER 12 INCHES.

DISTURBED BULK SAMPLE.

0 DEPTH TO WATER LEVEL ENCOUNTERED AT THE TIME OF DRILLING.

PRACTICAL AUGER REFUSAL.

NOTES

1. THE EXPLORATORY BORINGS WERE DRILLED ON SEPTEMBER 24 TO 26, 2014 WITH A 4-INCH DIAMETER CONTINUOUS FLIGHT POWER AUGER.
2. THE LOCATIONS AND ELEVATIONS OF THE EXPLORATORY BORINGS WERE MEASURED BY INSTRUMENT SURVEY PERFORMED BY LANDMARK CONSULTANTS.
3. THE EXPLORATORY BORING LOCATIONS AND ELEVATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
4. THE LINES BETWEEN MATERIALS SHOWN ON THE EXPLORATORY BORING LOGS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES AND THE TRANSITIONS MAY BE GRADUAL.
5. GROUND WATER LEVELS SHOWN ON THE LOGS WERE MEASURED AT THE TIME AND UNDER CONDITIONS INDICATED. FLUCTUATIONS IN THE WATER LEVEL MAY OCCUR WITH TIME.
6. BORINGS KB-6 TO KB-10 WERE FILLED AND ABANDONED ON JULY 24, 2017
7. PIEZOMETERS P-6 AND P-9 WERE INSTALLED ON NOVEMBER 6, 2017. SEE DRAWING C14 FOR TOP OF PIEZOMETER PVC ELEVATIONS.
8. LABORATORY TEST RESULTS:

WC	=	WATER CONTENT (%) (ASTM D 2216);
DD	=	DRY DENSITY (pcf) (ASTM D 2216);
+4	=	PERCENTAGE RETAINED ON NO. 4 SIEVE (ASTM D 422);
-200	=	PERCENTAGE PASSING NO. 200 SIEVE (ASTM D 1140);
LL	=	LIQUID LIMIT (ASTM D 4318);
PI	=	PLASTICITY INDEX (ASTM D 4318);
NP	=	NON-PLASTIC (ASTM D 4318);
NV	=	NO LIQUID LIMIT VALUE (ASTM D 4318);
Org	=	ORGANIC CONTENT (%) (AASHTO T 267);
k	=	PERMEABILITY (cm/sec);
PDP	=	PINHOLE DISPERSION POTENTIAL (ASTM D 4647).

COLORADO LICENSED PROFESSIONAL ENGINEER STEPHEN L. JAMIESON 25028 02/26/2016

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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G5.0

MACFARLANE DAM REHABILITATION
SUBSURFACE BORING LOGS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	5 OF 21

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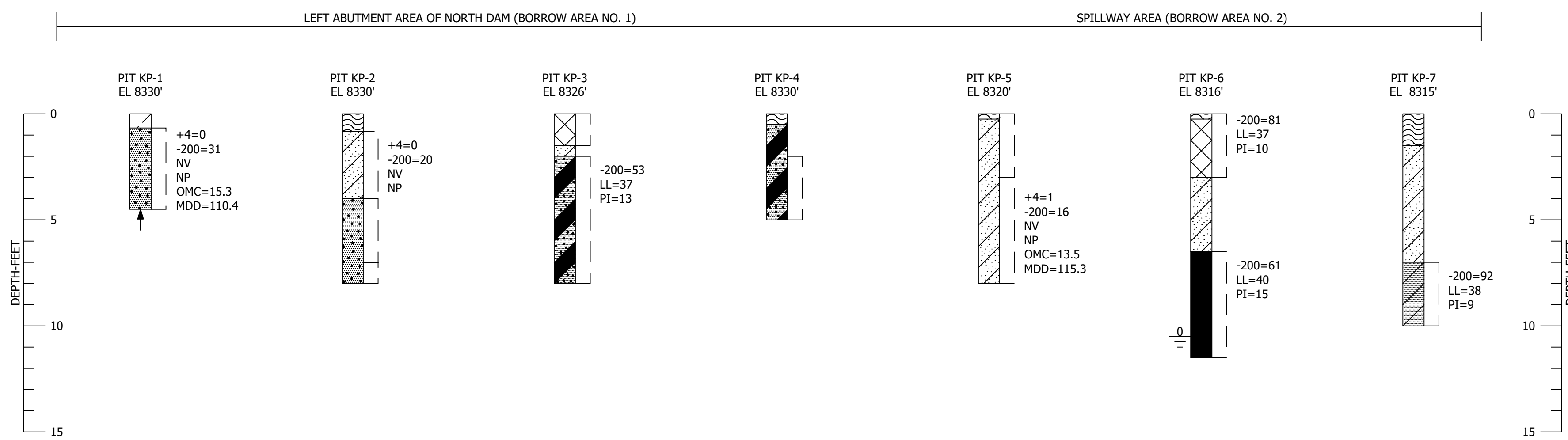
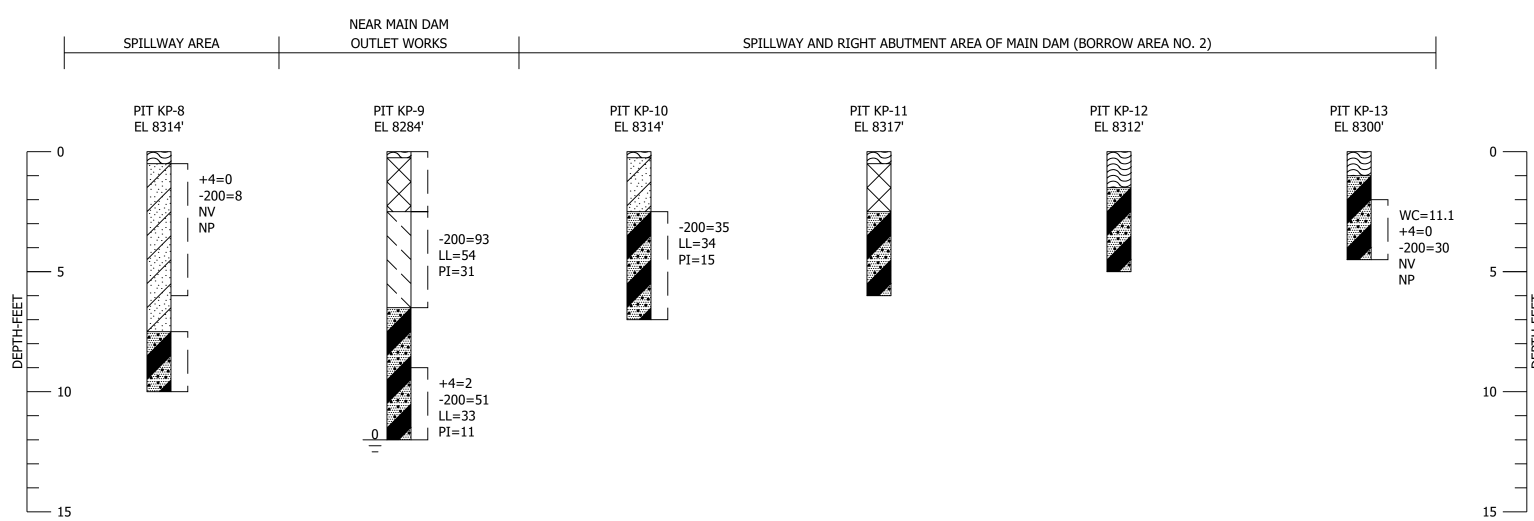
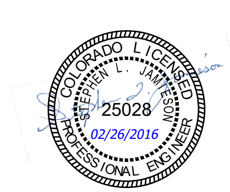




NOTES

1. THE EXPLORATORY PITS WERE EXCAVATED ON MAY 7, 2015 WITH A CASE 590 SUPER N BACKHOE EXCAVATOR.
2. THE LOCATIONS AND ELEVATIONS OF THE TEST PITS WERE MEASURED BY INSTRUMENT SURVEY PERFORMED BY LANDMARK CONSULTANTS. THE ELEVATIONS OF THE PITS WERE MEASURED BY INTERPOLATION BETWEEN THE CONTOURS ON THE PLAN PROVIDED.
3. THE TEST PIT LOCATIONS AND ELEVATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
4. THE LINES BETWEEN MATERIALS SHOWN ON THE EXPLORATORY BORING AND PIT LOGS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES AND THE TRANSITIONS MAY BE GRADUAL.
5. GROUND WATER LEVELS SHOWN ON THE LOGS WERE MEASURED AT THE TIME AND UNDER CONDITIONS INDICATED. FLUCTUATIONS IN THE WATER LEVEL MAY OCCUR WITH TIME.
6. LABORATORY TEST RESULTS:
   - WC = WATER CONTENT (%) (ASTM D 2216);
   - DD = DRY DENSITY (pcf) (ASTM D 2216);
   - +4 = PERCENTAGE RETAINED ON NO. 4 SIEVE (ASTM D 422);
   - -200 = PERCENTAGE PASSING NO. 200 SIEVE (ASTM D 1140);
   - LL = LIQUID LIMIT (ASTM D 4318);
   - PI = PLASTICITY INDEX (ASTM D 4318);
   - NP = NON-PLASTIC (ASTM D 4318);
   - NV = NO LIQUID LIMIT VALUE (ASTM D 4318);
   - Org = ORGANIC CONTENT (%) (AASHTO T 267);
   - k = PERMEABILITY (cm/sec);
   - PDP = PINHOLE DISPERSION POTENTIAL (ASTM D 4647).



C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R. G6.0

MACFARLANE DAM REHABILITATION
TEST PIT LOGS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	6 OF 21

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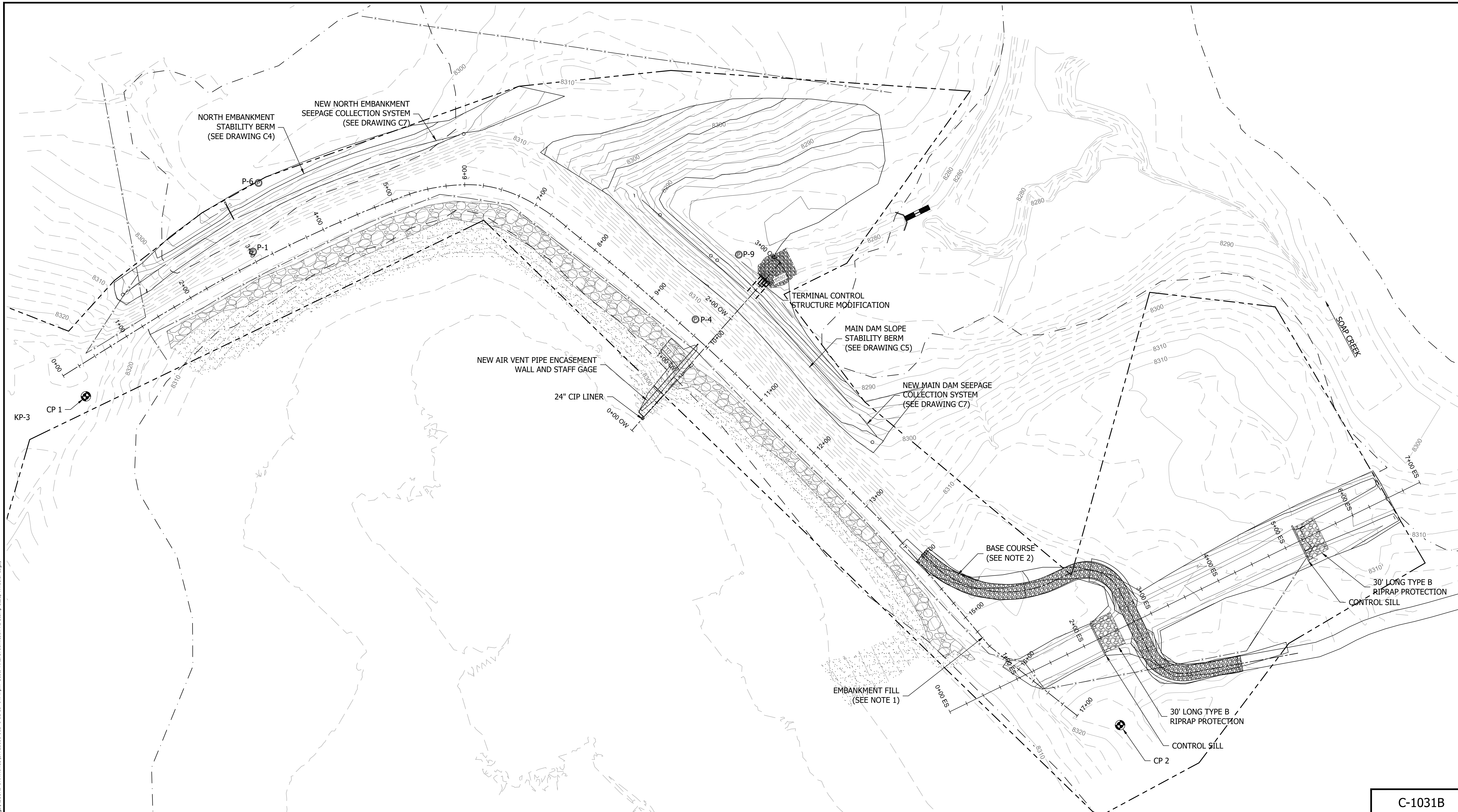


NOTES:

1. CONTRACTOR TO FILL IN LOW AREA BETWEEN DAM CREST AND SPILLWAY TO A MINIMUM EL. OF 8320.
2. CONTRACTOR RESPONSIBLE FOR BASE COURSE IN AREA INDICATED (ACCESS ROAD APPROACH, NEWLY CONSTRUCTED SPILLWAY AND UP TO DAM CREST). FINAL DAM CREST AND ACCESS ROAD BASE COURSE TO BE ADDED BY THE THE FWS MAINTENANCE TEAM AND IS NOT PART OF THE CONSTRUCTION CONTRACT.
3. CONTRACTOR TO PROJECT PIEZOMETERS IN KB-1 AND KB-4 AND ABANDON PIEZOMETERS IN KB-6 AND KB-9 PRIOR TO EARTHWORK OPERATIONS PER SPECIFICATION 13100. CONTRACTOR SHALL REPLACE PIEZOMETERS IN KB-6 AND KB-9 AFTER EARTHWORK OPERATIONS ARE COMPLETE PER SPECIFICATION 13100.

COLORADO LICENSED PROFESSIONAL ENGINEER STEPHEN L. JAMIESON 25028 02/26/2016

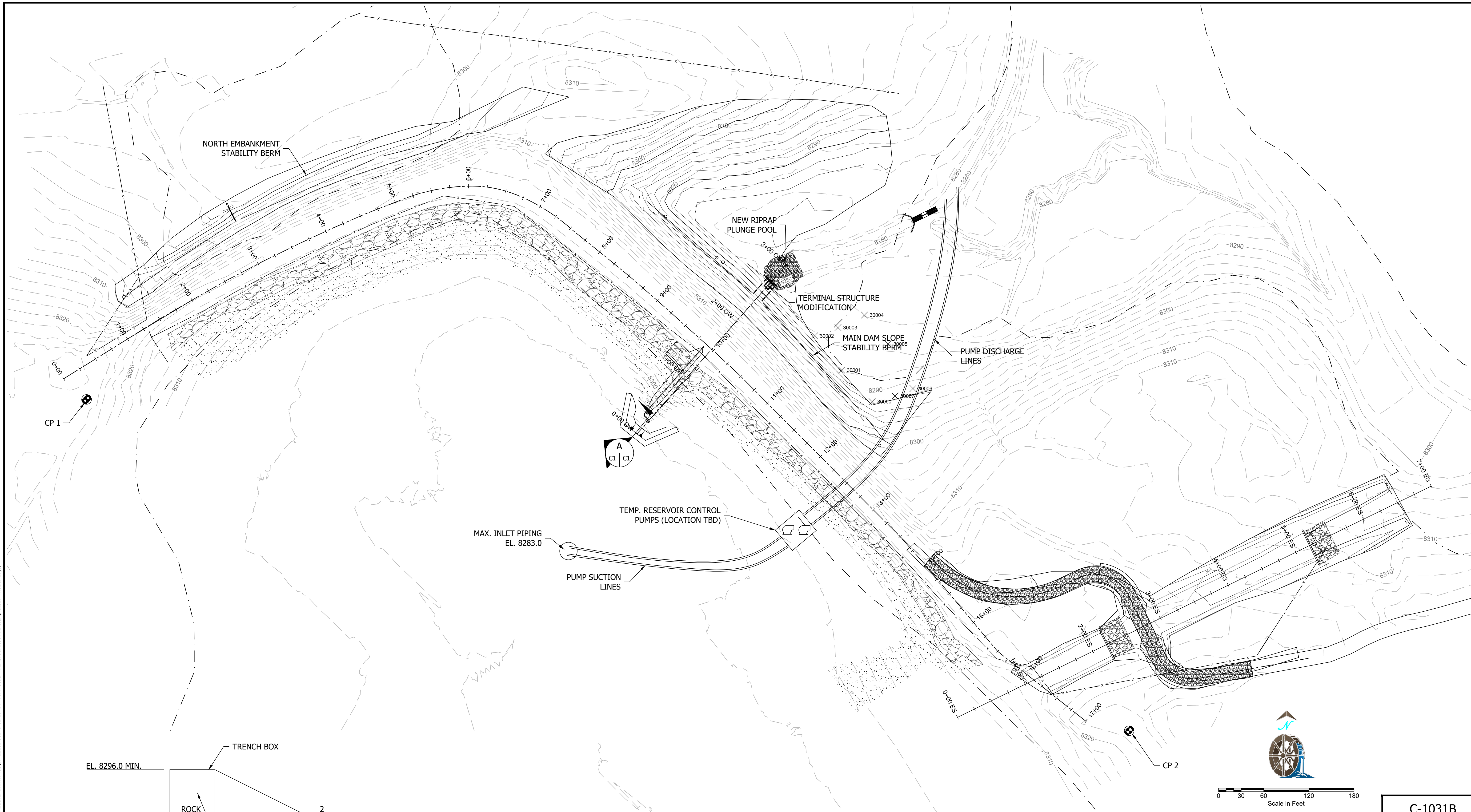
C-1031B

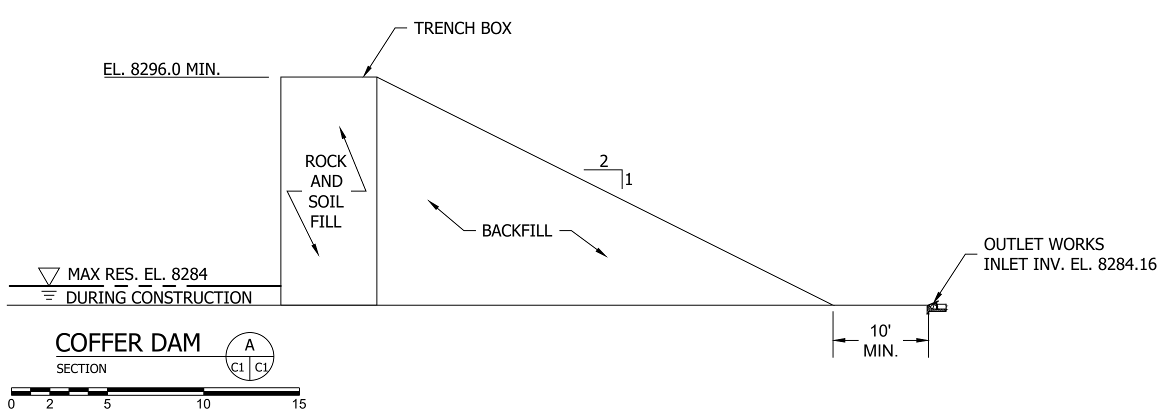
REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R. G7.0

MACFARLANE DAM REHABILITATION
GENERAL PLAN OF MODIFICATIONS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	7 OF 21





NOTES:

1. RESERVOIR LEVEL TO BE MAINTAINED BY THE CONTRACTOR AT EL. 8284 OR LOWER DURING OUTLET WORKS AND TERMINAL STRUCTURE CONSTRUCTION.
2. REFER TO SPECIFICATIONS SECTION 02065 FOR RESERVOIR CONTROL REQUIREMENTS.
3. THE TEMPORARY RESERVOIR CONTROL SHOWN ON THIS DRAWING IS FOR INFORMATION ONLY. THE CONTRACTOR MAY PROPOSE ALTERNATE RESERVOIR CONTROL PLANS FOR REVIEW BY THE ENGINEER. THE CONTRACTOR IS ULTIMATELY RESPONSIBLE FOR RESERVOIR CONTROL DURING OUTLET WORKS AND TERMINAL STRUCTURE CONSTRUCTION.
4. TEMPORARY RESERVOIR CONTROL IS REQUIRED DURING WORK ON THE OUTLET WORKS AND TERMINAL STRUCTURE MODIFICATIONS.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-312018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R.

C1.0

MACFARLANE DAM REHABILITATION
TEMPORARY RESERVOIR CONTROL PLAN

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	8 OF 21

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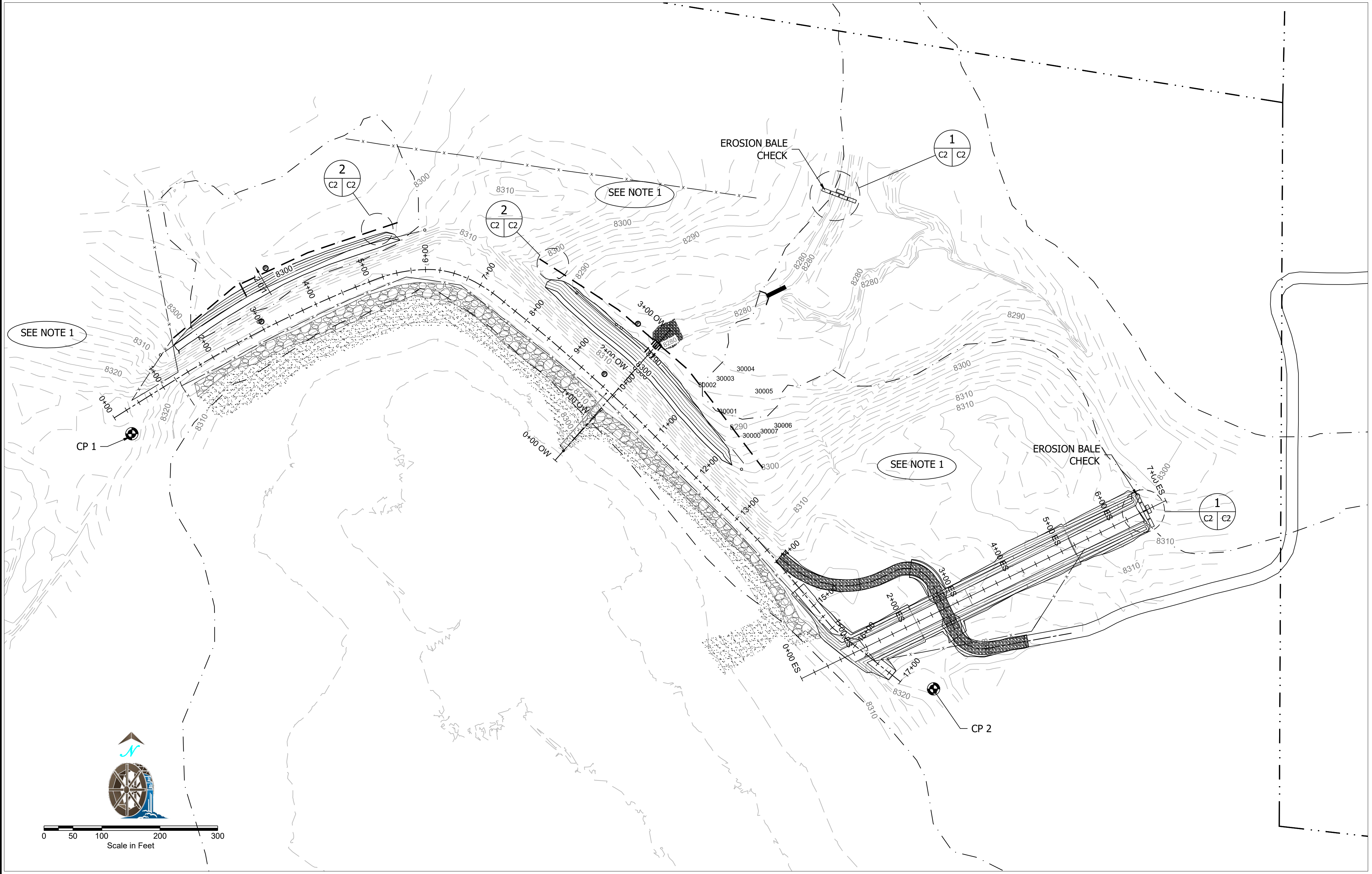
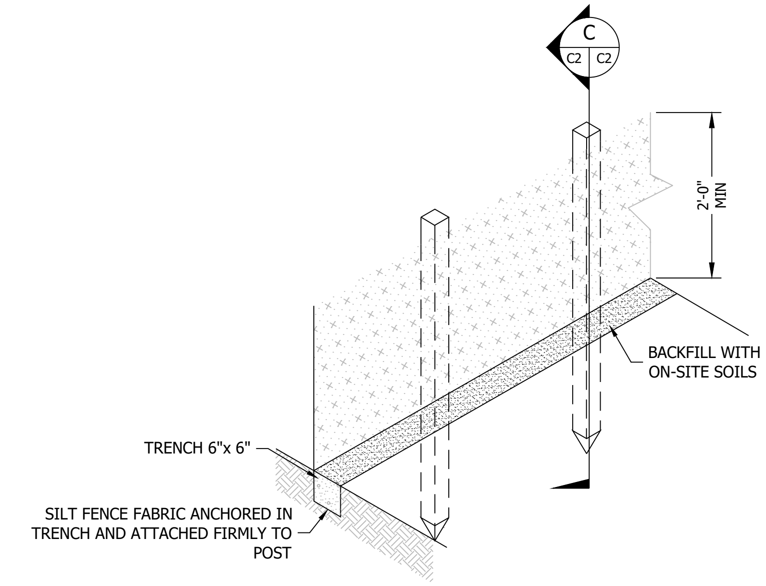
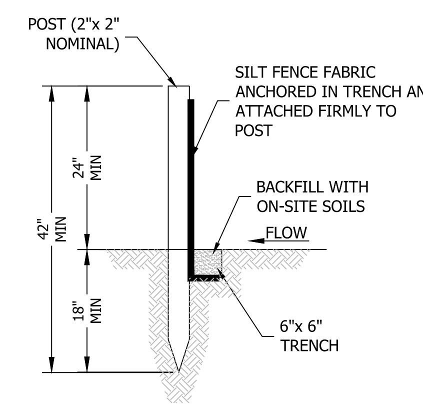
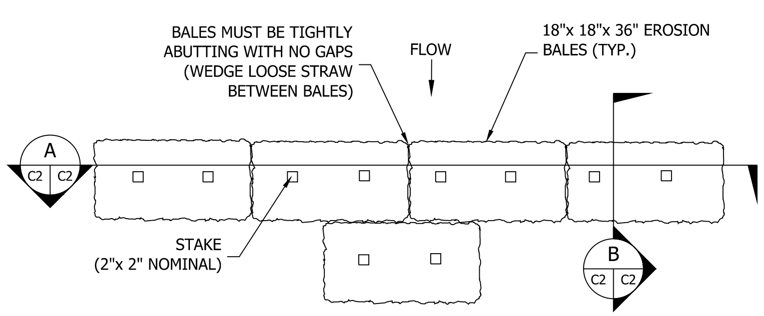




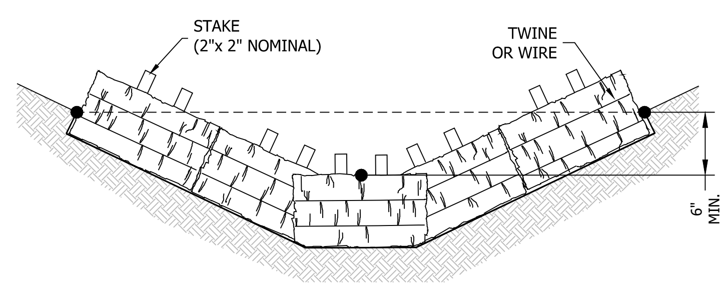
SILT FENCE
INSTALLATION DETAIL (N.T.S.) 2 C2 C2



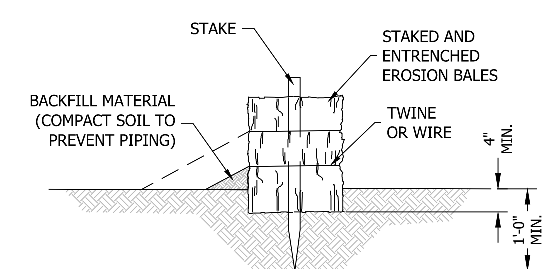
SILT FENCE
SECTION (N.T.S.) C C2 C2



EROSION BALE CHECK
DETAIL (N.T.S.) 1 C2 C2



EROSION BALE CHECK
SECTION (N.T.S.) A C2 C2



EROSION BALE CHECK
SECTION (N.T.S.) B C2 C2

NOTES:
1. SILT FENCE REQUIRED AROUND CONTRACTORS BORROW AREAS AND STAGING AREAS.
2. THE EROSION CONTROL PLANS AND DETAILS SHOWN ON THE DRAWING ARE THE MINIMUM REQUIREMENTS DURING CONSTRUCTION. SPECIFIC PERMITS MAY REQUIRE ADDITIONAL FEATURES AND MONITORING.
3. VEHICLE TRACKING PAD REQUIRED AT HIGHWAY 125 ENTRANCE TO ACCESS ROAD. SEE DETAIL 1 ON DRAWING C12.

COLORADO LICENSED PROFESSIONAL ENGINEER
STEPHEN L. JAMIESON
25028
02/26/2016

C-1031B

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1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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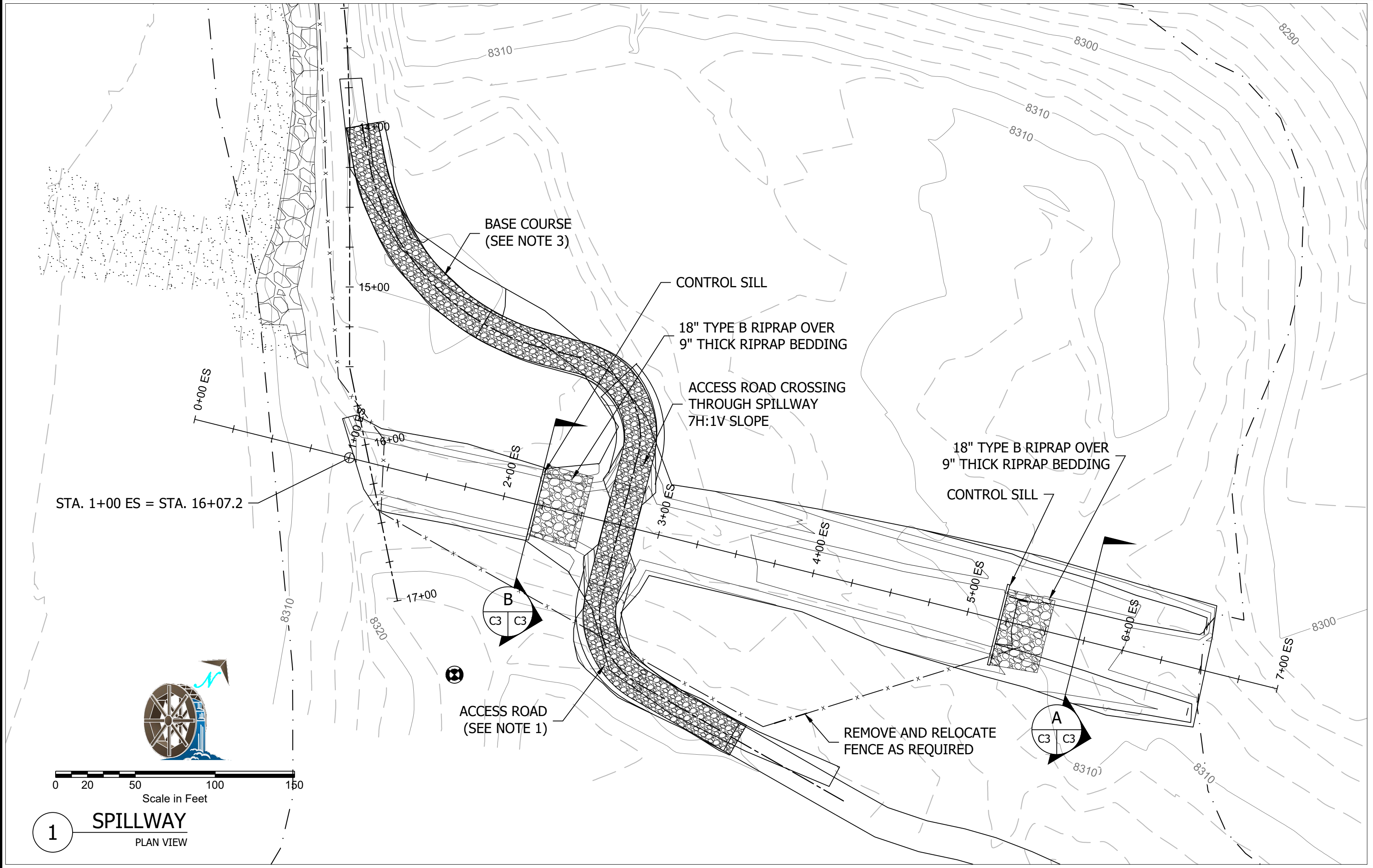
C2.0

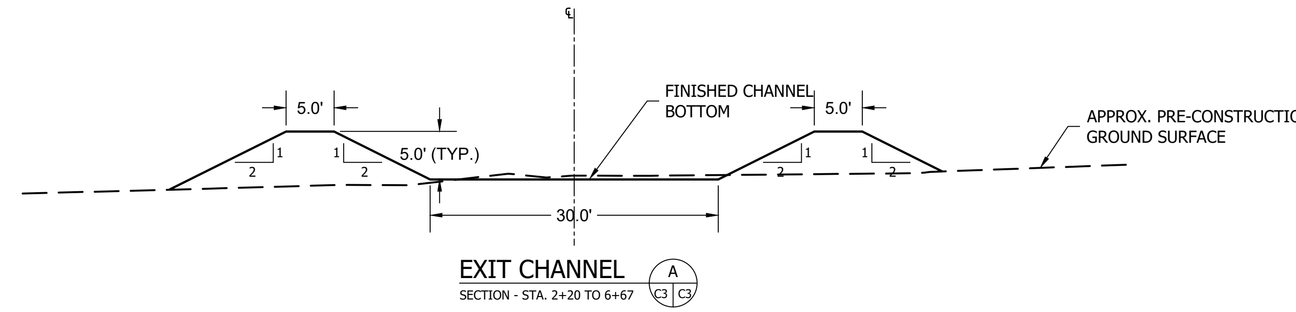
MACFARLANE DAM REHABILITATION
EROSION CONTROL PLAN AND DETAILS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	9 OF 21



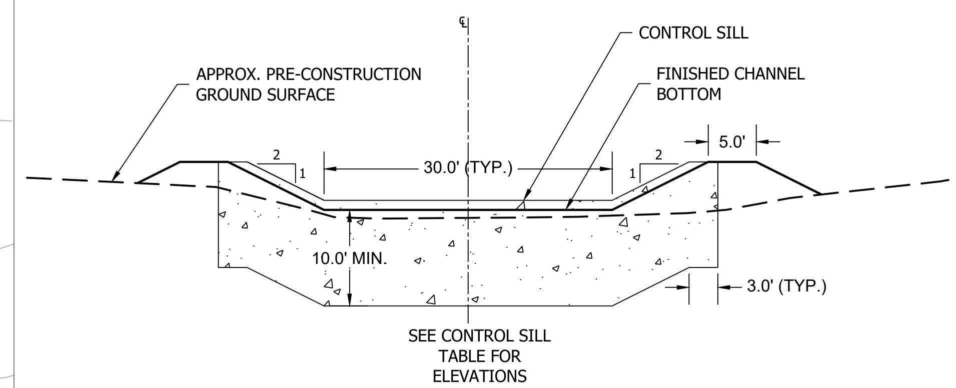
1 SPILLWAY

PLAN VIEW



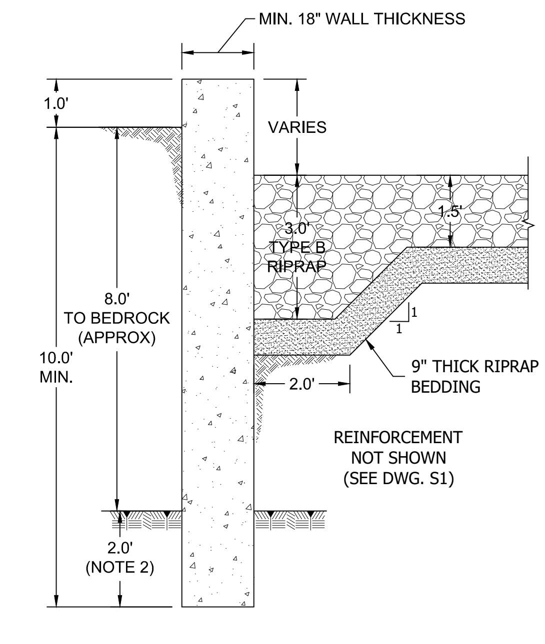
EXIT CHANNEL (A C3 C3)

SECTION - STA. 2+20 TO 6+67



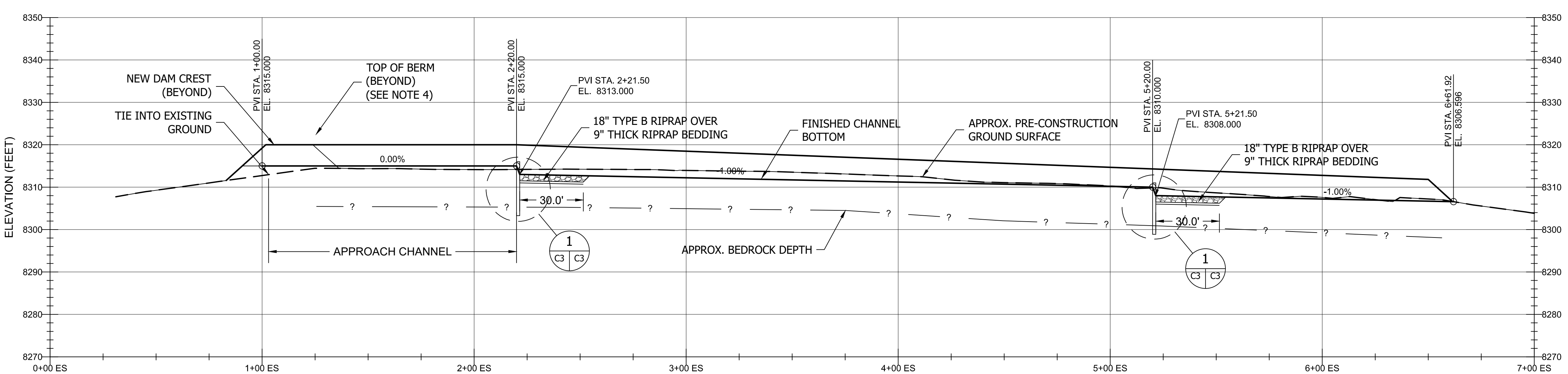
CONTROL SILL (B C3 C3)

SECTION - STA. 2+20 & 5+20



SPILLWAY CONTROL SILL (1 C3 C3)

TYPICAL DETAIL



SPILLWAY

PROFILE

CONTROL SILL TABLE

STATION	APPROACH CHANNEL CONCR EL.	CREST EL.	DISCHARGE CHANNEL EL.	LEFT BANK	RIGHT BANK
2+20	8315.0	8316.0	8313.0	8319.0	8319.0
5+20	8310.0	8311.0	8308.0	8314.0	8314.0

NOTES:

1. RECONSTRUCT ACCESS ROAD TO CROSS CHANNEL DIRECTLY DOWNSTREAM OF RIPRAP. CONSTRUCT CHANNEL SIDE SLOPES TO 7H:1V AT ACCESS ROAD CROSSINGS.
2. BOTTOM OF SPILLWAY CUTOFF WALL SHALL BE CUT 2-FEET INTO BEDROCK.
3. CONTRACTOR RESPONSIBLE FOR BASE COURSE IN AREA INDICATED (ACCESS ROAD APPROACH, THROUGH NEWLY CONSTRUCTED SPILLWAY AND UP TO DAM CREST).
4. CONSTRUCT T.O. BERM CONSISTENTLY 5-FEET ABOVE CHANNEL INVERT.

COLORADO LICENSED PROFESSIONAL ENGINEER STEPHEN L. JAMIESON 25028 02/26/2016

C-1031B

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0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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C3.0

MACFARLANE DAM REHABILITATION

SPILLWAY - PLAN, PROFILE AND SECTIONS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	10 OF 21

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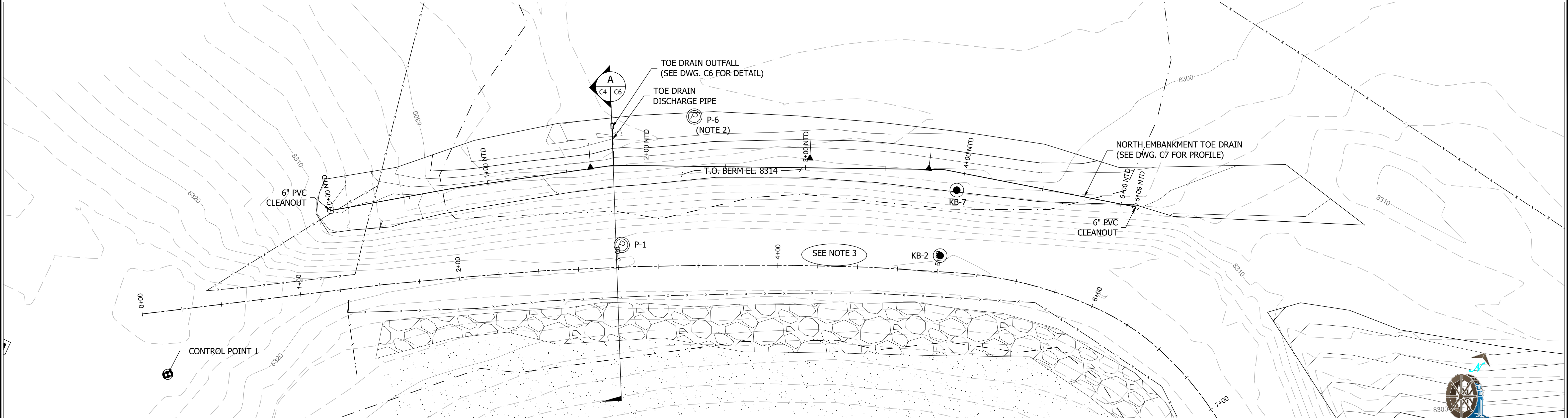
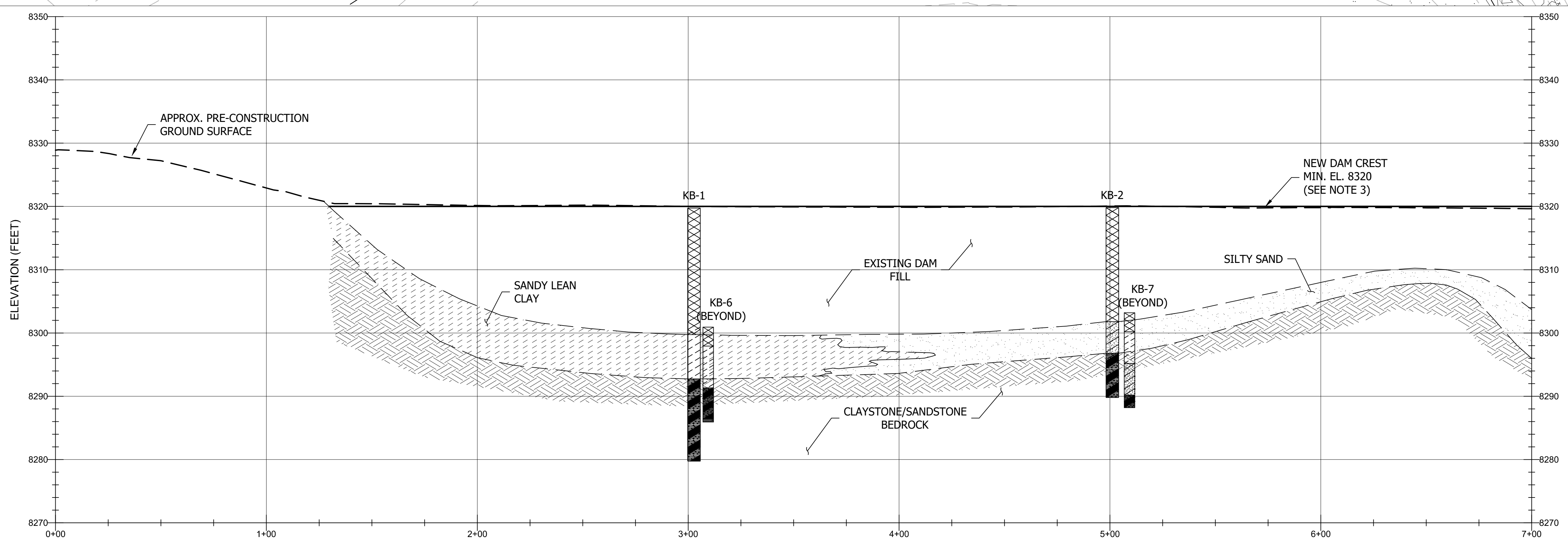


NORTH EMBANKMENT MODIFICATIONS
PLAN



NORTH EMBANKMENT
PROFILE

NOTES:
1. SUBSURFACE STRATIGRAPHY IS APPROXIMATE.
2. PIEZOMETER LOCATED IN KB-6 WAS REPLACED BY CONTRACTOR, SEE DWG C13 FOR DETAIL.
3. FINAL BASE COURSE PLACED TO ELEV. 8320 NOT REQUIRED BY CONSTRUCTION CONTRACT. WORK WILL BE COMPLETED BY U.S. FISH & WILDLIFE SERVICE MAINTENANCE TEAM.

COLORADO LICENSED
STEPHEN L. JAMIESON
25028
02/26/2016
PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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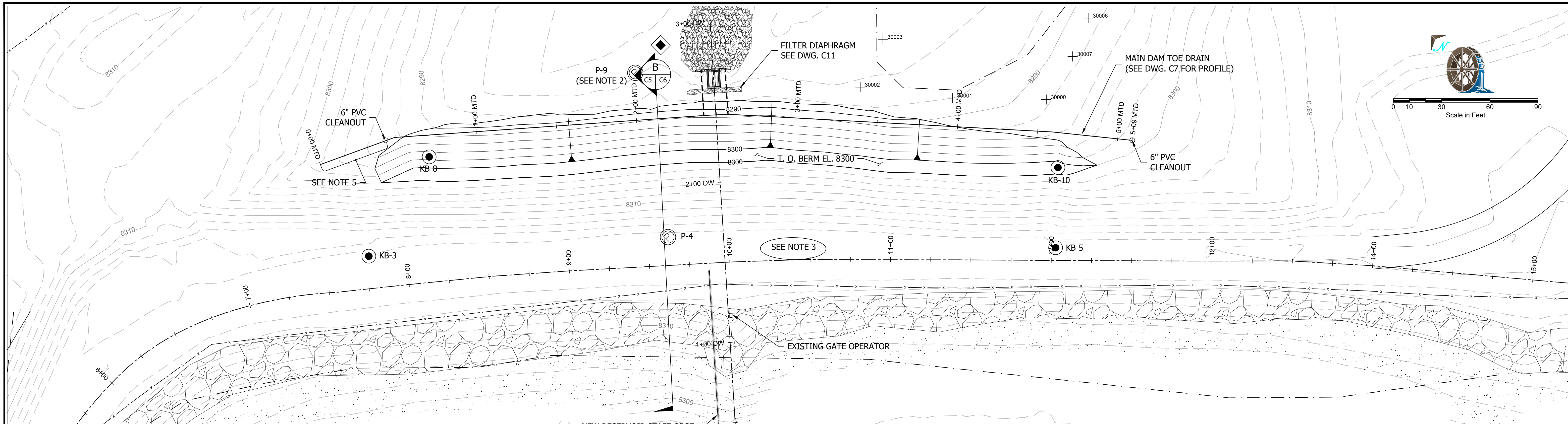
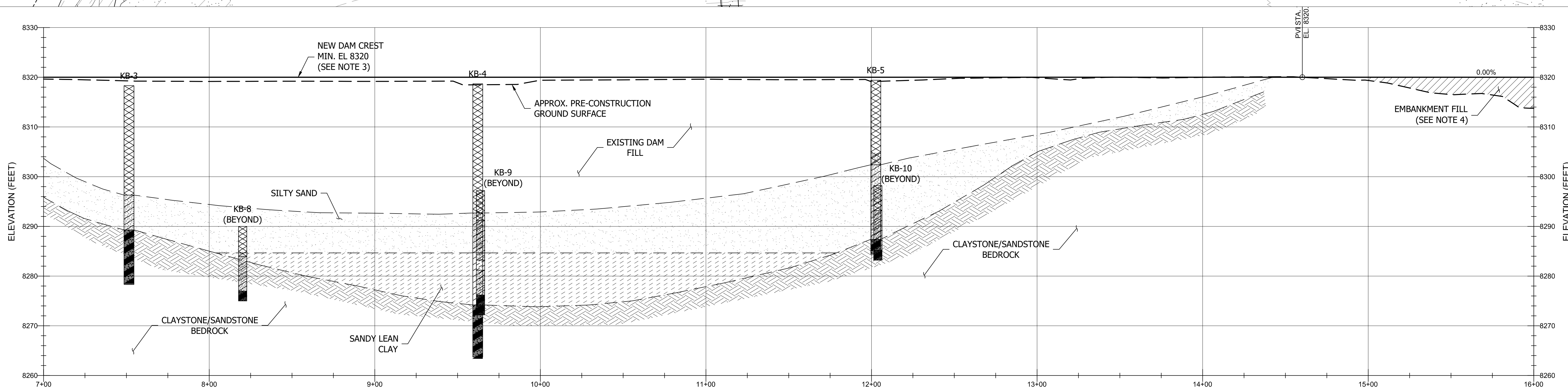
C4.0

MACFARLANE DAM REHABILITATION
NORTH EMBANKMENT - PLAN AND PROFILE

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	11 OF 21



MAIN DAM MODIFICATIONS
PLAN



MAIN DAM
PROFILE

NOTES:
1. SUBSURFACE STRATIGRAPHY IS APPROXIMATE.
2. PIEZOMETER KB-9 WAS REPLACED BY CONTRACTOR. SEE DWG C14 FOR DETAIL.
3. FINAL BASE COURSE PLACED TO EL. 8320 NOT REQUIRED BY CONSTRUCTION CONTRACT. WORK WILL BE COMPLETED BY U.S. FISH & WILDLIFE SERVICE MAINTENANCE TEAM.
4. CONTRACTOR TO PLACE FILL TO CREST EL. 8320 IN LOW AREA BETWEEN SPILLWAY AND EXISTING DAM CREST.
5. FINGER DRAIN INSTALLED FROM 0+00 MTD TO CLEANOUT AT STA. 0+43 MTD.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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C5.0

MACFARLANE DAM REHABILITATION
MAIN DAM - PLAN AND PROFILE

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	12 OF 21

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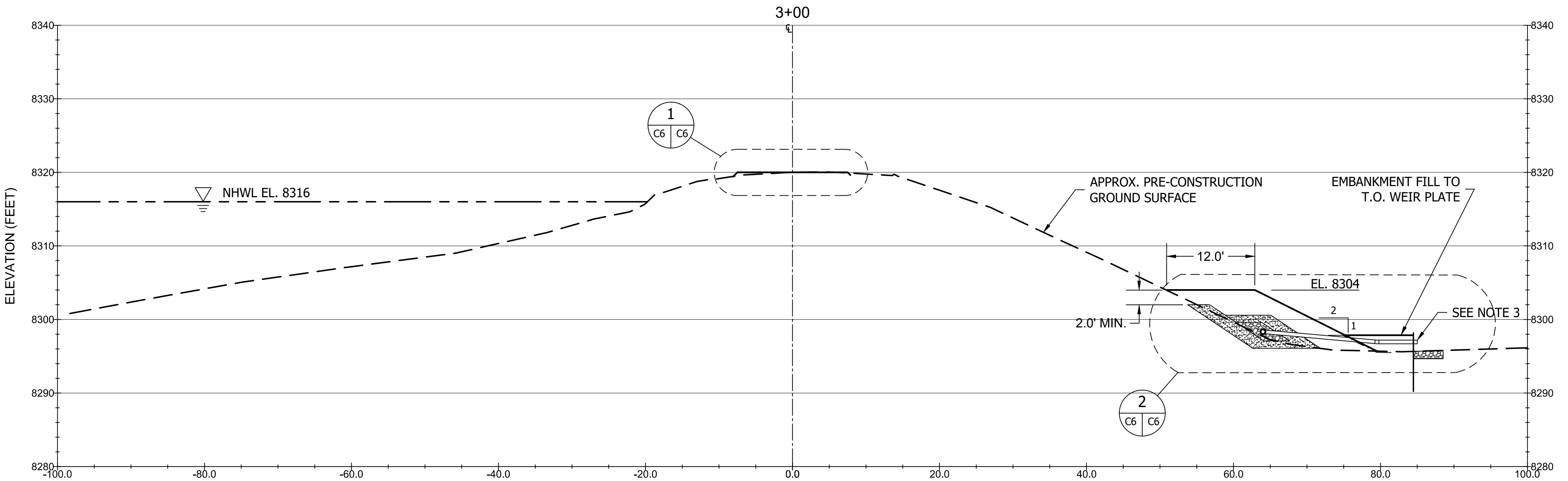
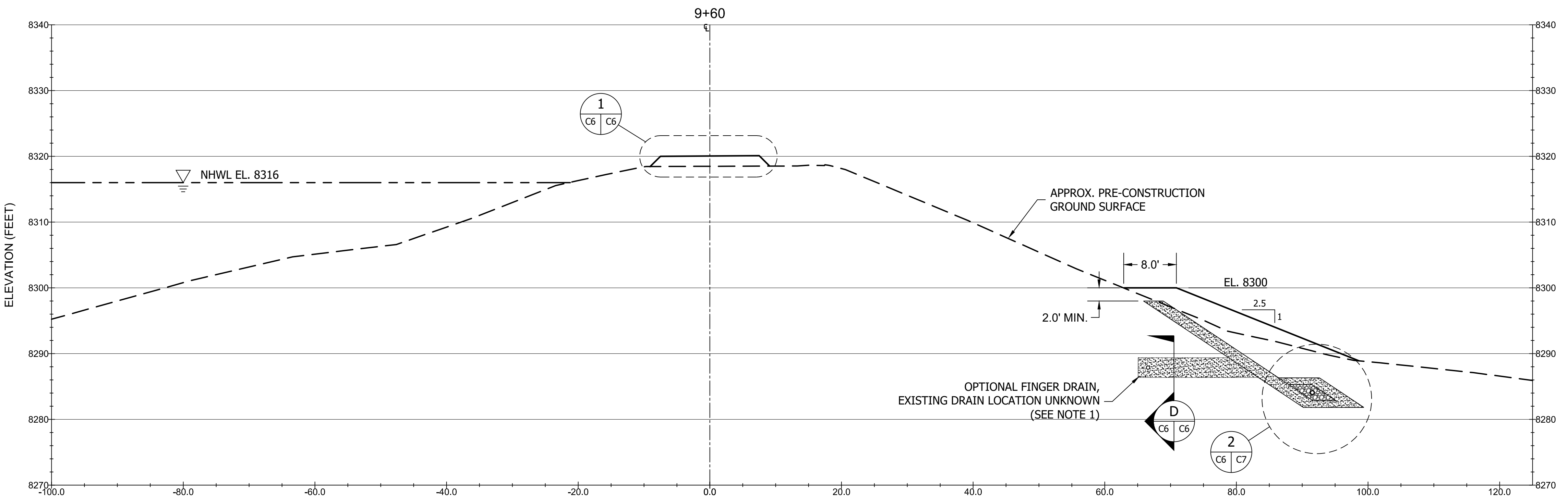


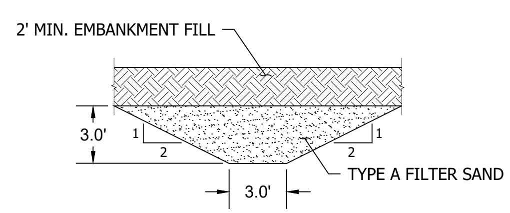
NORTH EMBANKMENT (A, C4 / C6)

MAXIMUM SECTION @ STA. 3+00



MAIN DAM (B, C5 / C6)

MAXIMUM SECTION @ STA. 9+60



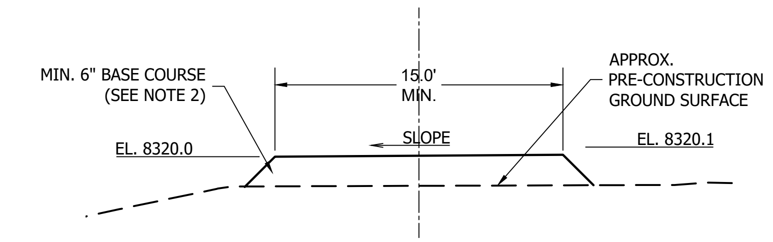
OPTIONAL FINGER DRAIN (D, C6 / C6)

TYPICAL SECTION

Scale in Feet: 0 2 5 10 15

NOTES:

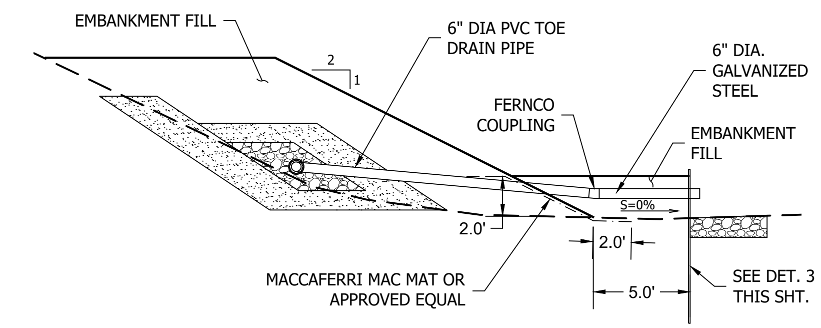
1. OPTIONAL TYPE A FILTER SAND FINGER DRAIN TO BE CONSTRUCTED AND DIRECTED AS NEEDED BY THE ENGINEER.
2. THIS WORK IS NOT REQUIRED BY CONSTRUCTION CONTRACT. WORK WILL BE COMPLETED BY U.S. FISH & WILDLIFE SERVICE MAINTENANCE TEAM.
3. INSTALL PLASTIC WAFER SWING CHECK VALVE TO GALVANIZED PIPE.



EMBANKMENT CREST (1, C6 / C6)

TYPICAL DETAIL

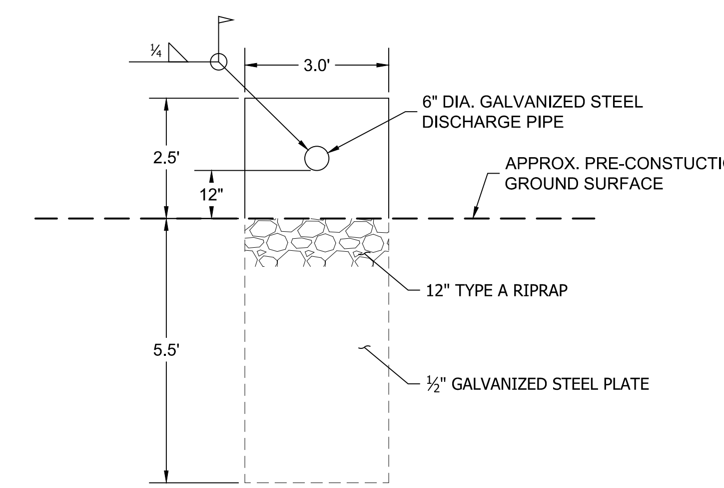
Scale in Feet: 0 2 5 10 15



NORTH EMBANKMENT CHIMNEY DRAIN OUTFALL (2, C6 / C6)

TYPICAL DETAIL

Scale in Feet: 0 2 5 10 15



NORTH EMBANKMENT TOE DRAIN OUTFALL (3, C13 / C13)

DETAIL

Scale in Feet: 0 1 2 4 6

C-1031B

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C6.0

MACFARLANE DAM REHABILITATION

EARTHWORK AND TOE DRAINS - SECTIONS AND DETAILS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	13 OF 21

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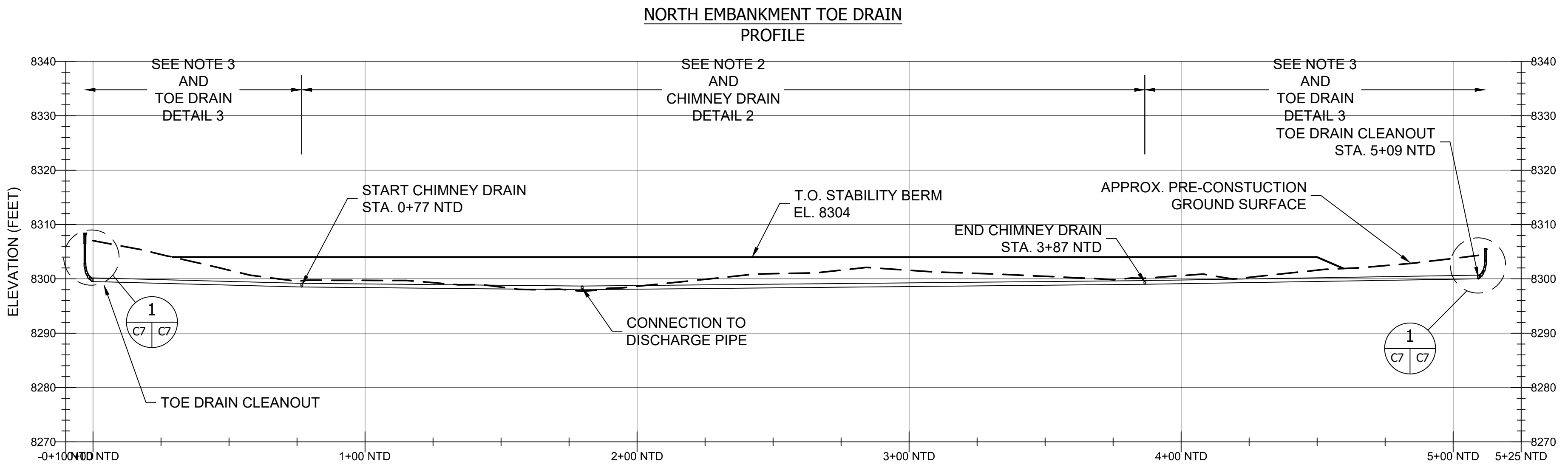
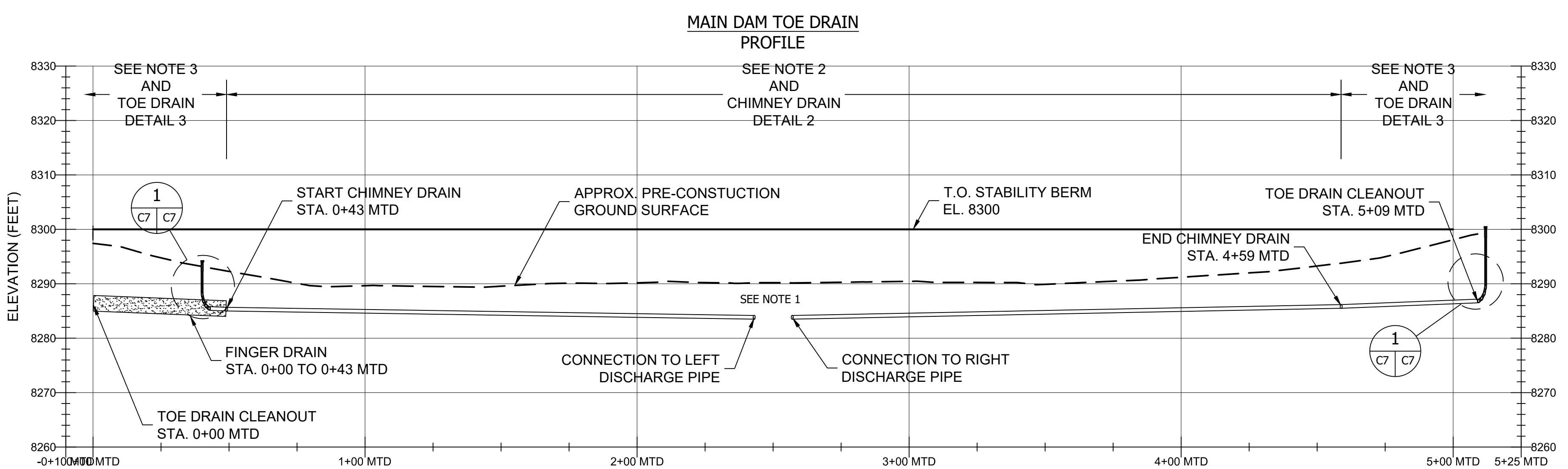


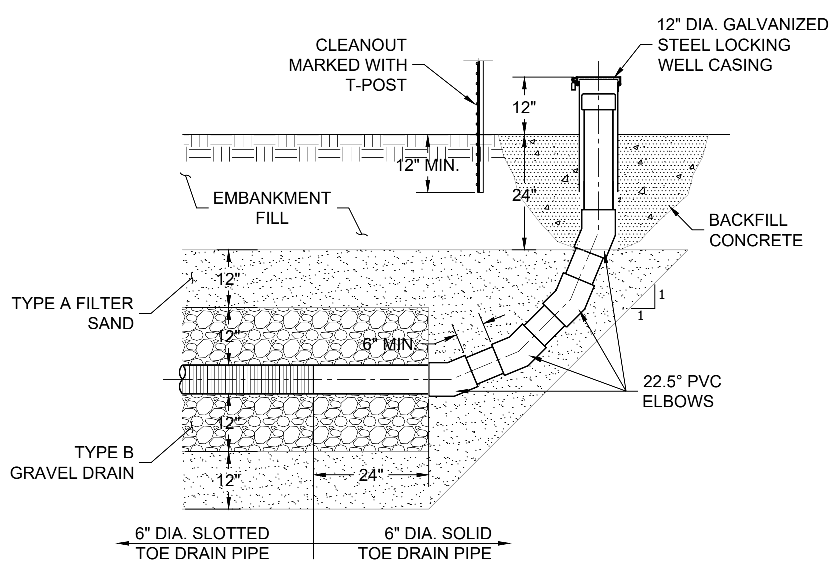
NORTH EMBANKMENT TOE DRAIN PIPE LAYOUT SCHEDULE

	NORTHING	EASTING	DRAIN PIPE INVERT ELEVATION (FT)	APPROX. STATION	COMMENT
LEFT TOE DRAIN	1445468.6	2779087.3	8299.5	0+00 NTD	B.O. CLEANOUT
	1445513.0	2779150.0	8298.5	0+77 NTD	START CHIMNEY DRAIN
	1445569.4	2779236.2	8298.0	1+79.8 NTD	CONNECTION TO DISCHARGE PIPE
	1445593.0	2779223.9	8295.9	1+79.8 NTD	D/S END OF DISCHARGE PIPE
RIGHT TOE DRAIN	1445593.0	2779223.9	8295.9	1+79.8 NTD	D/S END OF DISCHARGE PIPE
	1445569.4	2779236.2	8298.0	1+79.8 NTD	CONNECTION TO DISCHARGE PIPE
	1445654.4	2779424.9	8299.0	3+87 NTD	END CHIMNEY DRAIN
	1445684.0	2779543.8	8300.0	5+09.3 NTD	B.O. CLEANOUT

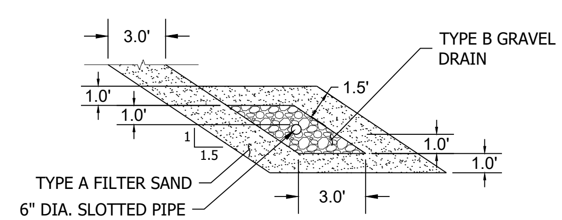


MAIN DAM TOE DRAIN PIPE LAYOUT SCHEDULE

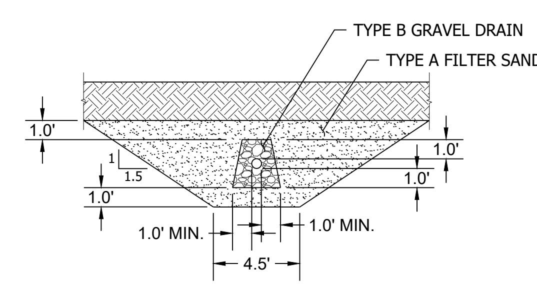
	NORTHING	EASTING	DRAIN PIPE INVERT ELEVATION (FT)	APPROX. STATION	COMMENT
LEFT TOE DRAIN	1445620.4	2779733.2	8286.0	0+00 MTD	B.O. CLEANOUT
	1445599.7	2779777.7	8285.55	0+49 MTD	START CHIMNEY DRAIN
	1445472.6	2779924.3	8283.5	2+43.9 MTD	CONNECTION TO LEFT DISCHARGE PIPE
	1445494.7	2779942.3	8283.0	2+43.2 MTD	D/S END OF LEFT DISCHARGE PIPE
RIGHT TOE DRAIN	1445484.7	2779953.6	8283.0	2+55.2 MTD	D/S END OF RIGHT DISCHARGE PIPE
	1445463.2	2779934.6	8283.5	2+57.4 MTD	CONNECTION TO RIGHT DISCHARGE PIPE
	1445313.0	2780069.4	8285.5	4+59 MTD	END CHIMNEY DRAIN
	1445273.9	2780101.0	8286.5	5+08.8 MTD	B.O. CLEANOUT



TOE DRAIN CLEANOUT 1 C7 C7
TYPICAL DETAIL (N.T.S.)



CHIMNEY DRAIN 2 C6 C7
TYPICAL DETAIL
0 2 5 10 15
Scale in Feet



TOE DRAIN 3 C7 C7
TYPICAL DETAIL
0 2 5 10 15
Scale in Feet

NOTES:
1. TYPE A FILTER SAND IS CONTINUOUS BETWEEN DISCHARGE PIPES.
2. CONSTRUCT CHIMNEY AS SHOWN ON DETAIL 2 PG C7 BETWEEN STATIONS SHOWN ON PROFILE.
3. CONSTRUCT TOE DRAIN AS SHOWN ON DETAIL 3 PG C7 OUTSIDE OF THE CHIMNEY DRAIN STATIONS SHOWN ON PROFILE.
4. INSTALL A TYPICAL T-POST MARKER AT EACH TOE DRAIN CLEANOUT.
5. FINGER DRAIN INSTALLED FROM STA. 0+00 TO 0+43 MTD ON THE MAIN DAM TOE DRAIN.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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C7.0

MACFARLANE DAM REHABILITATION
TOE DRAIN - PROFILES AND DETAILS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	14 OF 21

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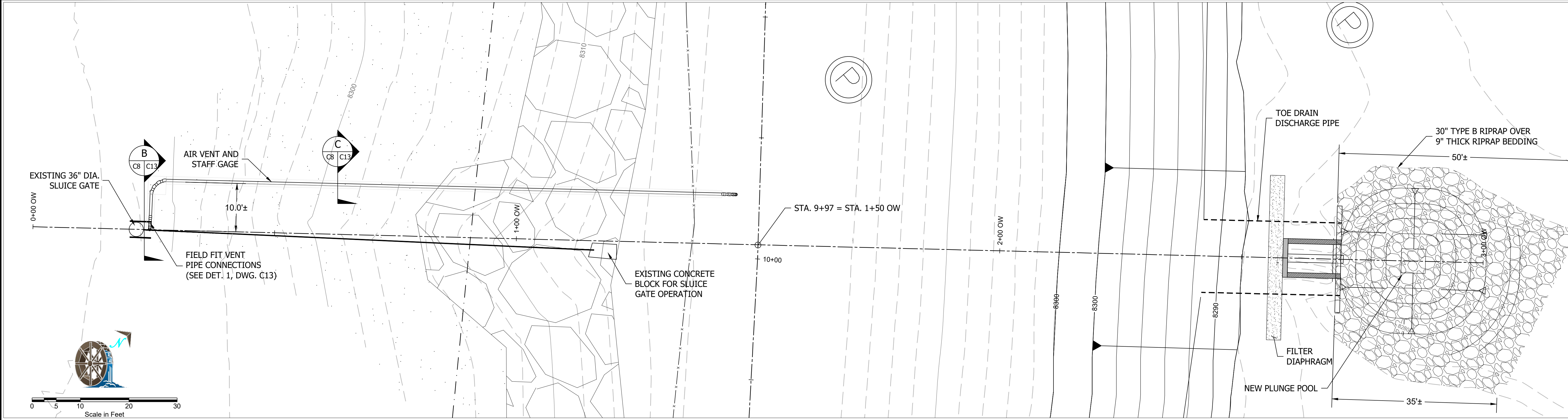

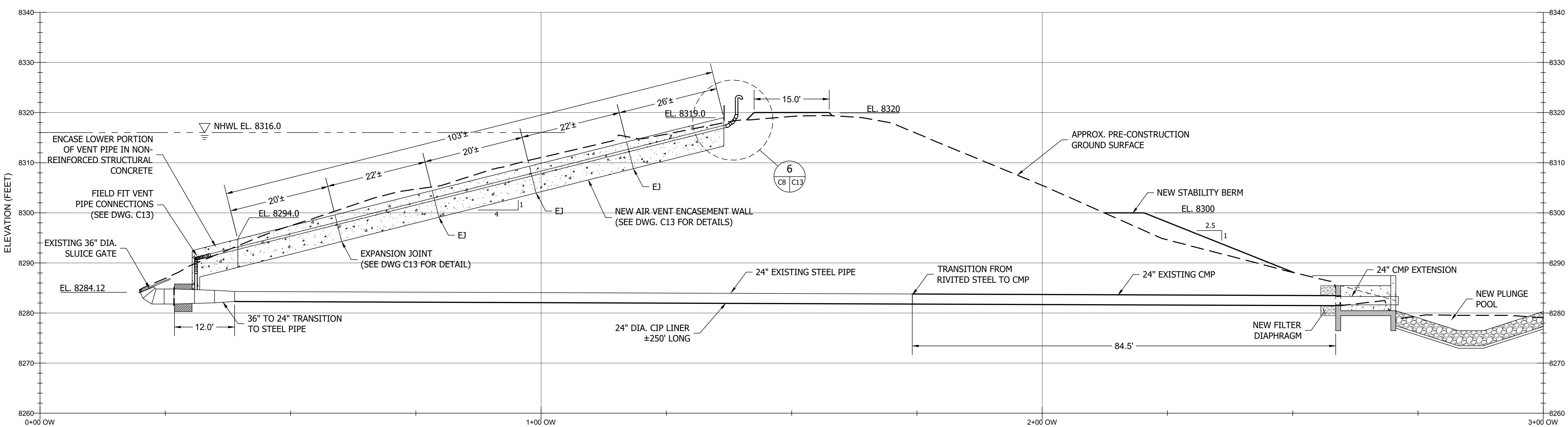

NOTES
1. AIR VENT TO BE CONSTRUCTED PARALLEL TO GATE OPERATOR.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

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REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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C8.0

MACFARLANE DAM REHABILITATION
OUTLET CONDUIT LINING - PLAN AND PROFILE

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	15 OF 21

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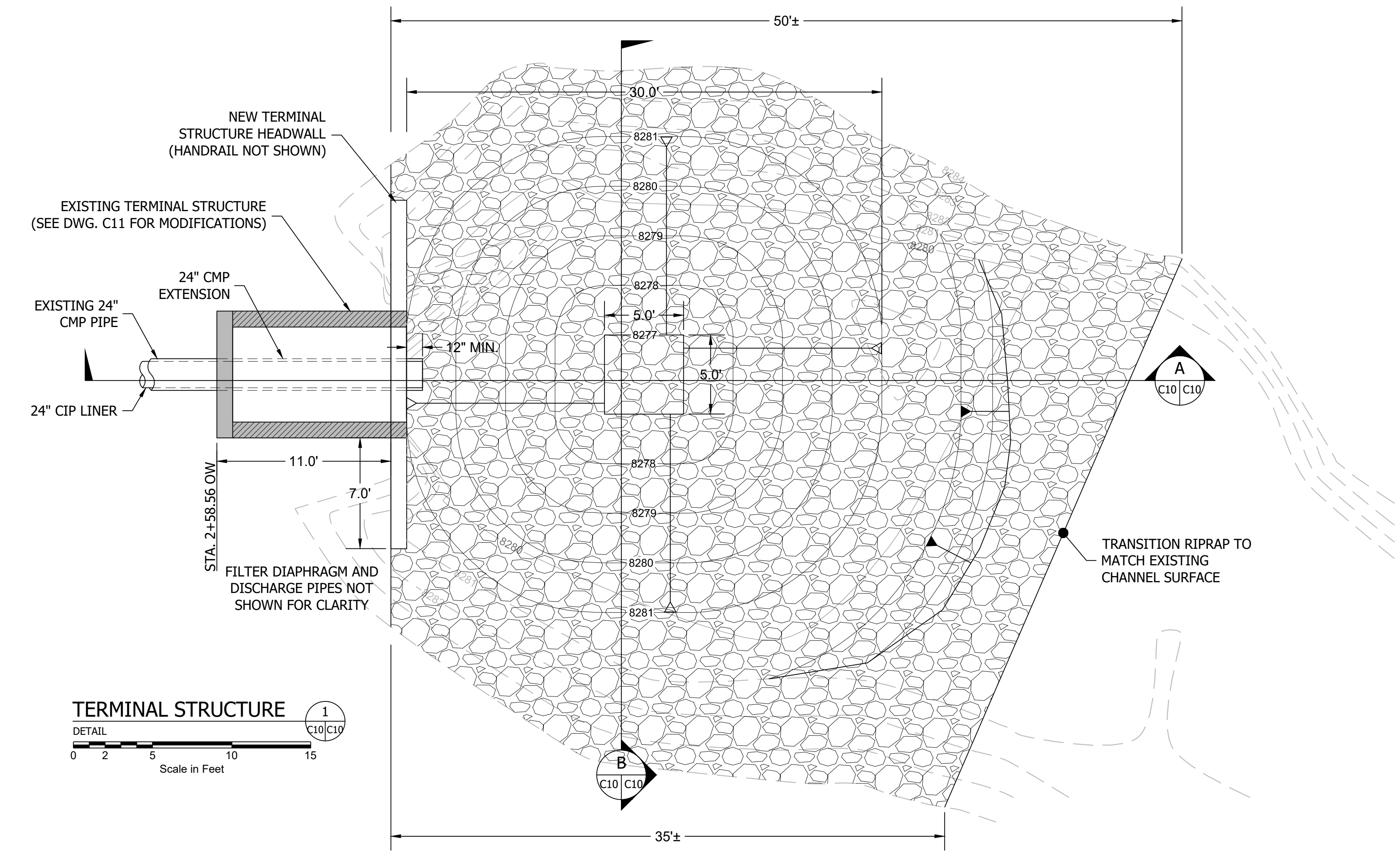
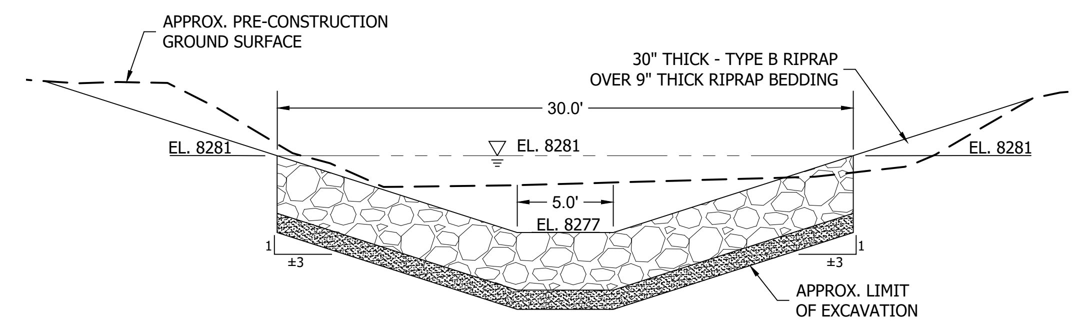


TERMINAL STRUCTURE (1, C10 C10)

DETAIL

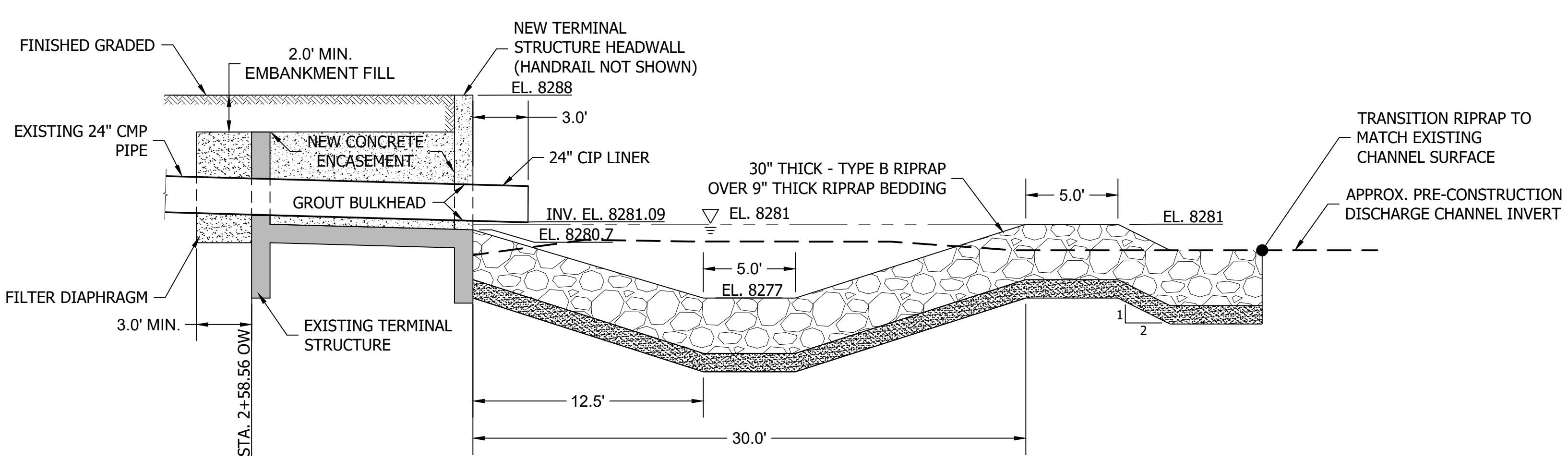
0 2 5 10 15
Scale in Feet



PLUNGE POOL (B, C10 C10)

SECTION

0 2 5 10 15
Scale in Feet



TERMINAL STRUCTURE (A, C10 C10)

SECTION

0 2 5 10 15
Scale in Feet

NOTE:
ENGINEER RESERVES THE RIGHT TO FIELD FIT FINAL PLUNGE POOL LINES AND GRADES.

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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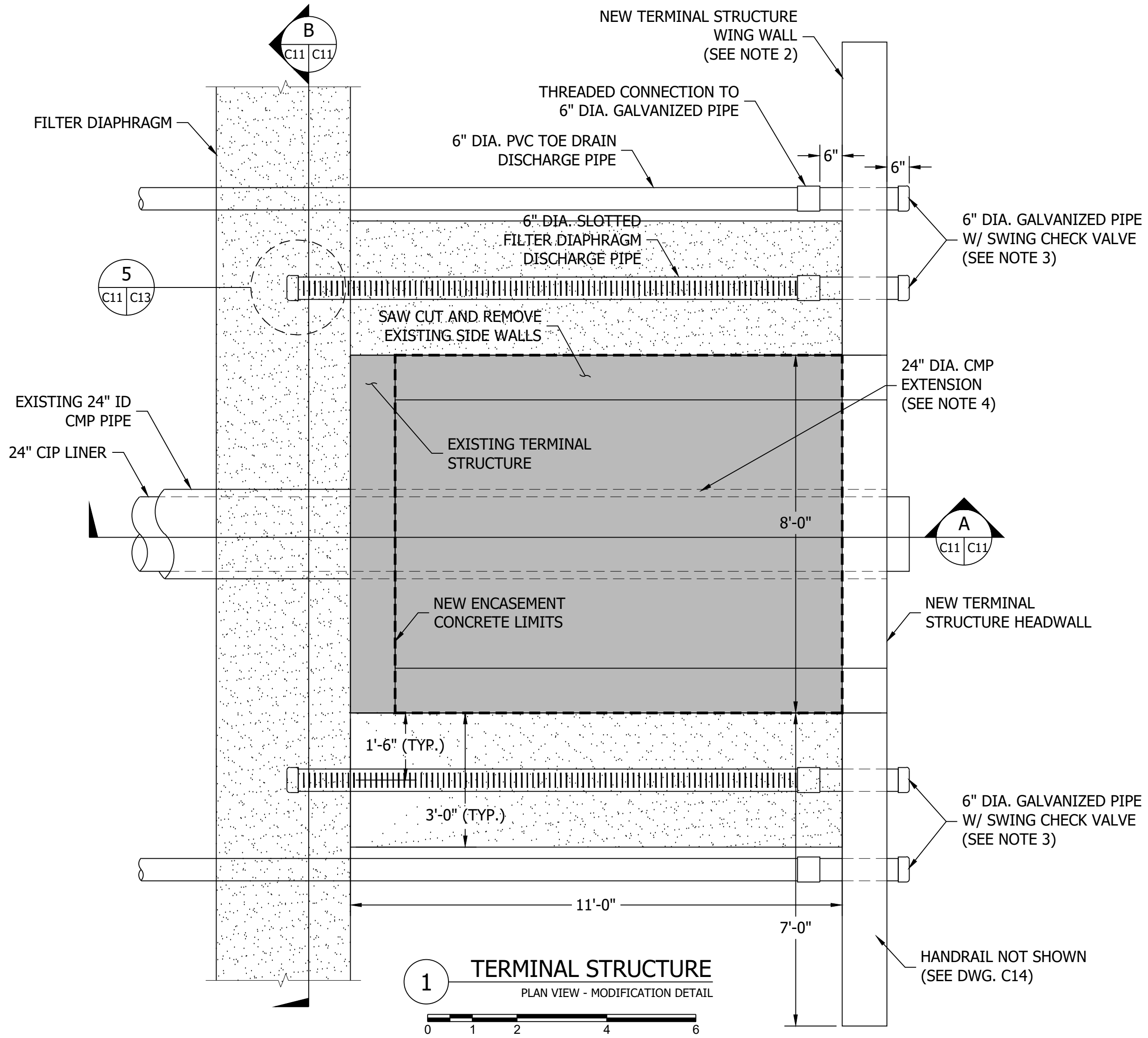
C10.0

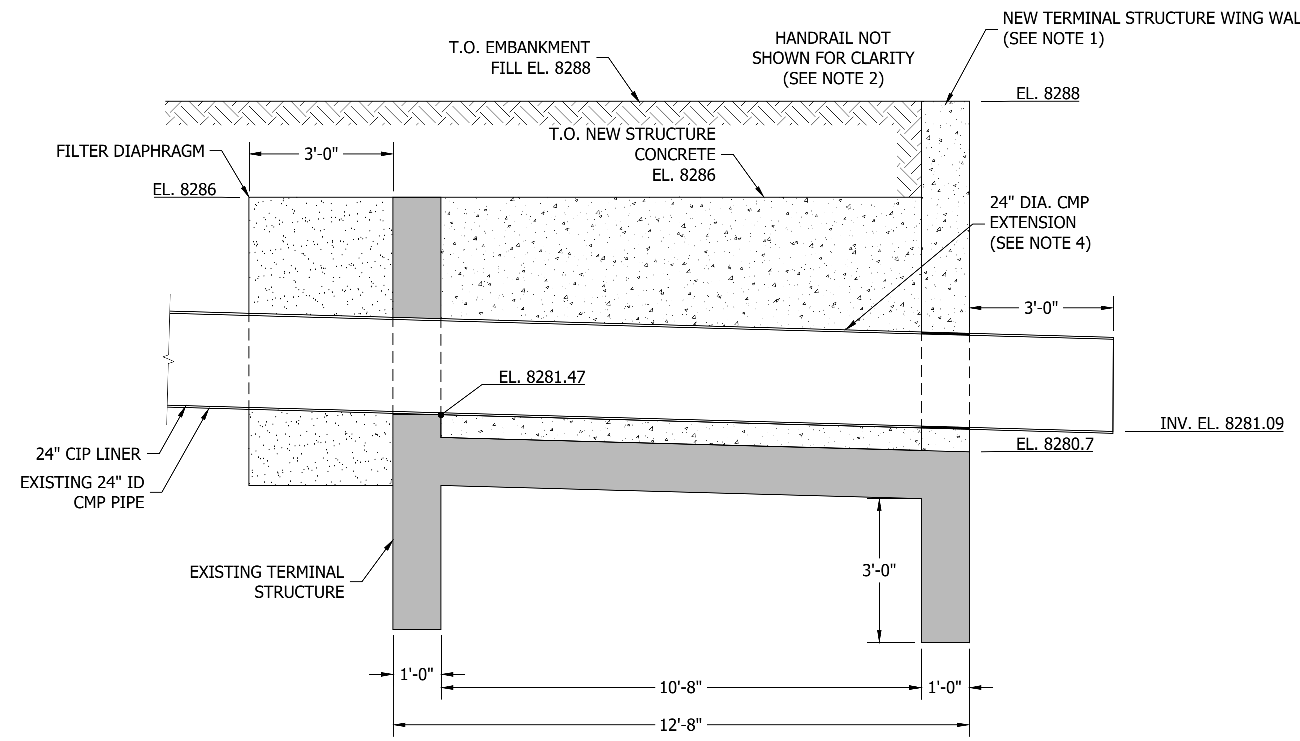
MACFARLANE DAM REHABILITATION
PLUNGE POOL - PLAN AND SECTIONS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	16 OF 21

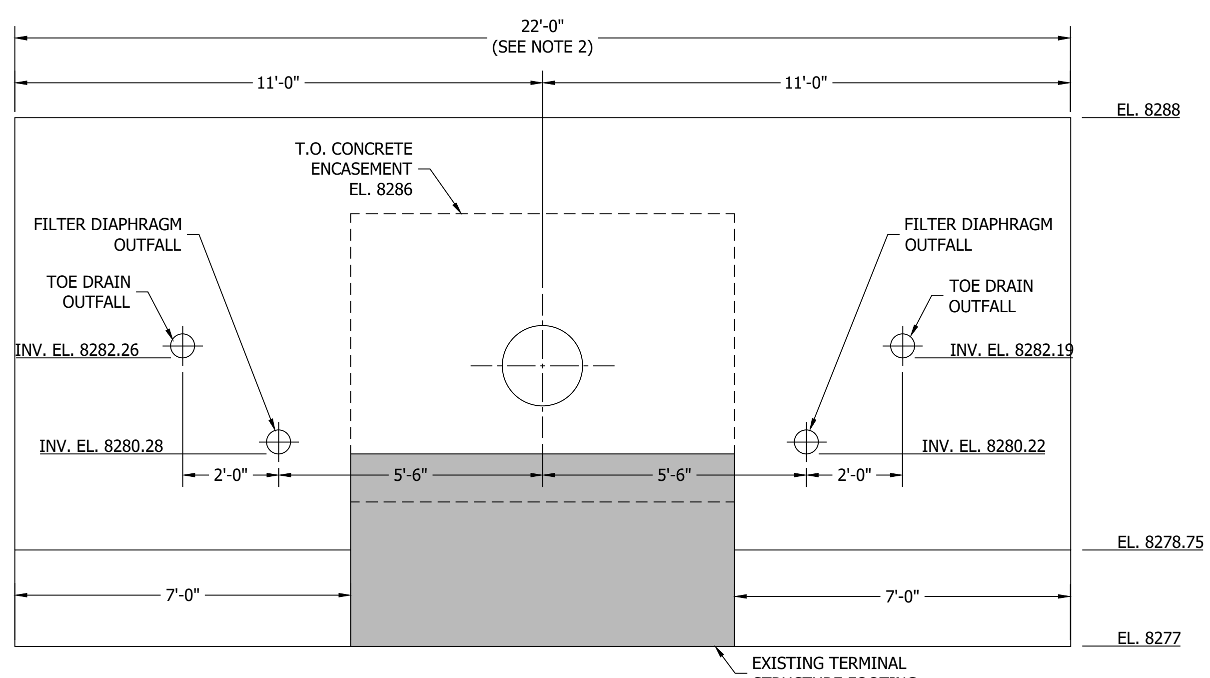
R:\1700\1772\1772.11.01_MacFarlaneDesign\Drawings\RECORD DRAWINGS\17721101-002 8-02-18 04:51pm Scott XREFS: Jamieson PE Stamp SLJ2; Wheeler Logo;



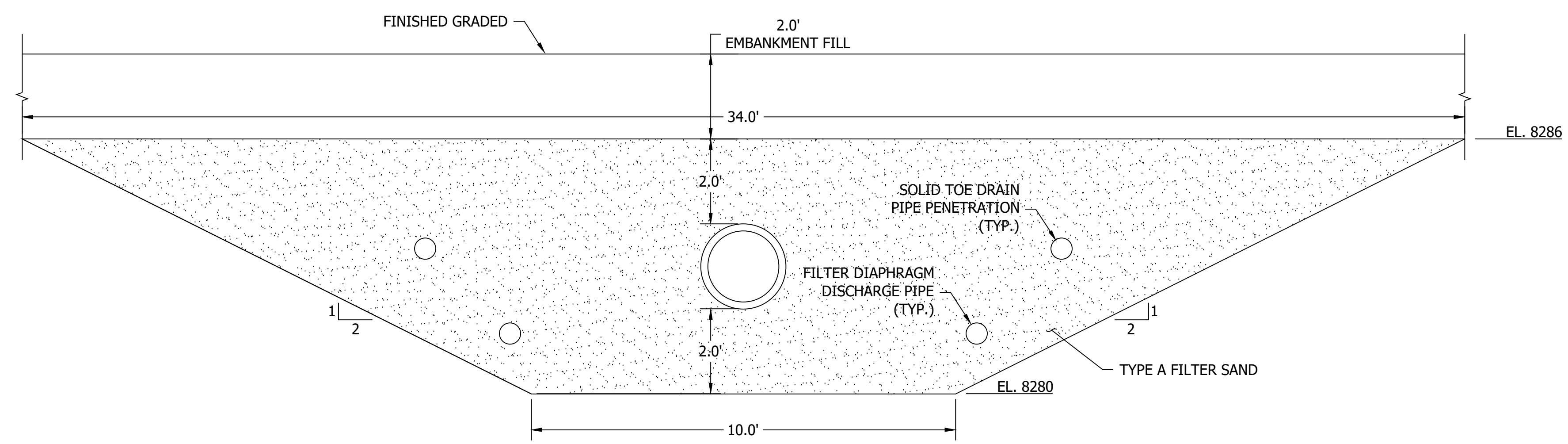
1 TERMINAL STRUCTURE
PLAN VIEW - MODIFICATION DETAIL
0 1 2 4 6
Scale in Feet



TERMINAL STRUCTURE A
SECTION C11 C11
0 1 2 4 6
Scale in Feet



2 TERMINAL STRUCTURE
FRONT ELEVATION
0 1 2 4 6
Scale in Feet



FILTER DIAPHRAGM B
SECTION C11 C11
0 1 2 4 6
Scale in Feet

NOTES
1. SEE S1 FOR REINFORCING DETAILS.
2. SEE C14 FOR HANDRAIL DETAILS.
3. INSTALL PLASTIC WAFER SWING CHECK VALVES TO GALVANIZED PIPE.
4. A 10-FOOT SECTION OF 24-INCH DIAMETER CMP WAS ADDED FROM THE END OF EXISTING TERMINAL STRUCTURE OUTLET THROUGH THE NEW TERMINAL STRUCTURE HEADWALL.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

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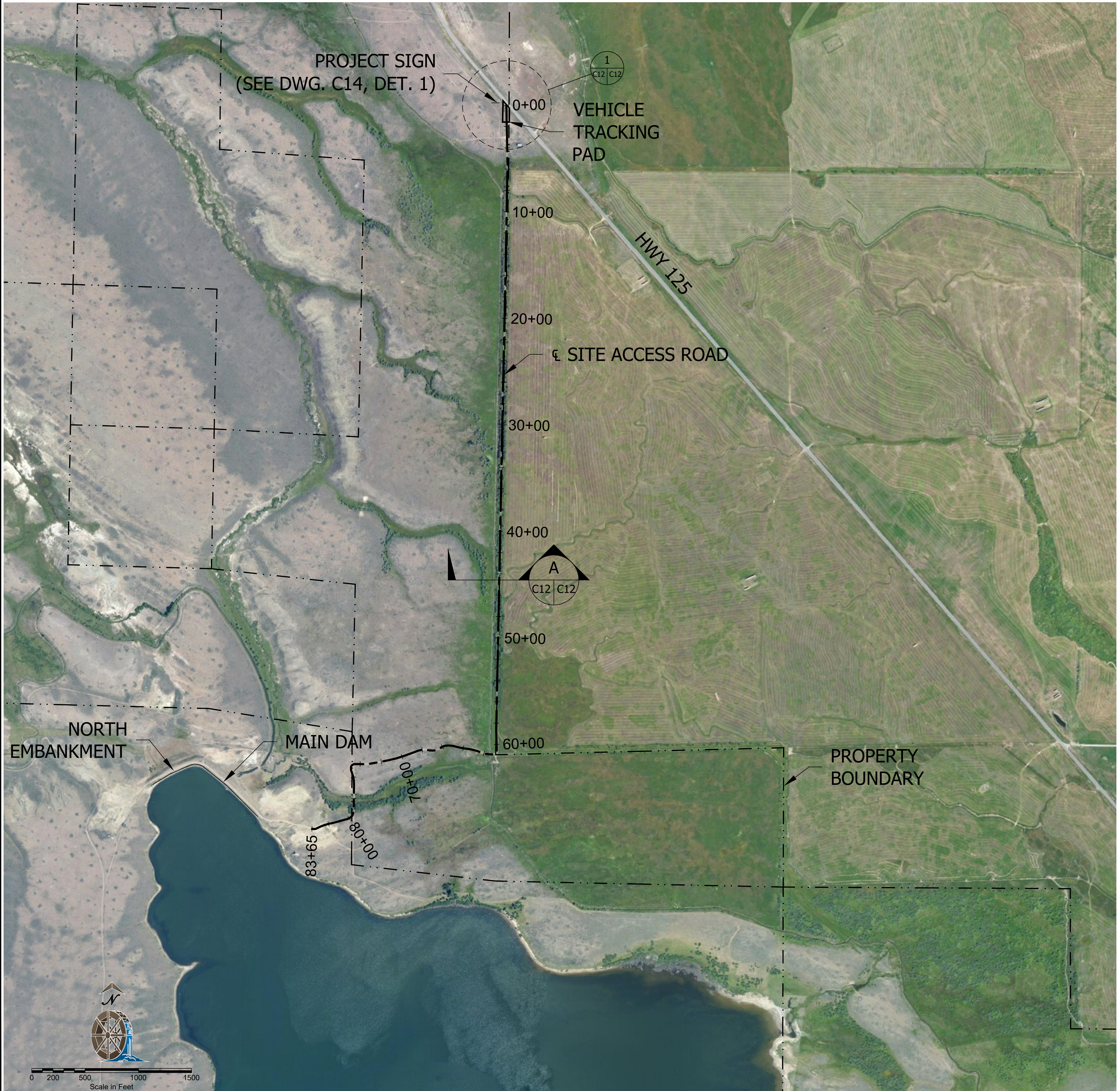
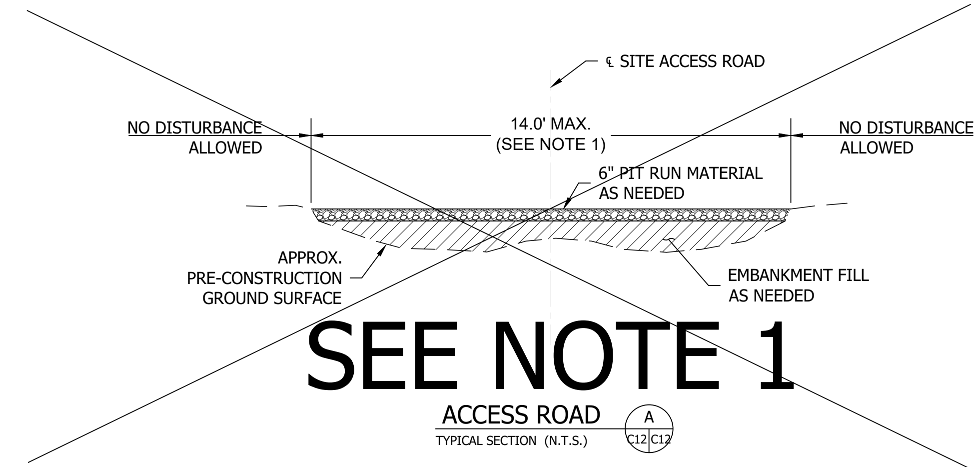
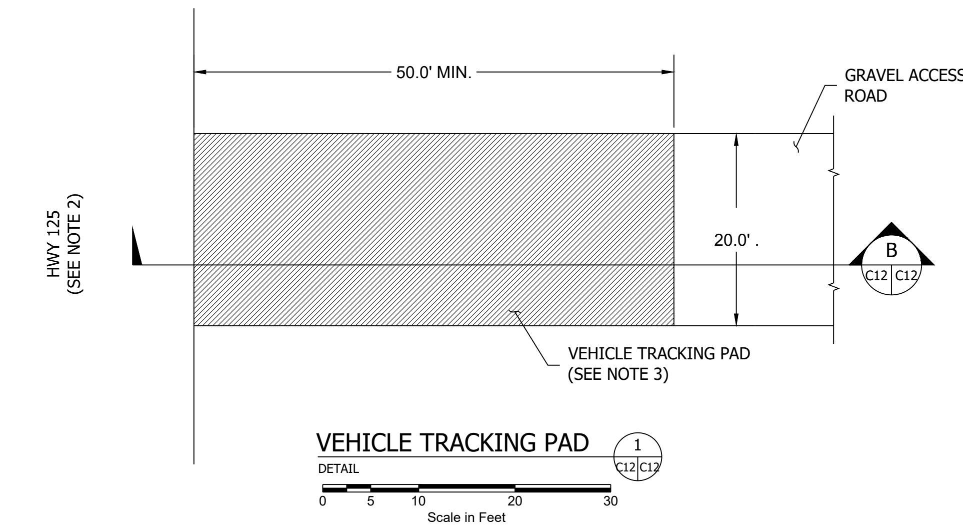
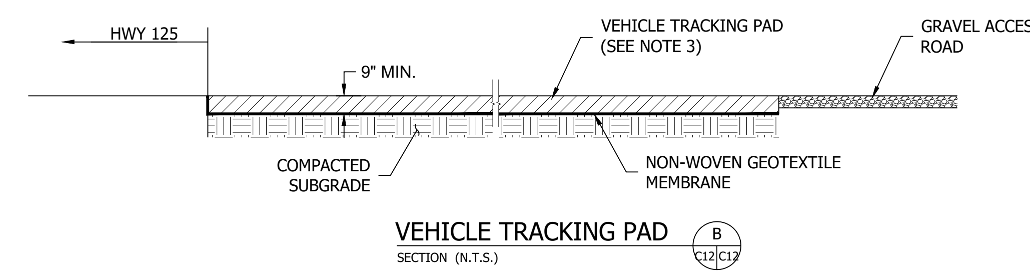
MACFARLANE DAM REHABILITATION
FILTER DIAPHRAGM - PLAN, SECTIONS AND DETAILS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	17 OF 21









NOTES:

1. SITE ACCESS ROAD IMPROVEMENTS WERE MADE BY THE GOVERNMENT PRIOR TO CONSTRUCTION. CONTRACTOR IS REQUIRED TO MAINTAIN THE ACCESS ROAD PER SPECIFICATION SECTION 02050.
2. HIGHWAY 125 TO BE KEPT CLEAN AND FREE OF MUD, DIRT AND DEBRIS AT ALL TIMES.

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

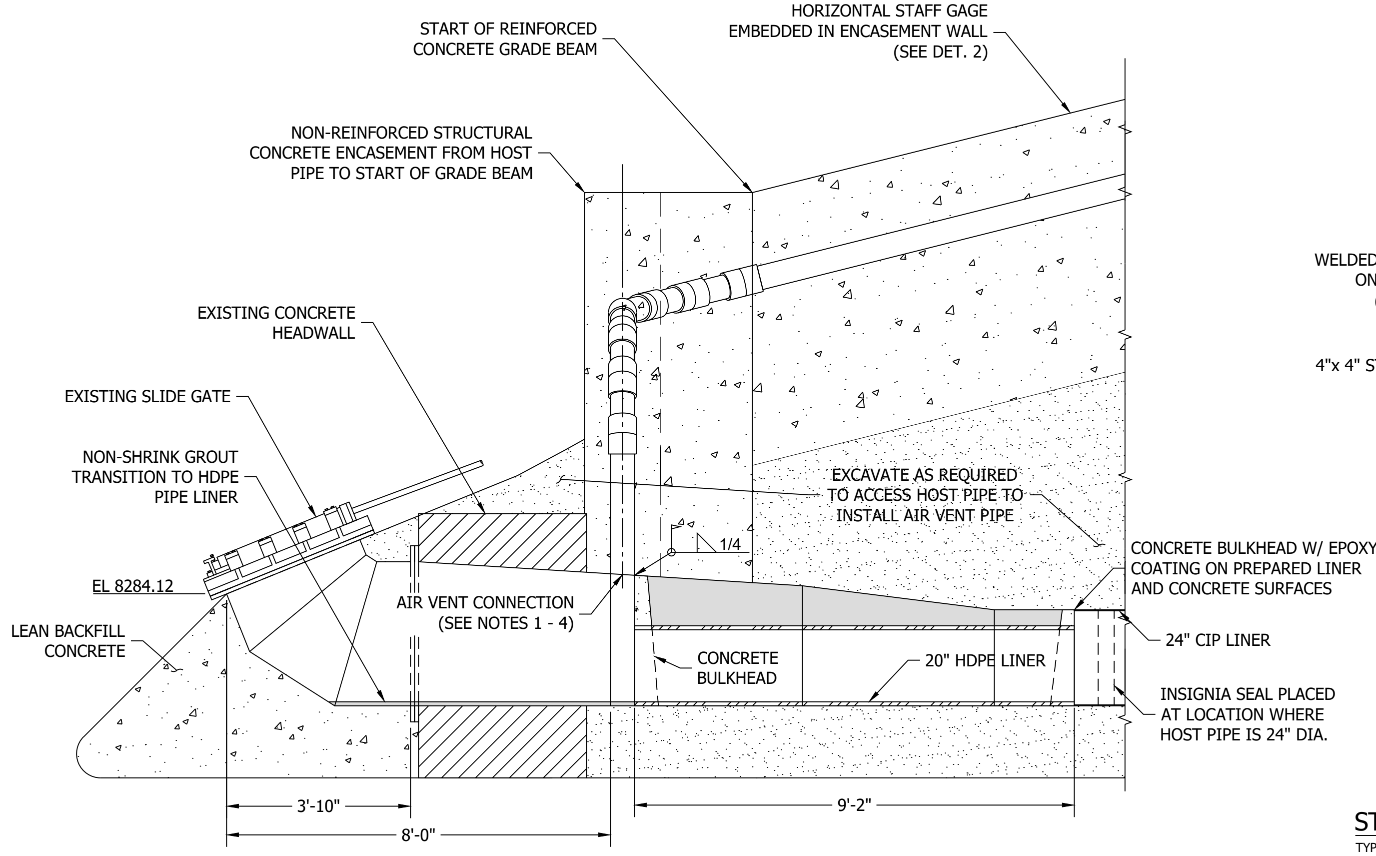
COLORADO LICENSED PROFESSIONAL ENGINEER STEPHEN L. JAMIESON 25028 02/26/2016

ARAPAHO N.W.R.

C12.0

MACFARLANE DAM REHABILITATION
ACCESS ROAD IMPROVEMENTS - PLAN AND DETAILS

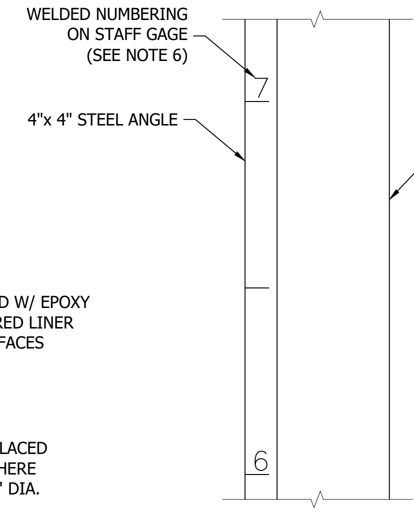
DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	18 OF 21



1 INLET MODIFICATION AND AIR VENT

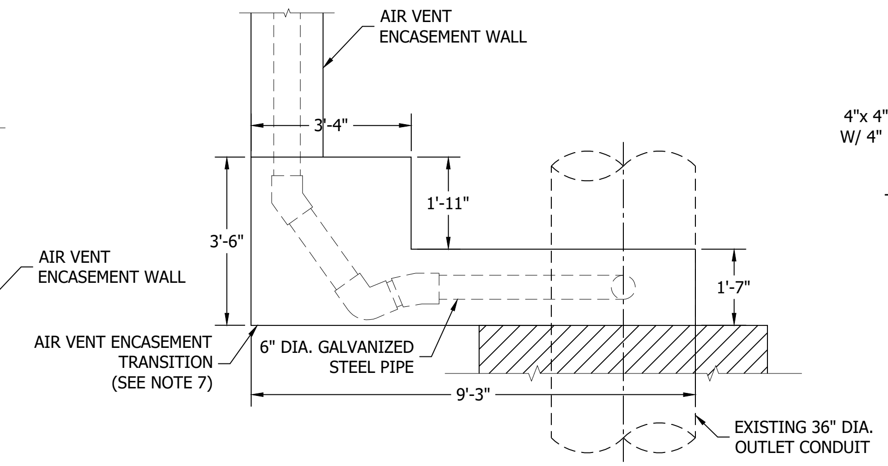
DETAIL

0 1 2 4 6 Scale in Feet



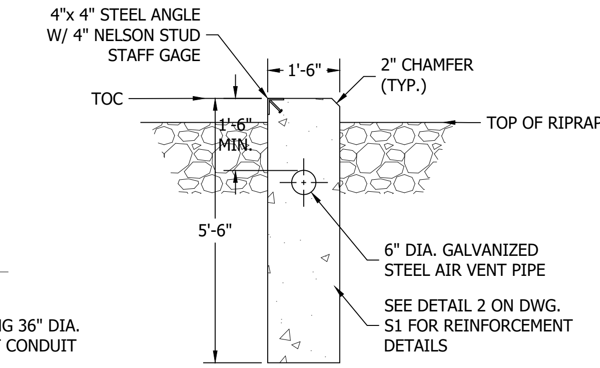
STAFF GAGE MOUNTED ON GRADE BEAM 2 C8 C13

TYPICAL DETAIL (N.T.S.)



AIR VENT ENCASEMENT TRANSITION 3 C8 C13

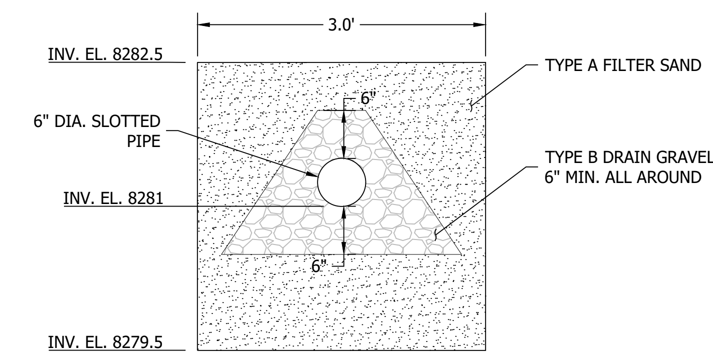
DETAIL (N.T.S.)



AIR VENT ENCASEMENT WALL C C8 C13

SECTION

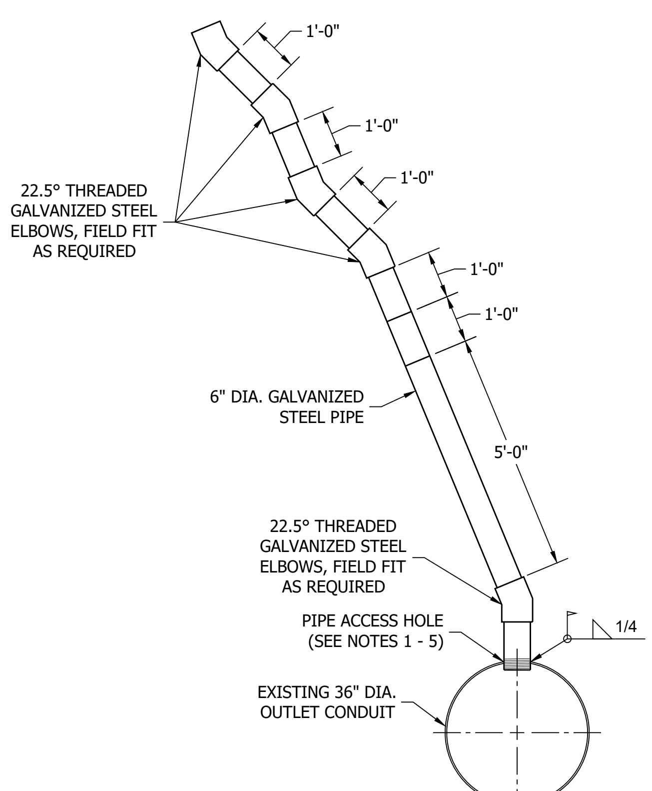
0 1 2 4 6 Scale in Feet



FILTER DIAPHRAGM DRAIN COLLECTOR PIPE A C13 C13

DETAIL

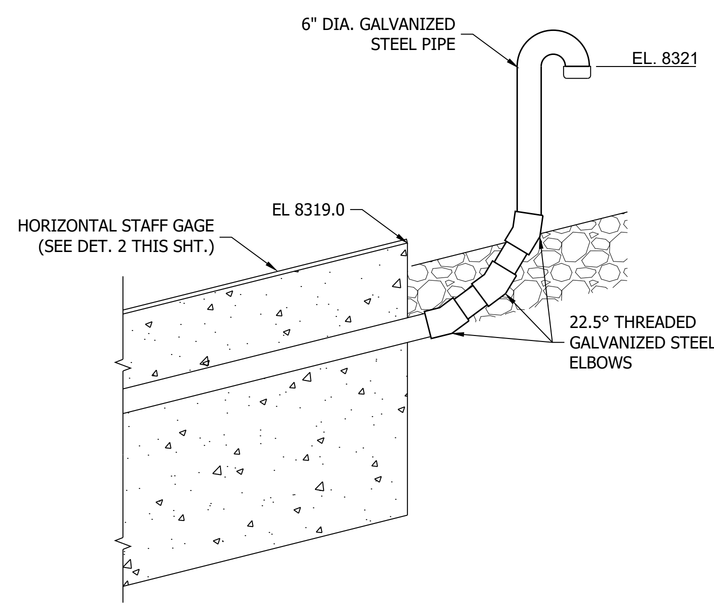
0 ½ 1 2 3 Scale in Feet



AIR VENT PIPE CONNECTION B C8 C13

DETAIL

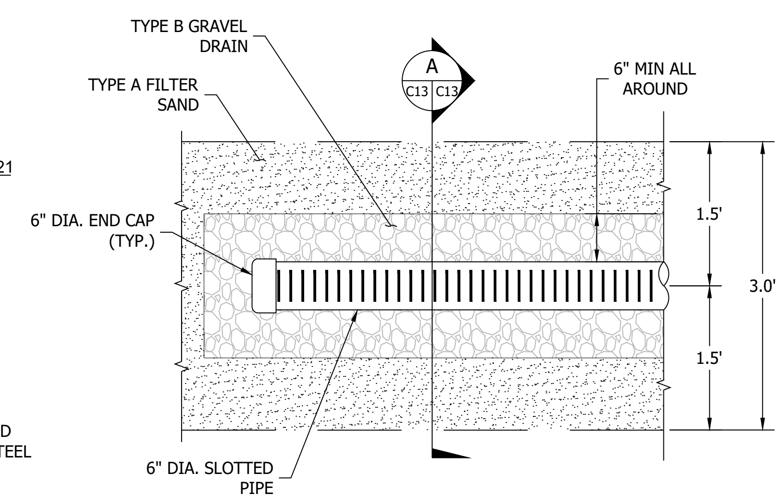
0 1 2 4 6 Scale in Feet



AIR VENT DISCHARGE 6 C8 C13

DETAIL

0 1 2 4 6 Scale in Feet

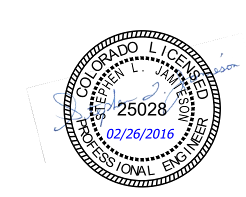


FILTER DIAPHRAGM DRAIN COLLECTOR PIPE 5 C11 C13

DETAIL

0 ½ 1 2 3 Scale in Feet

NOTES:
1. DRILL THROUGH EXISTING STEEL PIPE WITH A HOLE SAW AND INSTALL VENT PIPE AS SHOWN.
2. INSTALL THE VENT PIPE FLUSH WITH THE INSIDE OF THE HOST PIPE.
3. WELD THE VENT PIPE TO THE OUTSIDE OF THE HOST PIPE.
4. BACKFILL THE EXCAVATION ABOVE THE HOST PIPE WITH STRUCTURAL CONCRETE AFTER THE AIR VENT PIPE IS INSTALLED.
5. START STAFF GAGE AT AN EVEN FOOT BASED ON A FIELD SURVEY WITH THE OUTLET WORKS INLET EL. 8284.16
6. AIR VENT ENCASEMENT TRANSITION IS 5'-8" TALL.



C-1031B

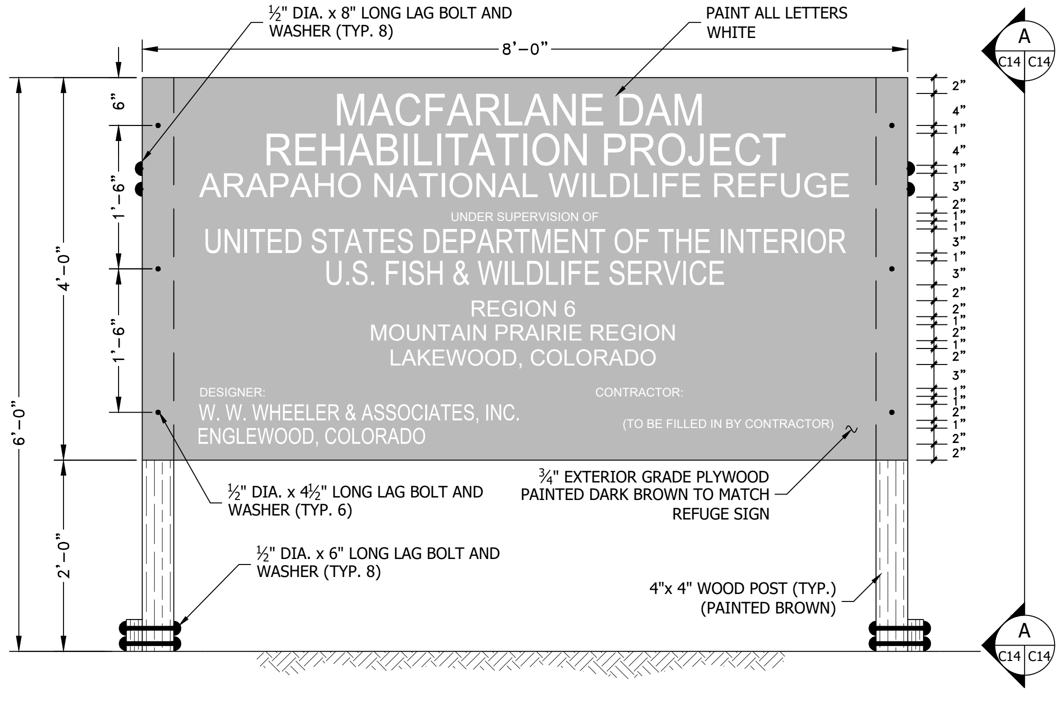
REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R. C13.0

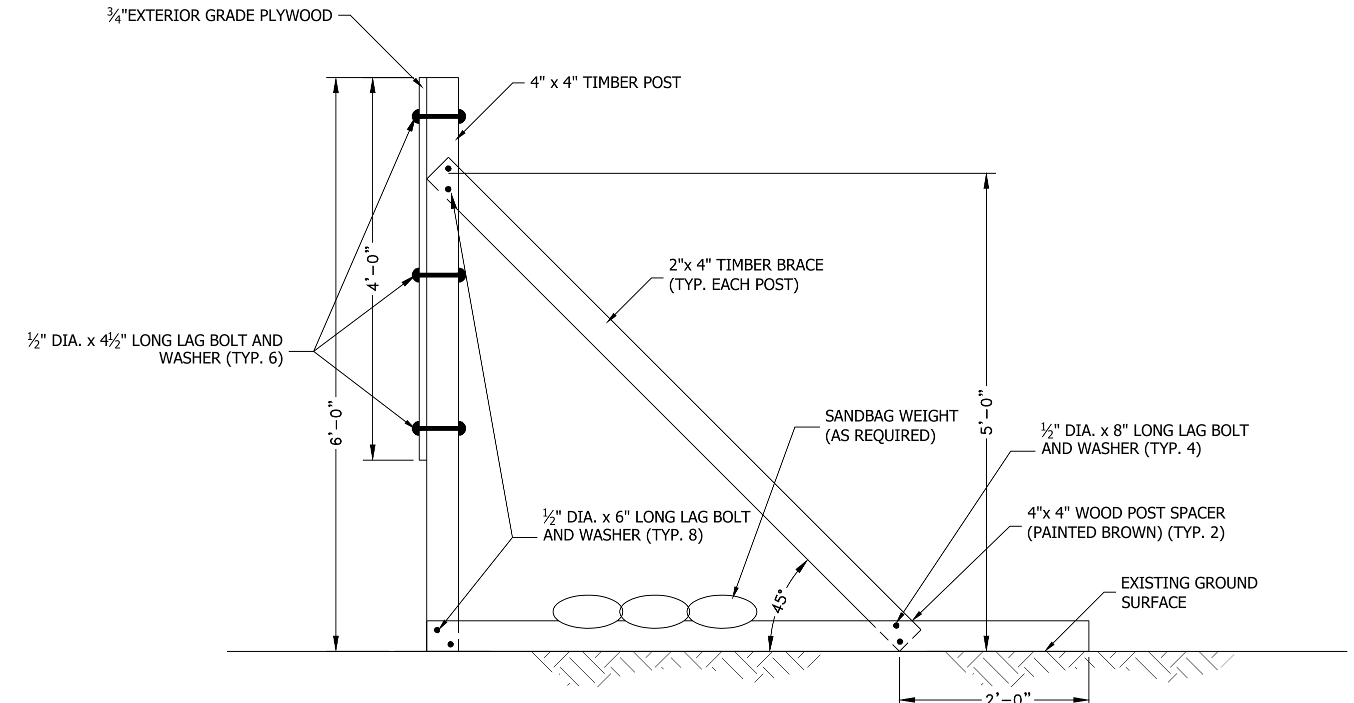
MACFARLANE DAM REHABILITATION
MISCELLANEOUS DETAILS 1

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	19 OF 21

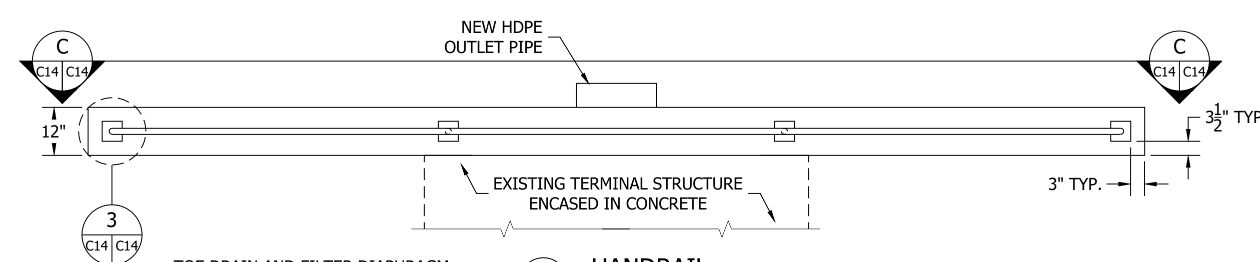
R:\1700\1772\1772.11.01_MacFarlaneDesign\Drawings\RECORD DRAWINGS\1772101-004 8-02-18 04:52pm Scott XREFS: SLJ2;



PROJECT SIGN 1 C12 C14
DETAIL (N.T.S)

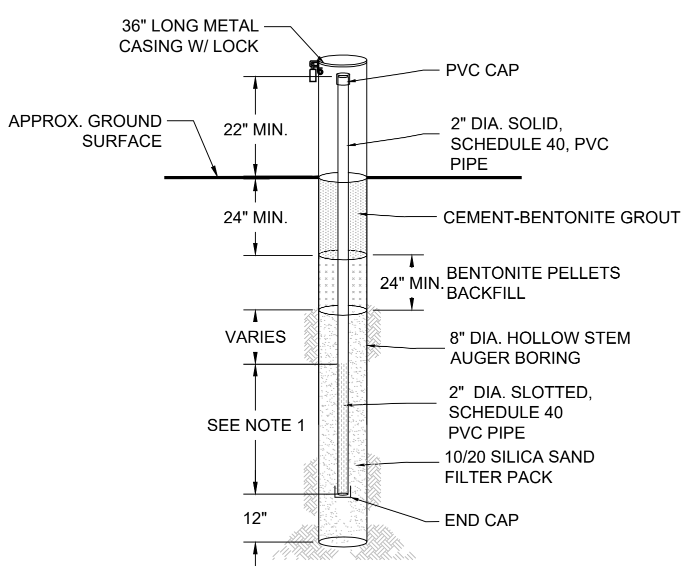


PROJECT SIGN A C14 C14
ELEVATION (N.T.S.)

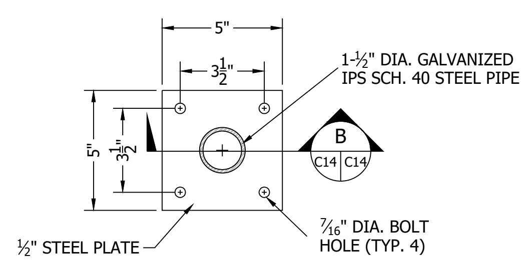


TOE DRAIN AND FILTER DIAPHRAGM DISCHARGE PIPES NOT SHOWN FOR CLARITY

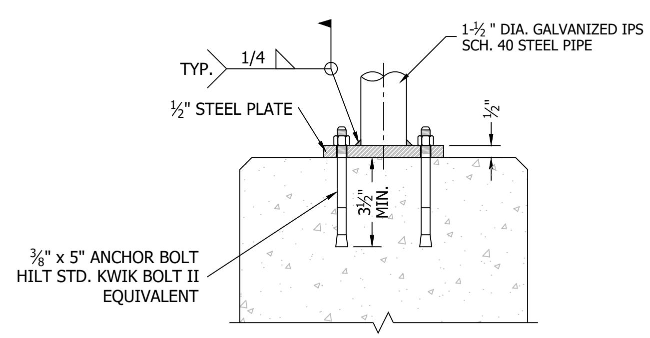
1 HANDRAIL
PLAN VIEW
0 1 2 4 6
Scale in Feet



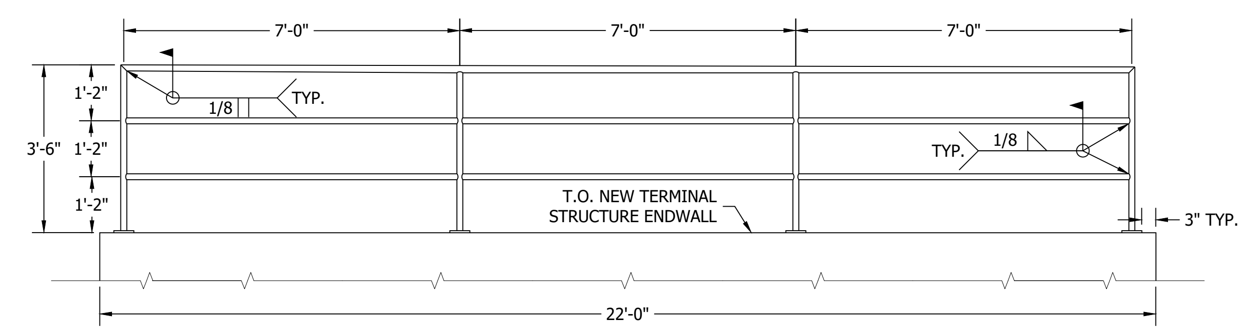
3 REPLACEMENT PIEZOMETER
DETAIL (N.T.S.)



HANDRAIL BASEPLATE 3 C4 C14
DETAIL
0 2 4 8 12
Scale in Inches



HANDRAIL BASEPLATE B C14 C14
SECTION
0 2 4 8 12
Scale in Inches



HANDRAIL C C14 C14
ELEVATION
0 1 2 4 6
Scale in Feet

REPLACEMENT PIEZOMETER INFORMATION

PIEZOMETER	STA.	OFFSET DOWNSTREAM OF BASELINE (FEET)	APPROX. TOP OF PVC PIEZOMETER (FEET)	APPROX. BOTTOM OF PVC PIEZOMETER (FEET)	APPROX. DEPTH (FEET)
P-6	3+50	90'	8299.95'	8283.0'	17.0'
P-9	9+45	120'	8287.77'	8271.0'	16.8'

NOTES:
1. 5 FOOT SLOTTED PVC PIPE SECTION

COLORADO LICENSED STEPHEN L. JAMIESON 25028 02/26/2016 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

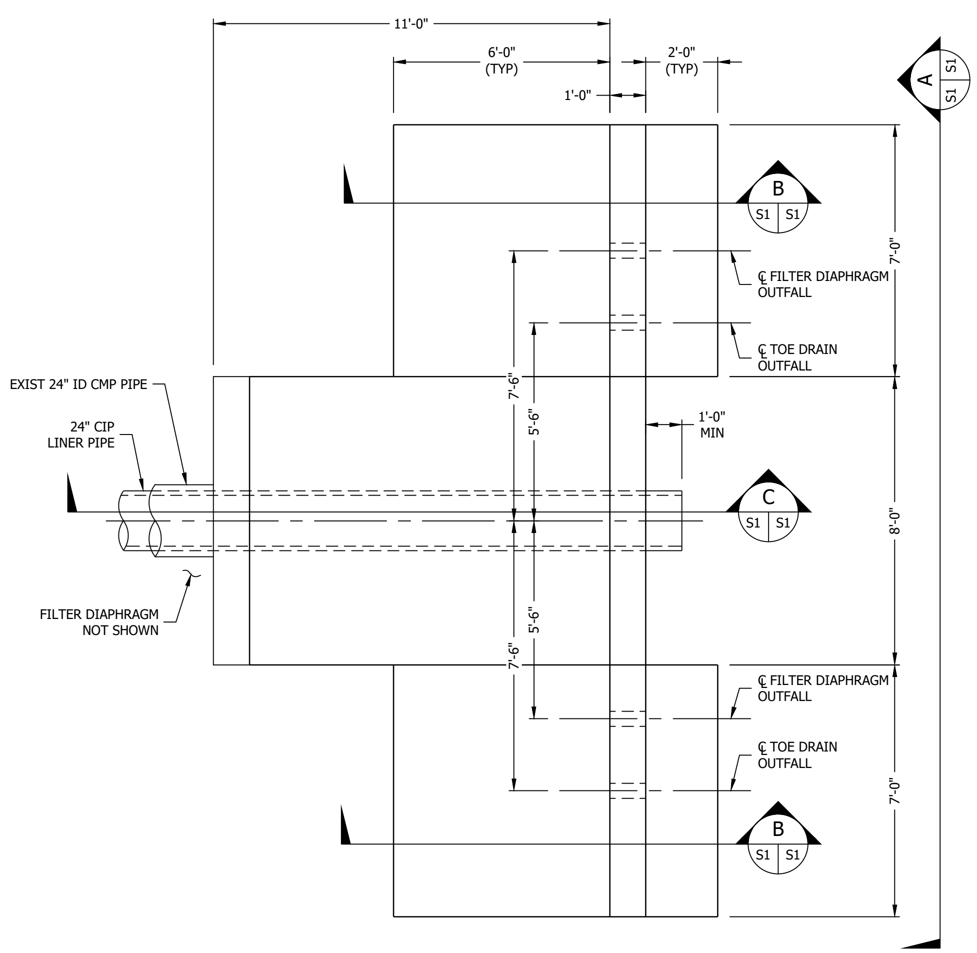
ARAPAHO N.W.R.

C14.0

MACFARLANE DAM REHABILITATION
MISCELLANEOUS DETAILS 2

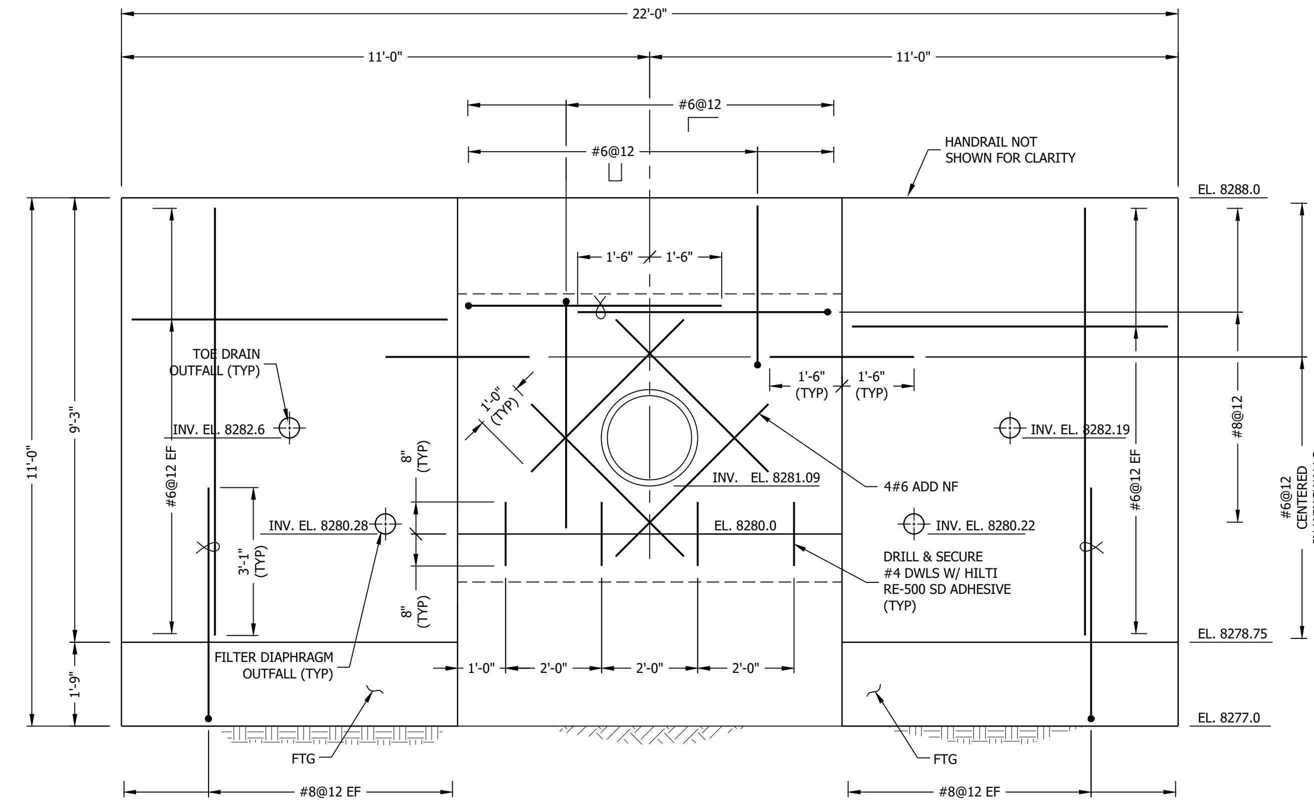
DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	2-26-2016	20 OF 21

R:\1700\1772\1772.11.01_MacFarlaneDesign\Drawings\RECORD DRAWINGS\1772101-004 8-02-18 04:52pm Scott XREFS: SLJ2;



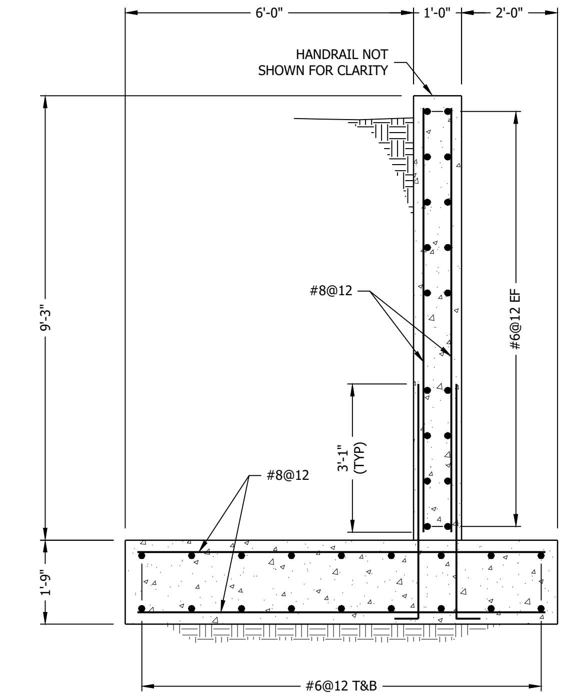
1 TERMINAL STRUCTURE OUTLINE
PLAN VIEW

0 2 4 6
Scale in Feet



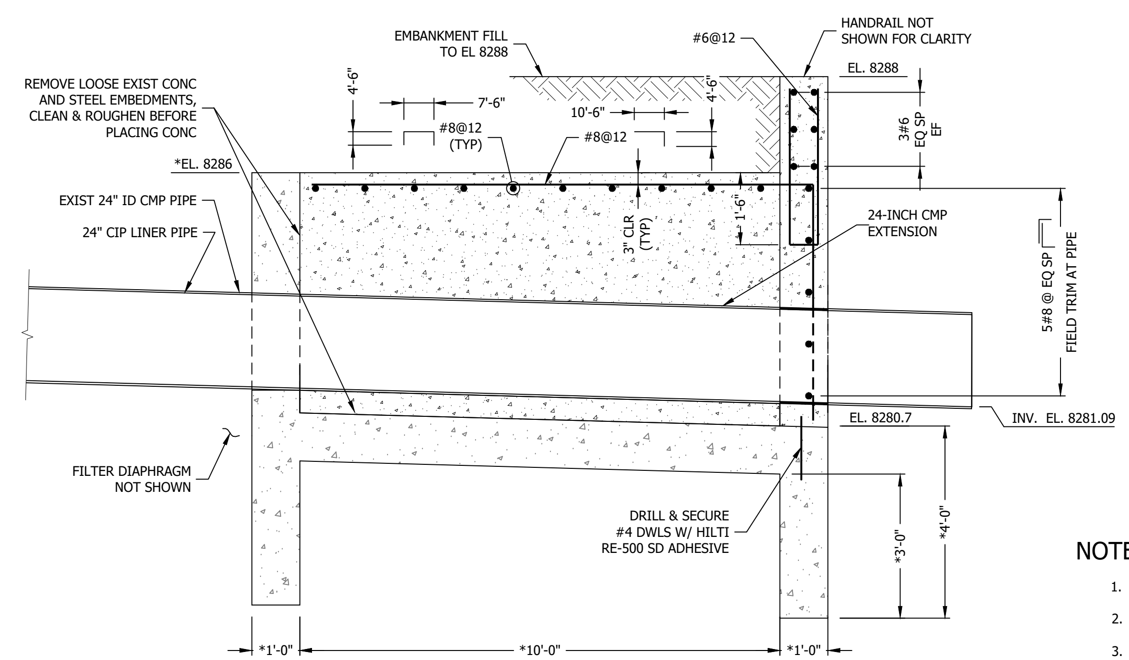
TERMINAL STRUCTURE A S1 S1
FRONT ELEVATION

0 1 2 4 6
Scale in Feet



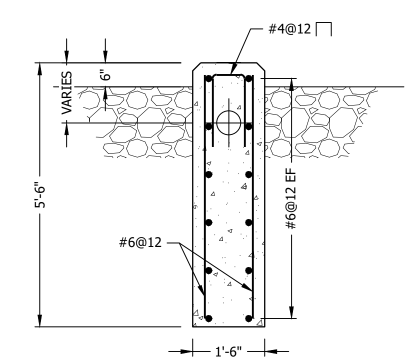
WING WALL B S1 S1
SECTION

0 1 2 4 6
Scale in Feet



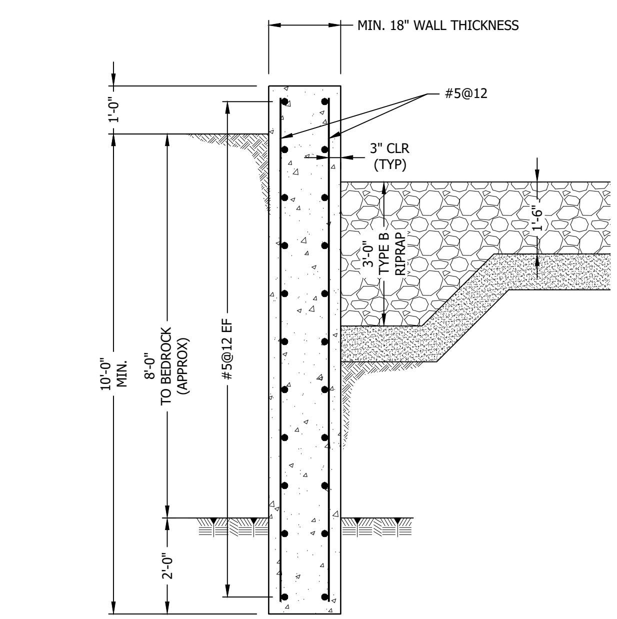
TERMINAL STRUCTURE C S1 S1
SECTION

0 1 2 4 6
Scale in Feet



AIR VENT ENCASEMENT WALL 2 S1 S1
DETAIL

0 1 2 4 6
Scale in Feet



SPILLWAY CONTROL SILL REINFORCEMENT 1 S1 C3
TYPICAL SECTION

0 1 2 4 6
Scale in Feet

NOTES:

1. DENOTES EXISTING DIMENSION OR ELEVATION TO BE FIELD VERIFIED.
2. LINER SHALL BE WEIGHED AND SUPPORTED TO PREVENT FLOTATION.
3. NONSHRINK GROUT AND CONCRETE SHALL HAVE A MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 4500 PSI.

COLORADO LICENSED STEPHEN L. JAMIESON 25028 PROFESSIONAL ENGINEER 02/26/2016

C-1031B

REV.	DATE	DESCRIPTION	BY
1	7-31-2018	RECORD DRAWINGS	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R. S1.0

MACFARLANE DAM REHABILITATION
TERMINAL STRUCTURE - PLAN AND SECTIONS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
MW	RC	SLJ	2-26-2016	21 OF 21

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APPENDIX C

MATERIALS SAMPLING AND TESTING RESULTS

APPENDIX C-1

Concrete Testing

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

MacFarlane Dam Rehabilitation Concrete Test Results

			Field Data								Compressive strength (psi)						
											Age (Days)						
Date	Truck Number	Location	Volume Delivered (CY)	Air Content (%)	Wet Unit Weight (pcf)	Concrete Temp. (ºF)	Slump (in)	Slump + Air	Water Added (gal)	Cylinders Cast?	Design (psi)	7	7	28	28	28	Comments
8/18/2017	96	Control Sill Station 2+20	8	6.0	140.9	70	3 1/4	9.3	No	5	4500	4,190	4,030	5,170	5,370	5,310	Material sampled from the point of discharge.
9/27/2017	87	Control Sill Station 2+20	8	5.0	143.1	60	3 3/4	8.8	No	5	4500	4,410	4,610	4,920	5,070	5,010	Material sampled from the point of discharge.
9/27/2017	97	Control Sill Station 5+20	8	4.4	142.7	65	4	8.4	23	5	4500	3,950	4,130	5,100	5,070	5,190	Material sampled from the point of discharge.
10/18/2017	96	Wing Wall Footing-Right Side	7	4.4	142.9	68	3	7.4	No	5	4500	3,440	3,560	4,930	4,860	4,680	Material sampled from the point of discharge.
10/18/2017	87	Wing Wall Footing-Left Side	7	4.9	142.2	65	4	8.9	No	5	4500	3,350	3,440	5,240	4,880	5,030	Material sampled from the point of discharge.
10/23/2017	96	Wing Walls at Outlet	8.5	4	142.6	62	4 3/4	12.8	No	5	4500	3,632	3,756	4,560	4,550	4,530	Material sampled from the point of discharge.
10/30/2017	96	Grade Beam-Air Vent Encasement Wall	8	4.4	143.3	61	3.75	8.2	No	5	4500	3,290	3,150	5,440	5,170	5,410	Material sampled from the point of discharge.
10/30/2017	87	Outlet Works Terminal Structure CMP Extension Encasement	8	3.4[A]	143.5	60	3	6.4	11	5	4500	3,340	3660	5100	5530	5180	Material sampled from the point of discharge.

Notes:
All tests shown were done by Kumar and Associates, Inc.
[A] Wheeler decided to not reject the batch due to low air content. The concrete was placed as backfill concrete for the encasement around the Outlet Works Terminal Structure CMP extension.

APPENDIX C-2

Lab Testing of Materials

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

MacFarlane Dam 2017: Kumar and Associates, Inc. Project No. 17-1-463
Type A Filter Sand Comparison Table

MacFarlane Dam Figure and Sample No.	Processing Lab No. *	Date Sampled	Sample location/Specifications	% Passing 1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
Sample 7926	poorly graded sand	8/28/2017		100	100	100	100	100	98	79	52	36	15	5	2.2
F12 - C214	poorly graded sand	8/29/2017	2 passes with smooth drom roller during compaction	100	100	100	100	100	100	78	58	34	16	6	3.4
F13 - C215	poorly graded sand	8/29/2017	4 passes with smooth drom roller during compaction	100	100	100	100	100	100	77	57	33	15	6	3.0
F14 - C216	poorly graded sand	8/29/2017	6 passes with smooth drom roller during compaction	100	100	100	100	100	100	76	56	33	15	6	3.0
F15 - C217	poorly graded sand	8/31/2017	On-site stock pile	100	100	100	100	100	100	78	58	35	15	5	2.9
F16 - C218	poorly graded sand	8/31/2017	4 passes with smooth drom roller during compaction	100	100	100	100	100	100	76	57	34	15	6	3.3
F17 - C219	poorly graded sand	8/31/2017	8 passes with smooth drom roller during compaction	100	100	100	100	100	100	77	58	35	16	6	3.3
F26 - C 238	poorly graded sand	9/23/2017		100	100	100	100	100	97	79	62	39	17	6	2.7
			Average	**100**	**100**	**100**	**100**	**100**	**99**	**78**	**57**	**35**	**16**	**6**	**3**
			Specification					**100**	**80-100**	**60-100**	**40-82**	**20-65**	**2-45**	**0-20**	**0-3**

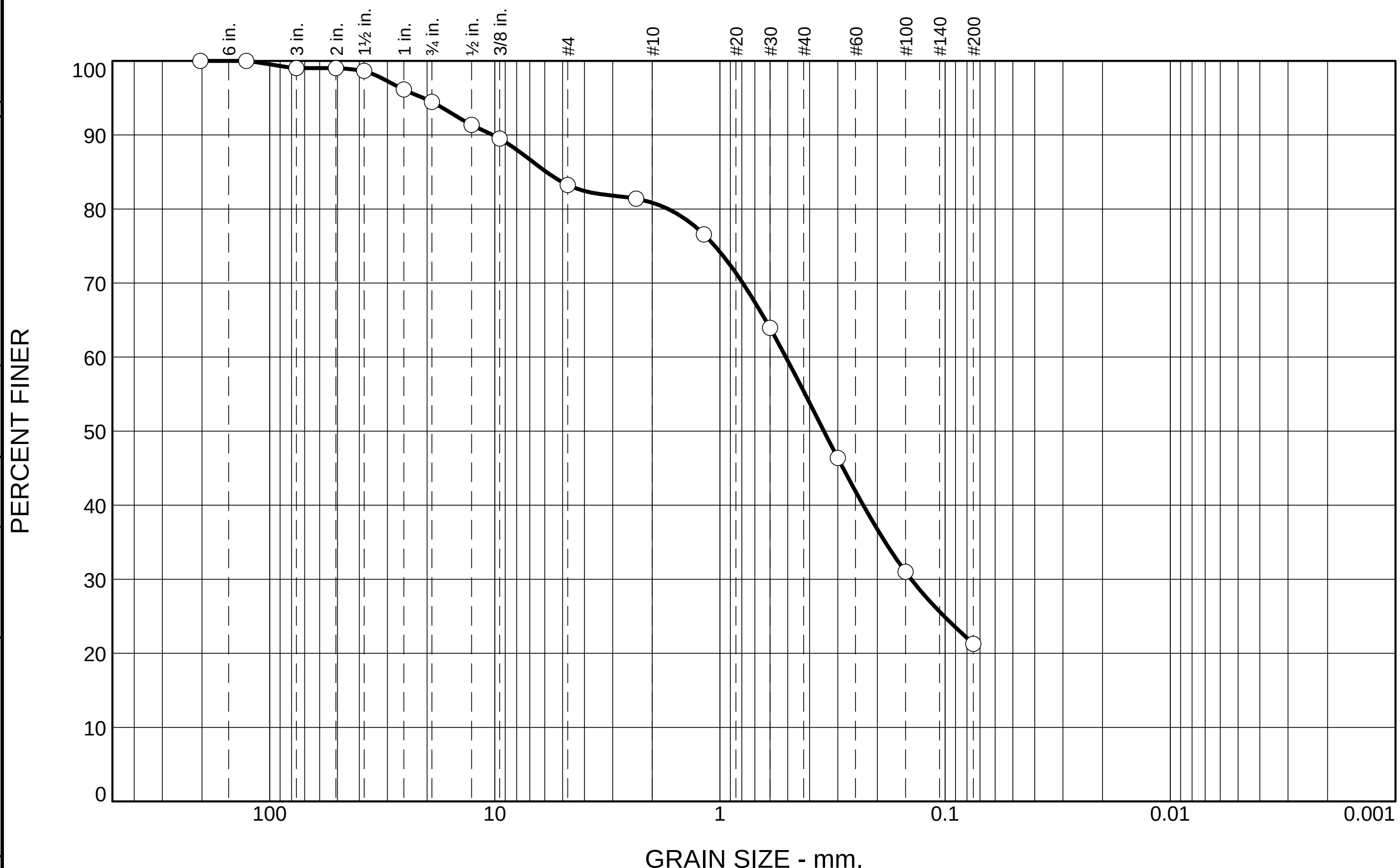
MacFarlane Dam 2017: Kumar and Associates, Inc. Project No. 17-1-463
Type B Gravel Drain Material Comparison Table

MacFarlane Dam Figure and Sample No.	Processing Lab Material Description	Date Sampled	Sample location/Specifications	% Passing 1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
F11 - C212	poorley graded gravel	8/29/2017	On-site stockpile	100	100	100	76	48	5	3	3	2	2	1	0.8
F27 - C239	poorley graded gravel	9/23/2017		100	100	100	81	57	15	5	3	2	2	1	0.9
			Average	**100**	**100**	**100**	**79**	**53**	**10**	**4**	**3**	**2**	**2**	**1**	**1**
			Specification	**100**		**60-100**		**35-100**	**12-65**	**0-42**	**0-15**	**0-5**			**0-3**

MacFarlane Dam 2017: Kumar and Associates, Inc. Project No. 17-1-463
Embankment Fill Comparison Table

MacFarlane Dam Figure and Sample No.	Processing Lab Material Description	Date Sampled	Sample location/Specifications	% Passing 8"	5"	3"	2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#16	#30	#50	#100	#200
F1 - C180	silty sand with gravel and cobbles	8/4/2017	On-site borrow, blended w/ ESW Sta. 6+25	100	100	99	99	99	96	94	91	90	83	81	77	64	46	31	21
F3 - C181	clayey sand with gravel	8/4/2017	On-site stockpile	100	100	100	98	97	96	94	89	85	72	71	68	60	45	32	23
F10 - C213	lean clay with sand	8/29/2017	Proctor Curve, "On Site Soils"	100	100	100	100	100	100	100	100	100	100	100	99	98	94	85	72
F18 - C226	silty sand with gravel and cobbles	9/9/2017	West Borrow Pit	100	100	97	95	93	92	87	81	78	68	68	67	64	52	34	22
F20 - C232	poorly graded sand with silt, gravel and cobbles	9/14/2017		100	100	97	94	90	87	82	74	69	58	56	53	44	26	15	11
Sample No. 7963	silty sand	9/21/2017	Proctor Curve, Borrow Area No. 2	100	100	100	100	100		97		95	93	91	85	67	45	29	20
Sample No. 7964	embankment fill/silty sand	9/21/2017	Proctor Curve, Borrow Area No. 2					100		95		94	93	91	87	78	60	42	29
Sample No. 7965	sandy silt	9/21/2017	Proctor Curve, Borrow Area No. 1										100	98	93	85	77	70	55
Sample No. 7966	embankment fill/sandy lean clay	9/21/2017	Proctor Curve, Borrow Area No. 1							100		100	100	97	95	90	83	73	60
Sample No. 7974	silty sand with gravel	9/21/2017	Proctor Curve, "On Site"					100		90		87	84	82	75	63	48	33	22
			Average	**100**	**100**	**99**	**97**	**97**	**94**	**93**	**87**	**87**	**83**	**82**	**79**	**70**	**56**	**42**	**32**
			Specification				**100**						**85-100**			**40-90**			**15-50**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
1	5	11	2	26	34	21	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8"	100		
5"	100		
3"	99		
2"	99		
1-1/2"	99		
1"	96		
3/4"	94		
1/2"	91		
3/8"	90		
#4	83		
#8	81		
#16	77		
#30	64		
#50	46		
#100	31		
#200	21		

* (no specification provided)

Material Description

silty sand with gravel and cobbles

Atterberg Limits

PL= 25 LL= 29 PI= 4

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Location: South of Spillway, On-Site Borrow, Blended w/ Sta. 6+25
Sample Number: C180 **Depth:** Composite **Date:** 08/04/2017

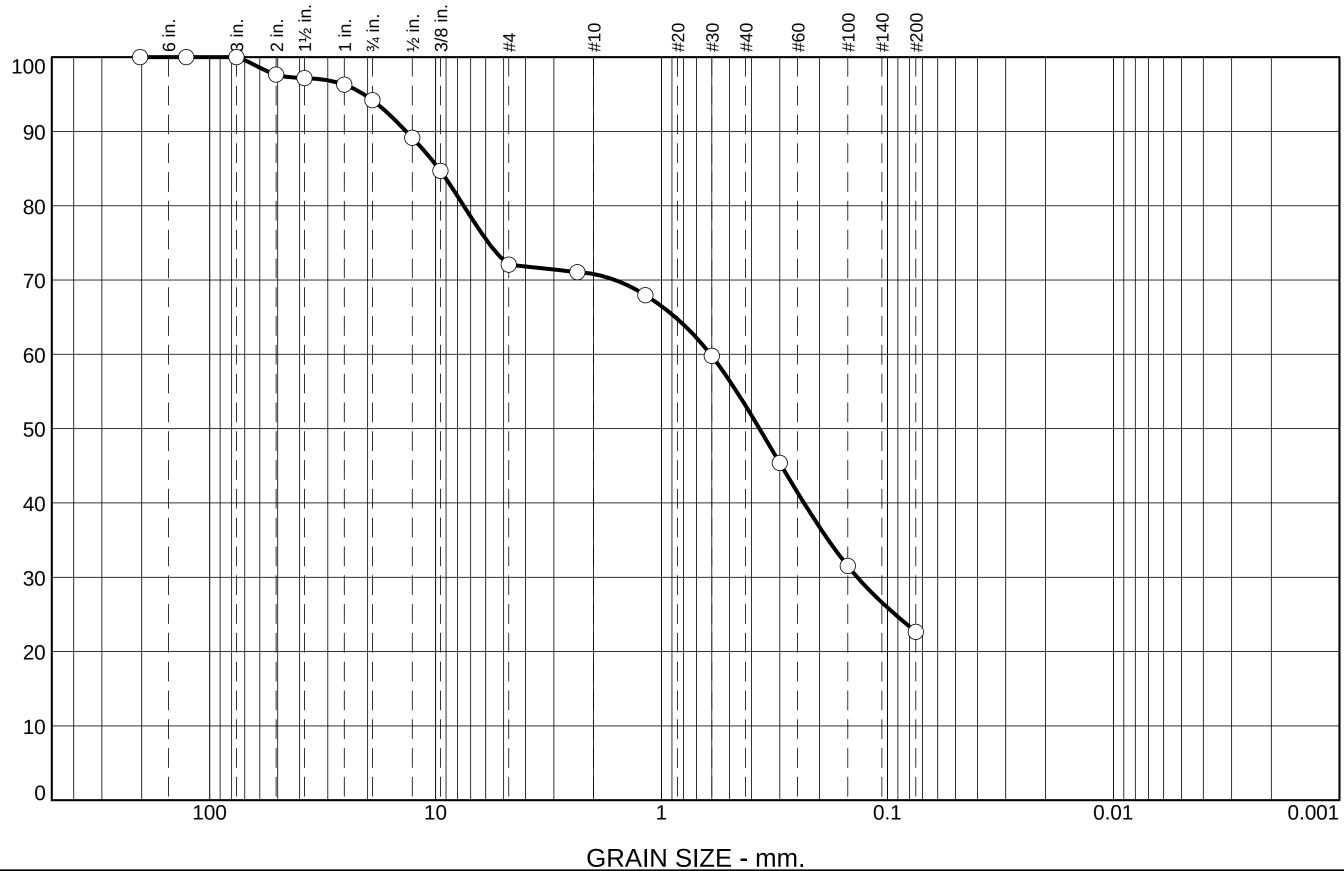
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 1

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	6	22	1	18	30	23	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8"	100		
5"	100		
3"	100		
2"	98		
1-1/2"	97		
1"	96		
3/4"	94		
1/2"	89		
3/8"	85		
#4	72		
#8	71		
#16	68		
#30	60		
#50	45		
#100	32		
#200	23		

* (no specification provided)

Material Description

clayey sand with gravel

Atterberg Limits

PL= 23 LL= 33 PI= 10

Classification

USCS= SC AASHTO= A-2-4(0)

Remarks

Location: On-Site Stockpile
Sample Number: C181 **Depth:** Composite **Date:** 08/04/2017

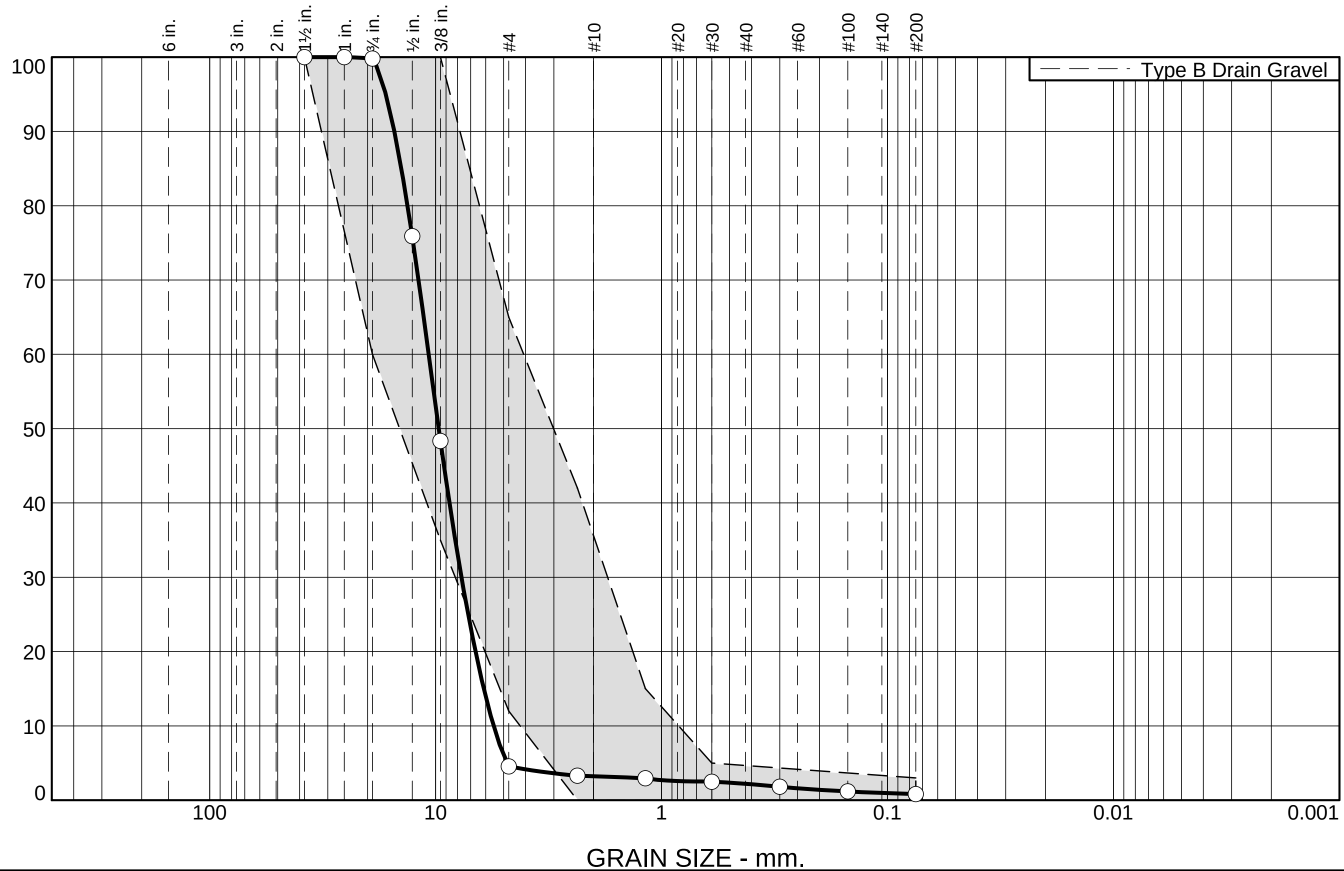
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 3

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	95	2	1	1	1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100	100	
1"	100		
3/4"	100	60 - 100	
1/2"	76		
3/8"	48	35 - 100	
#4	5	12 - 65	X
#8	3	0 - 42	
#16	3	0 - 15	
#30	2	0 - 5	
#50	2		
#100	1		
#200	0.8	0.0 - 3.0	

* Type B Drain Gravel

Material Description

poorly graded gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= GP AASHTO= A-1-a

Remarks

Location: Type B Drain Gravel
Sample Number: C212 **Depth:** Composite **Date:** 08/29/2017

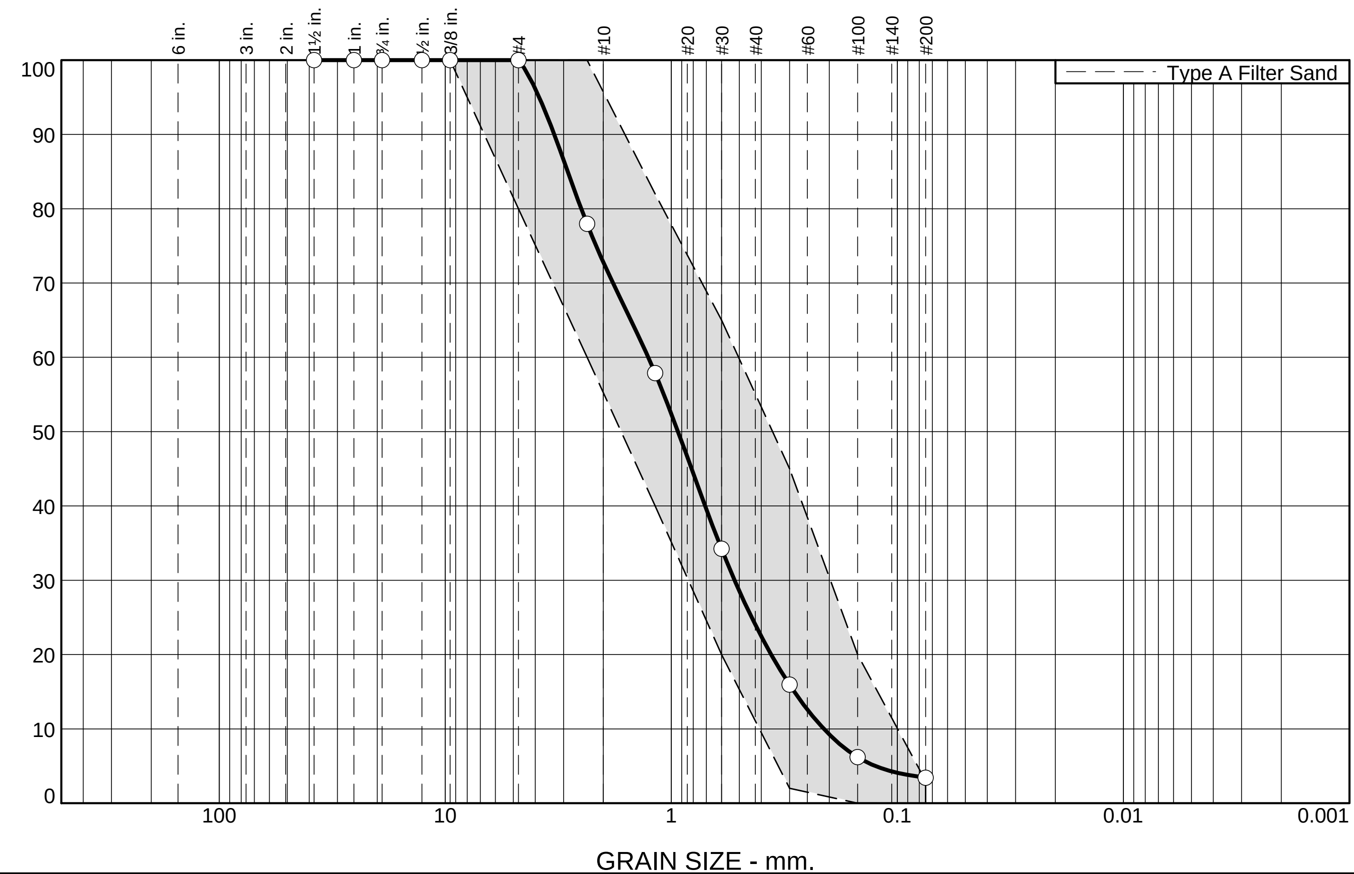
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 11

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	27	49	21	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	78	60 - 100	
#16	58	40 - 82	
#30	34	20 - 65	
#50	16	2 - 45	
#100	6	0 - 20	
#200	3.4	0.0 - 3.0	X

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Filter Sand
Sample Number: C214 **Depth:** 2 Passes **Date:** 08/29/2017

Kumar & Associates

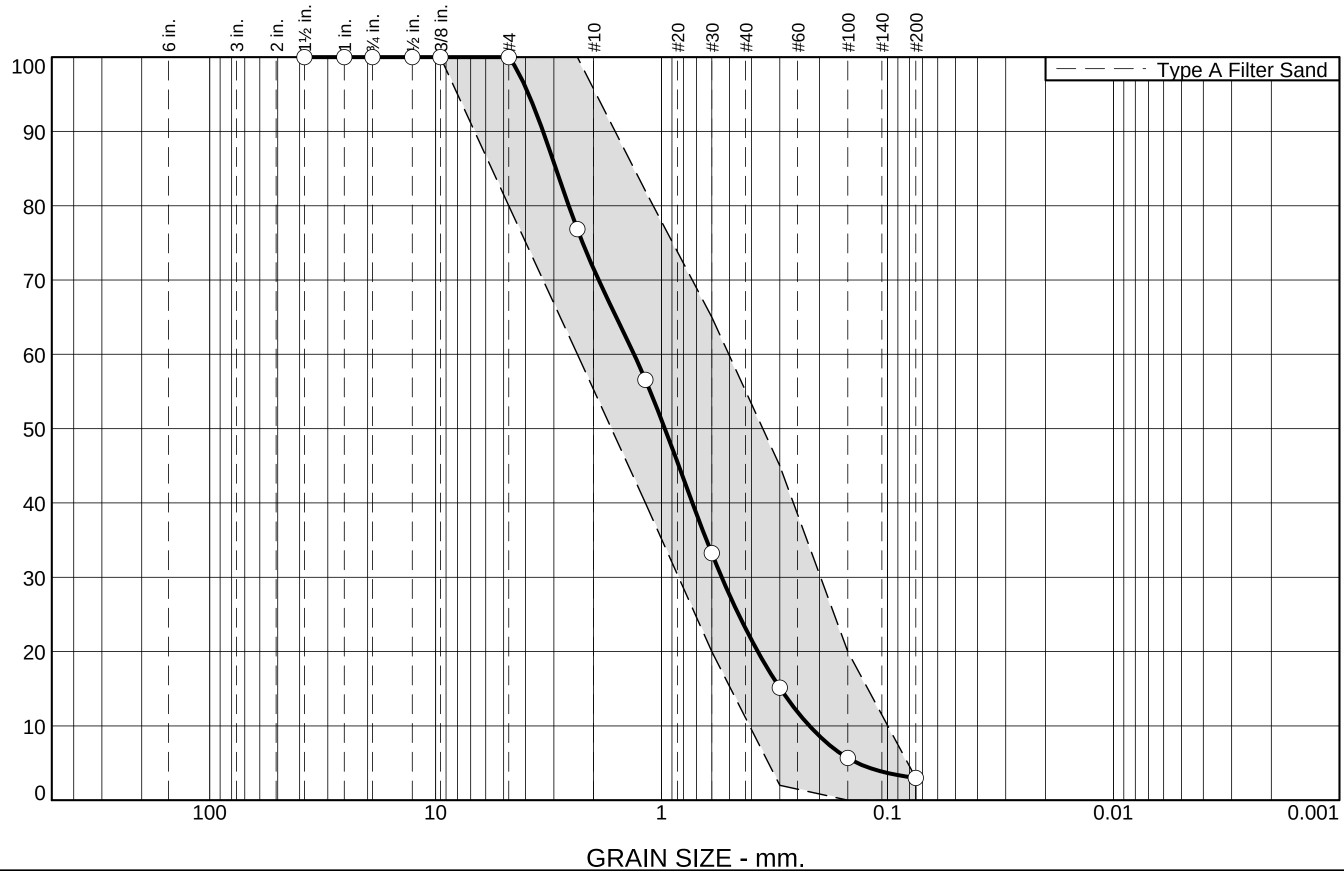
Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden

Project No: 17-1-463 **Figure** 12

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	28	49	20	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	77	60 - 100	
#16	57	40 - 82	
#30	33	20 - 65	
#50	15	2 - 45	
#100	6	0 - 20	
#200	3.0	0.0 - 3.0	

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Filter Sand
Sample Number: C215 **Depth:** 4 Passes **Date:** 08/29/2017

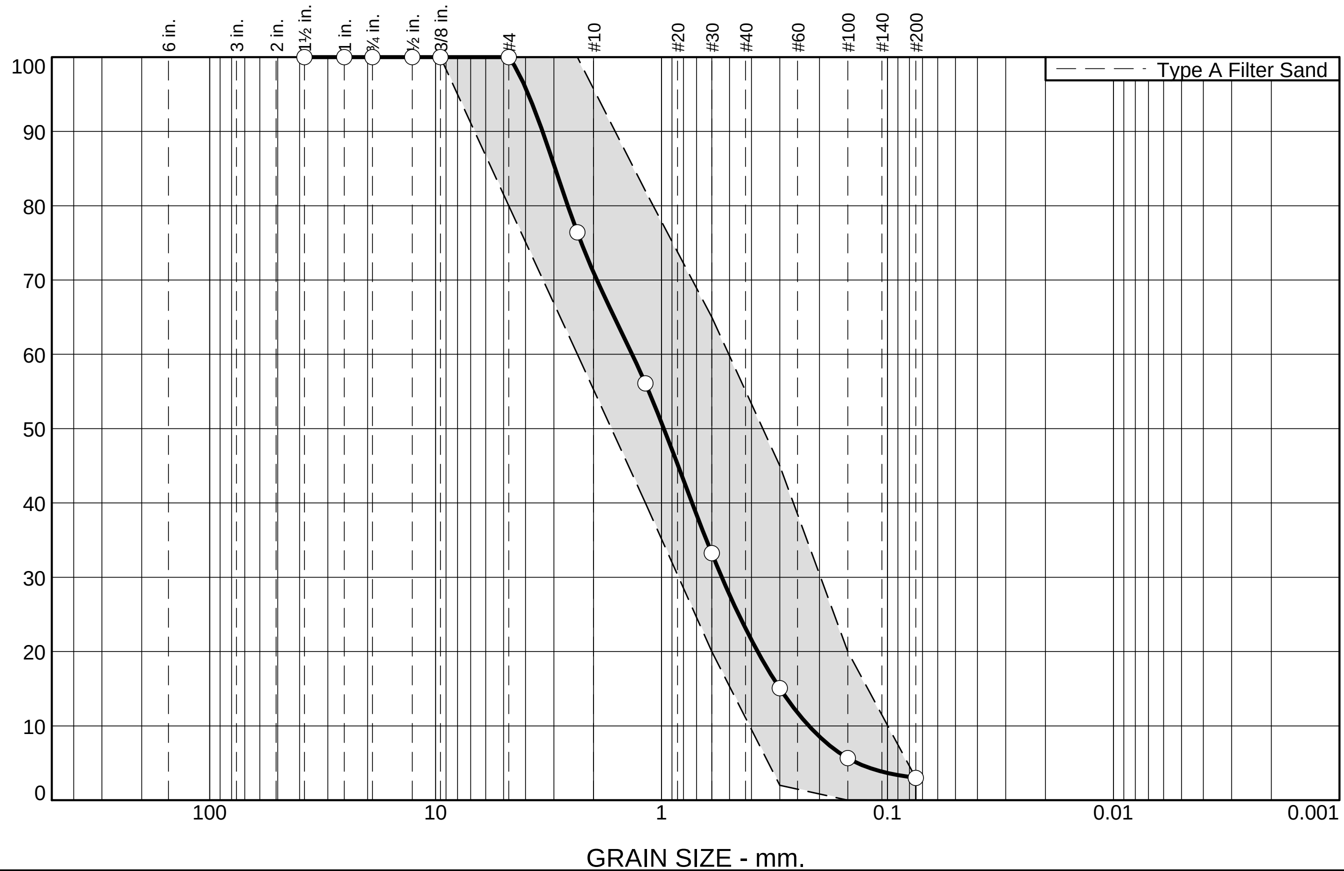
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 13

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	29	48	20	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	76	60 - 100	
#16	56	40 - 82	
#30	33	20 - 65	
#50	15	2 - 45	
#100	6	0 - 20	
#200	3.0	0.0 - 3.0	

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Filter Sand
Sample Number: C216 **Depth:** 6 Passes **Date:** 08/29/2017

Kumar & Associates

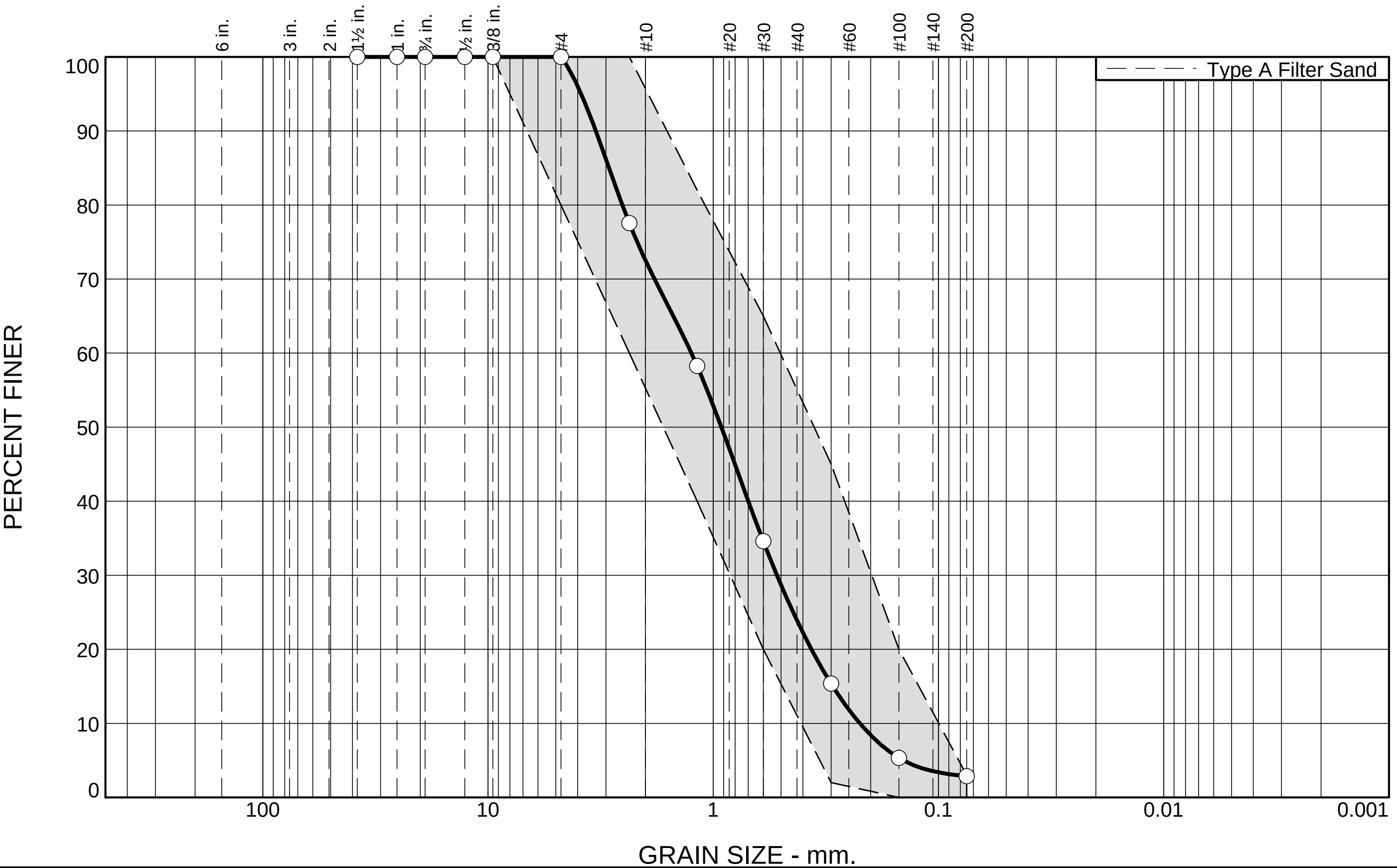
Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden

Project No: 17-1-463 **Figure** 14

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	27	49	21	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	78	60 - 100	
#16	58	40 - 82	
#30	35	20 - 65	
#50	15	2 - 45	
#100	5	0 - 20	
#200	2.9	0.0 - 3.0	

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Filter Sand
Sample Number: C217 **Depth:** As Is **Date:** 08/31/2017

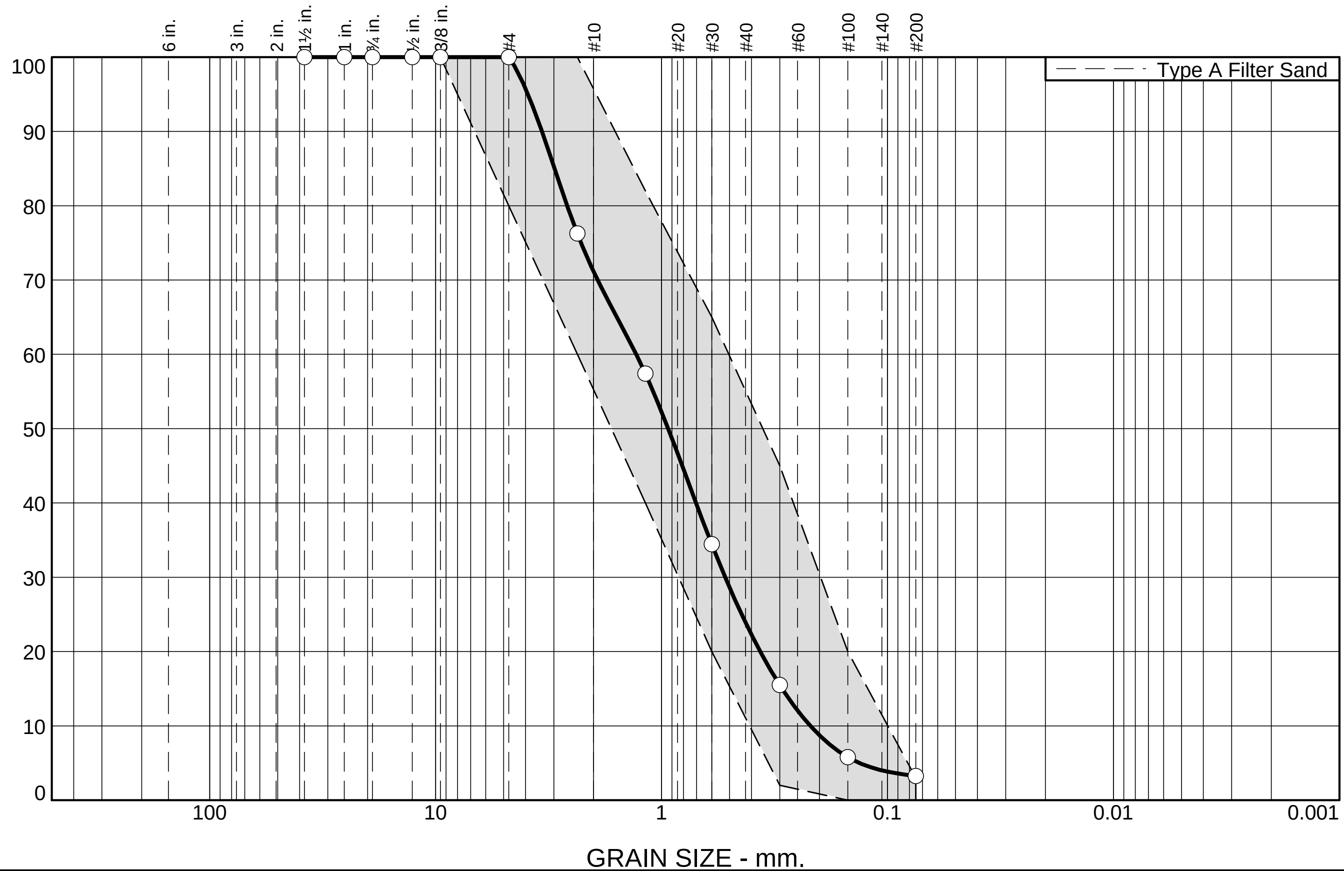
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 15

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	29	47	21	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	76	60 - 100	
#16	57	40 - 82	
#30	34	20 - 65	
#50	15	2 - 45	
#100	6	0 - 20	
#200	3.3	0.0 - 3.0	X

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Filter Sand
Sample Number: C218 **Depth:** 4 Passes Smooth Drum **Date:** 08/31/2017

Kumar & Associates

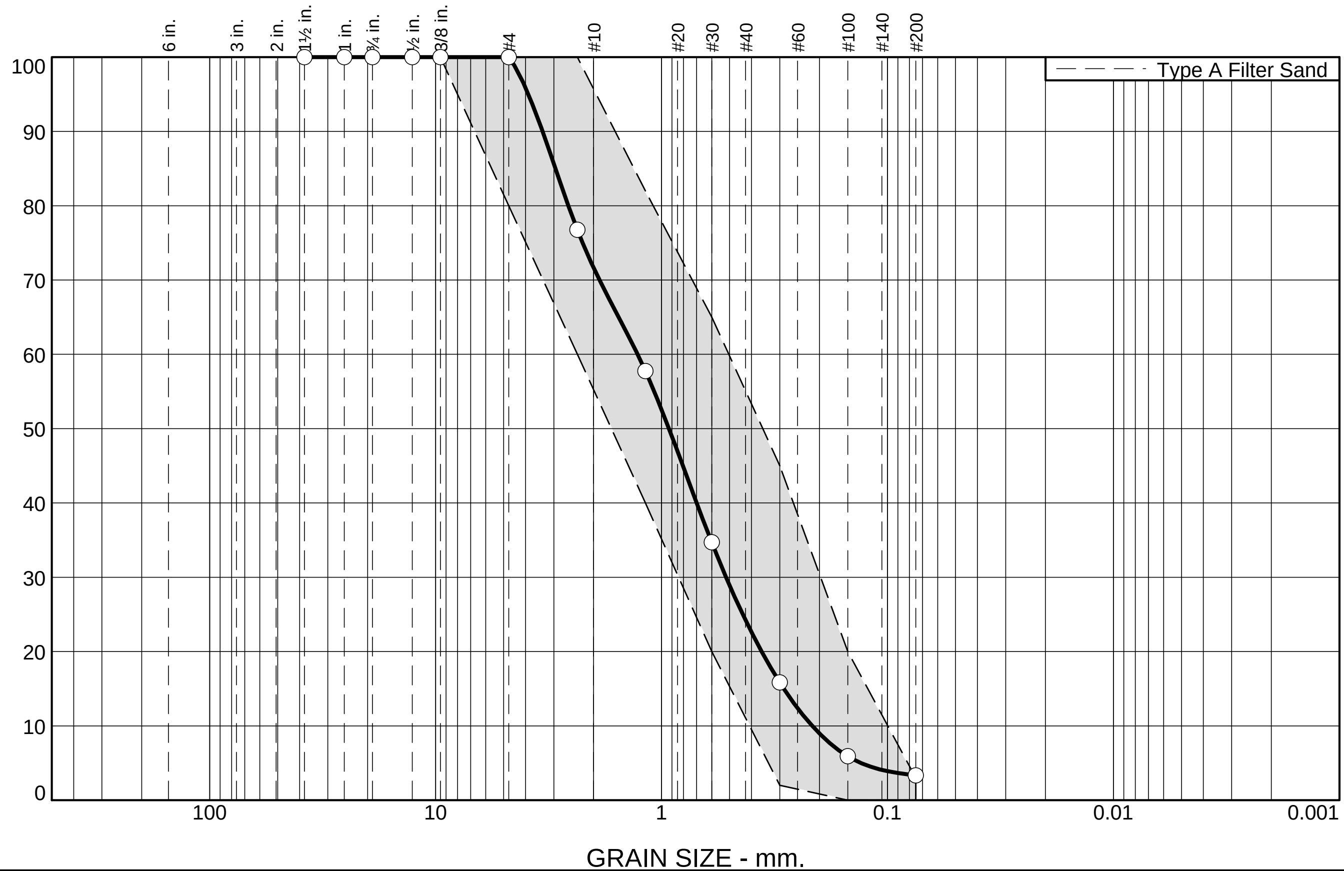
Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden

Project No: 17-1-463 **Figure** 16

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	28	48	21	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	100	80 - 100	
#8	77	60 - 100	
#16	58	40 - 82	
#30	35	20 - 65	
#50	16	2 - 45	
#100	6	0 - 20	
#200	3.3	0.0 - 3.0	X

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

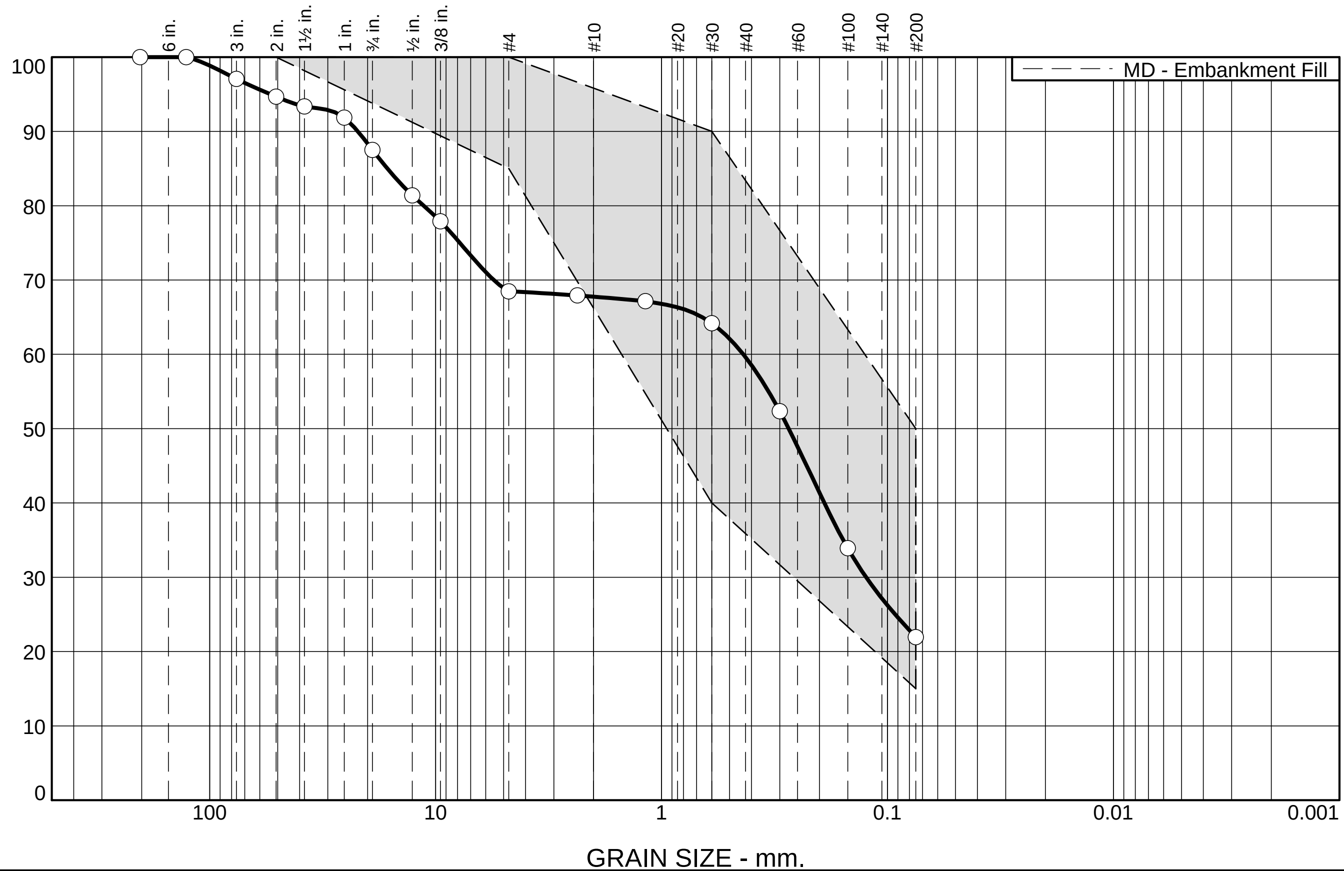
Remarks

Location: Filter Sand
Sample Number: C219 **Depth:** 8 Passes Smooth Drum **Date:** 08/31/2017

Kumar & Associates Silverthorne, CO	**Client:** WW Wheeler & Associates **Project:** MacFarlane Dam, Walden **Project No:** 17-1-463 **Figure** 17

Tested By: AMW **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
3	10	19	0	8	38	22	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8"	100		
5"	100		
3"	97		
2"	95	100	X
1-1/2"	93		
1"	92		
3/4"	87		
1/2"	81		
3/8"	78		
#4	68	85 - 100	X
#8	68		
#16	67		
#30	64	40 - 90	
#50	52		
#100	34		
#200	22	15 - 50	

* MD - Embankment Fill

Material Description

silty sand with gravel and cobbles

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Location: Embankment Fill - West Borrow Pit
Sample Number: C226 **Depth:** North Dam **Date:** 09/09/2017

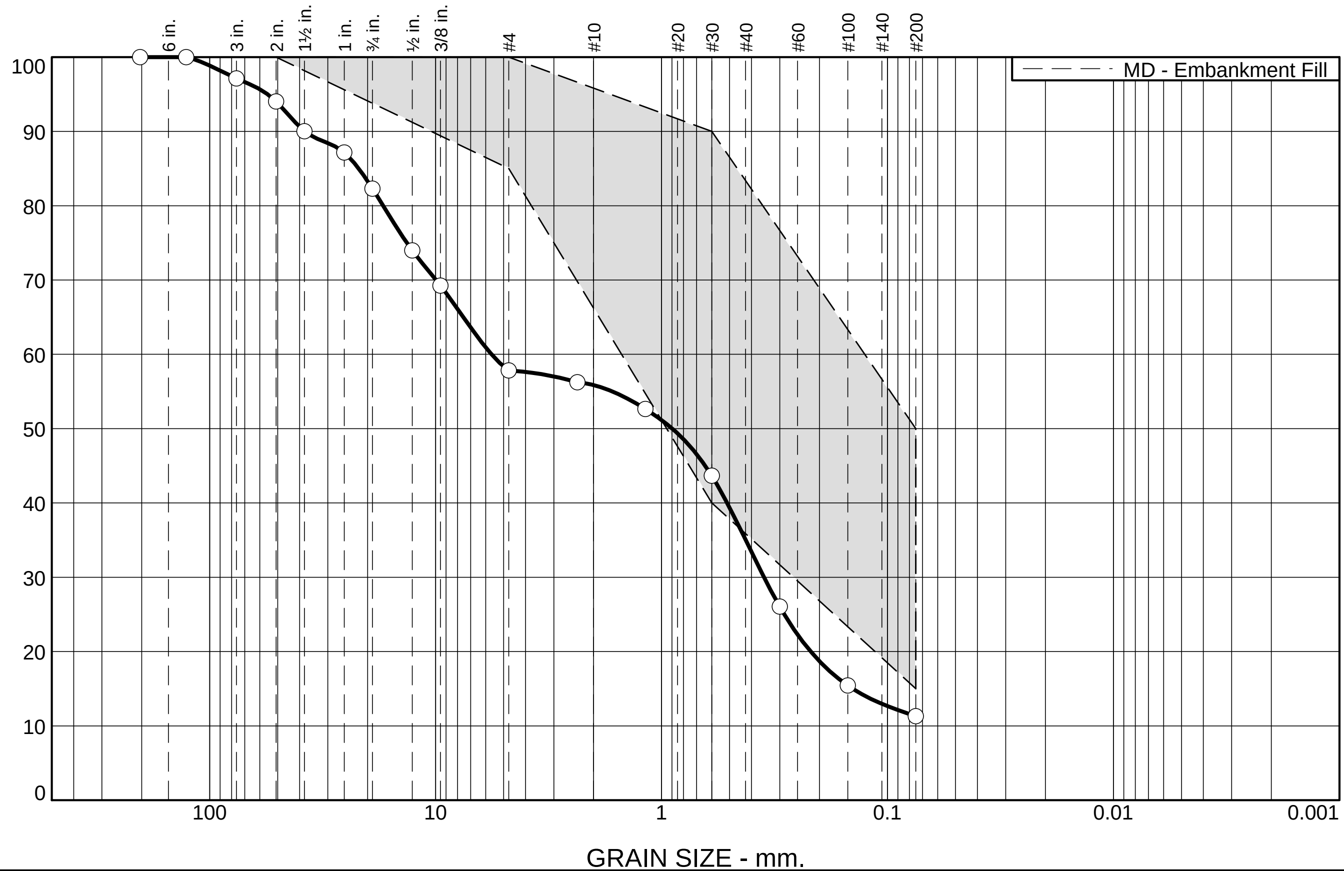
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 18

Tested By: CH **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
3	15	24	2	21	24	11	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
8"	100		
5"	100		
3"	97		
2"	94	100	X
1-1/2"	90		
1"	87		
3/4"	82		
1/2"	74		
3/8"	69		
#4	58	85 - 100	X
#8	56		
#16	53		
#30	44	40 - 90	
#50	26		
#100	15		
#200	11	15 - 50	X

* MD - Embankment Fill

Material Description

poorly graded sand with silt, gravel, and cobbles

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP-SM AASHTO= A-1-b

Remarks

Location: Embankment Fill
Sample Number: C232 **Depth:** Composite **Date:** 09/14/2017

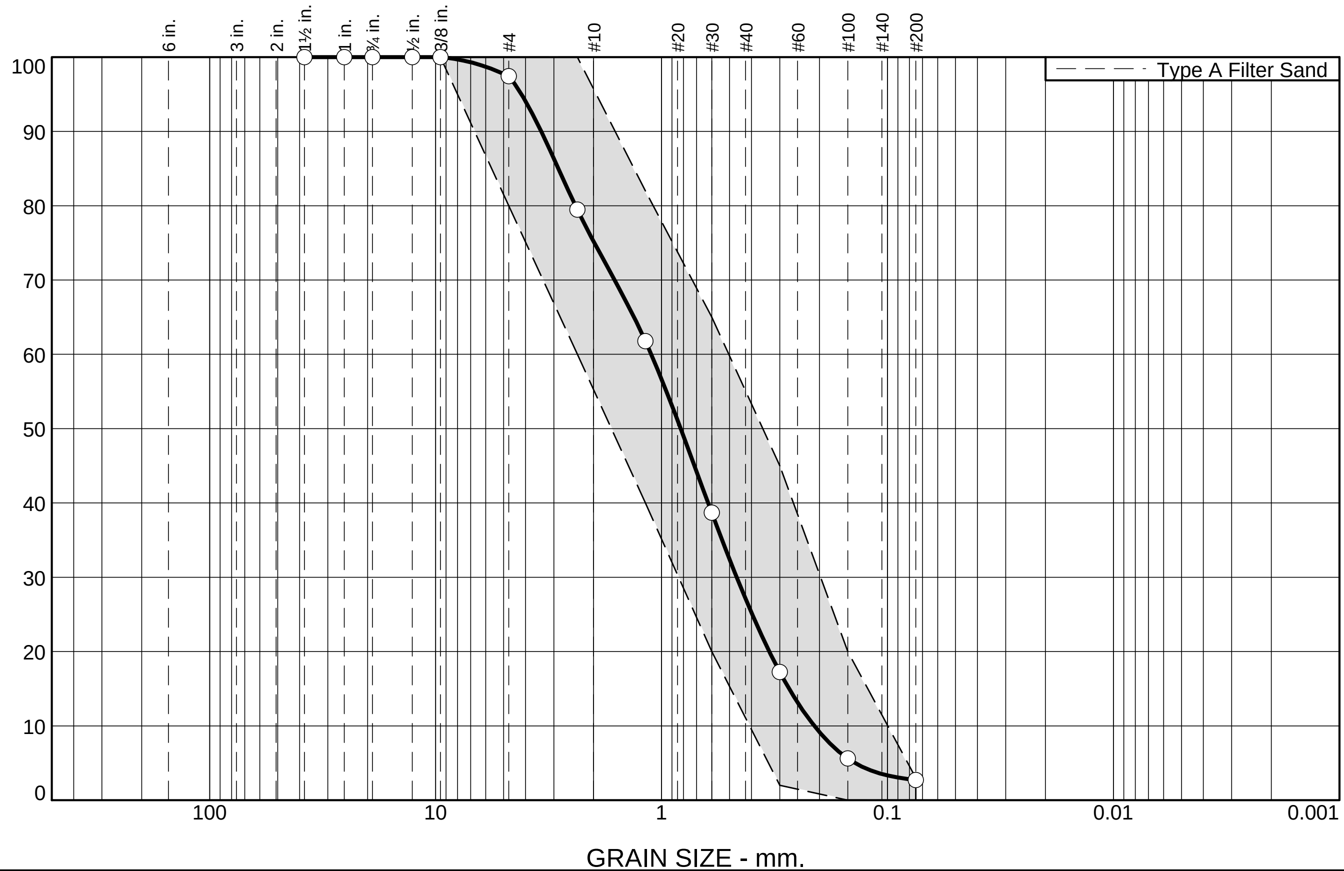
Kumar & Associates

Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden
Project No: 17-1-463 **Figure** 20

Tested By: CH **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	3	22	48	24	3	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
1"	100		
3/4"	100		
1/2"	100		
3/8"	100	100	
#4	97	80 - 100	
#8	79	60 - 100	
#16	62	40 - 82	
#30	39	20 - 65	
#50	17	2 - 45	
#100	6	0 - 20	
#200	2.7	0.0 - 3.0	

* Type A Filter Sand

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: Sand C33
Sample Number: C238

Date: 09/23/2017

Kumar & Associates

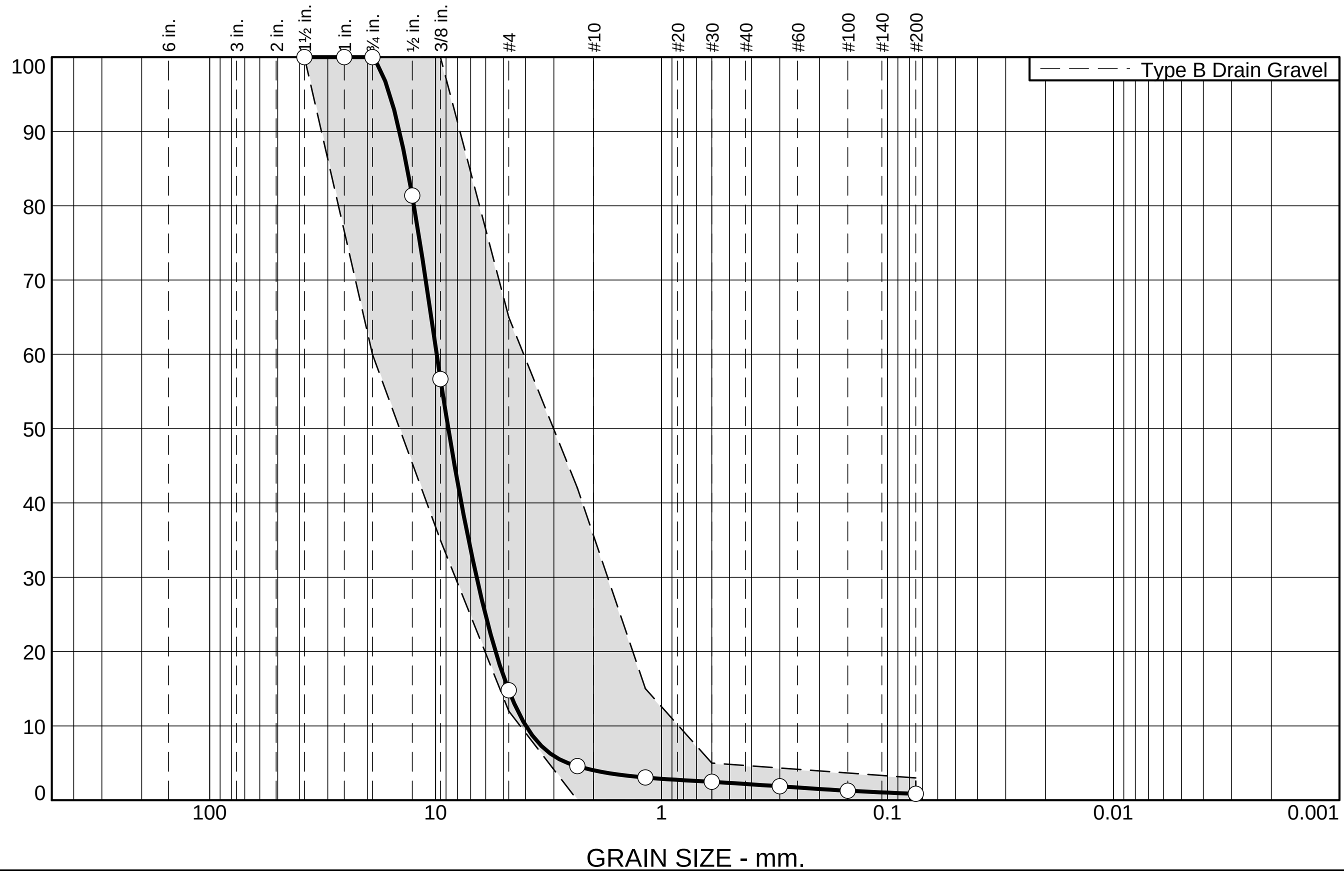
Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden

Project No: 17-1-463 **Figure** 26

Tested By: CH **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	85	11	2	1	1	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100	100	
1"	100		
3/4"	100	60 - 100	
1/2"	81		
3/8"	57	35 - 100	
#4	15	12 - 65	
#8	5	0 - 42	
#16	3	0 - 15	
#30	2	0 - 5	
#50	2		
#100	1		
#200	0.9	0.0 - 3.0	

* Type B Drain Gravel

Material Description

poorly graded gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= GP AASHTO= A-1-a

Remarks

Location: Gravel
Sample Number: C239

Date: 09/23/2017

Kumar & Associates

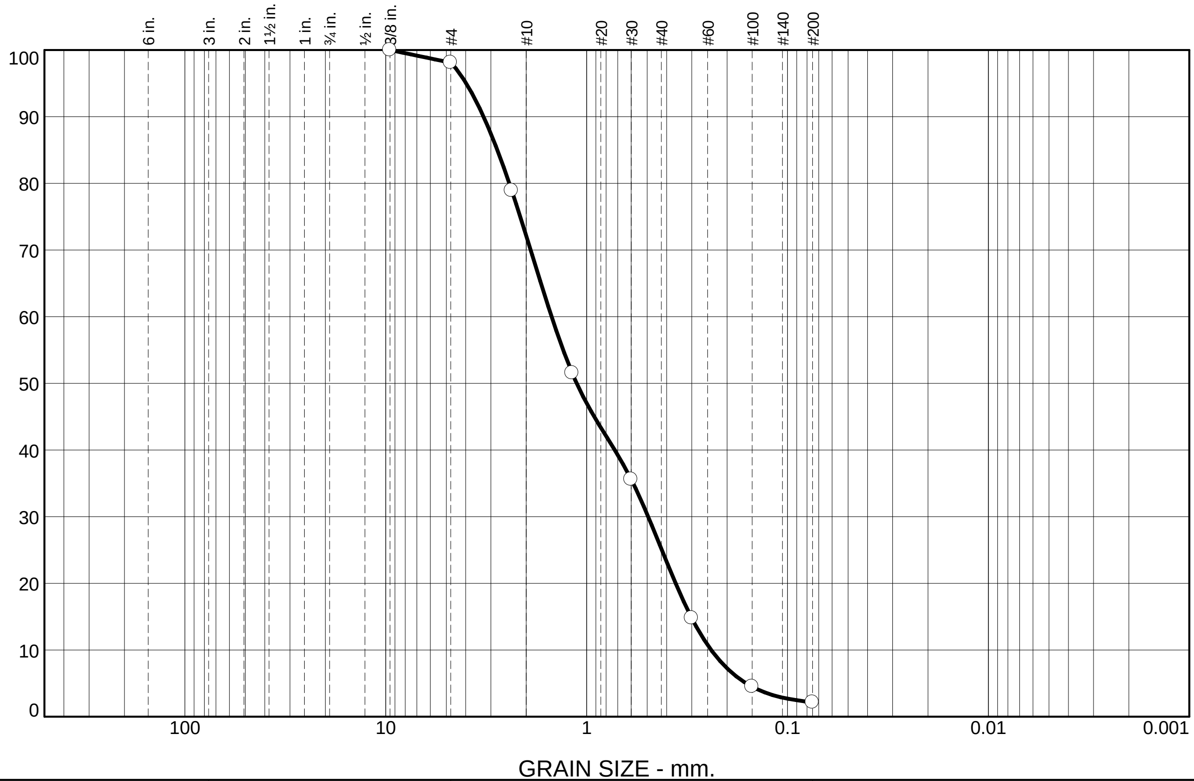
Silverthorne, CO

Client: WW Wheeler & Associates
Project: MacFarlane Dam, Walden

Project No: 17-1-463 **Figure** 27

Tested By: CH **Checked By:** JLC

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	2	26	47	23	2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8"	100		
#4	98		
#8	79		
#16	52		
#30	36		
#50	15		
#100	5		
#200	2.2		

* (no specification provided)

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: On-Site
Sample Number: 7920

Date: 8-28-17

Kumar & Associates, Inc.

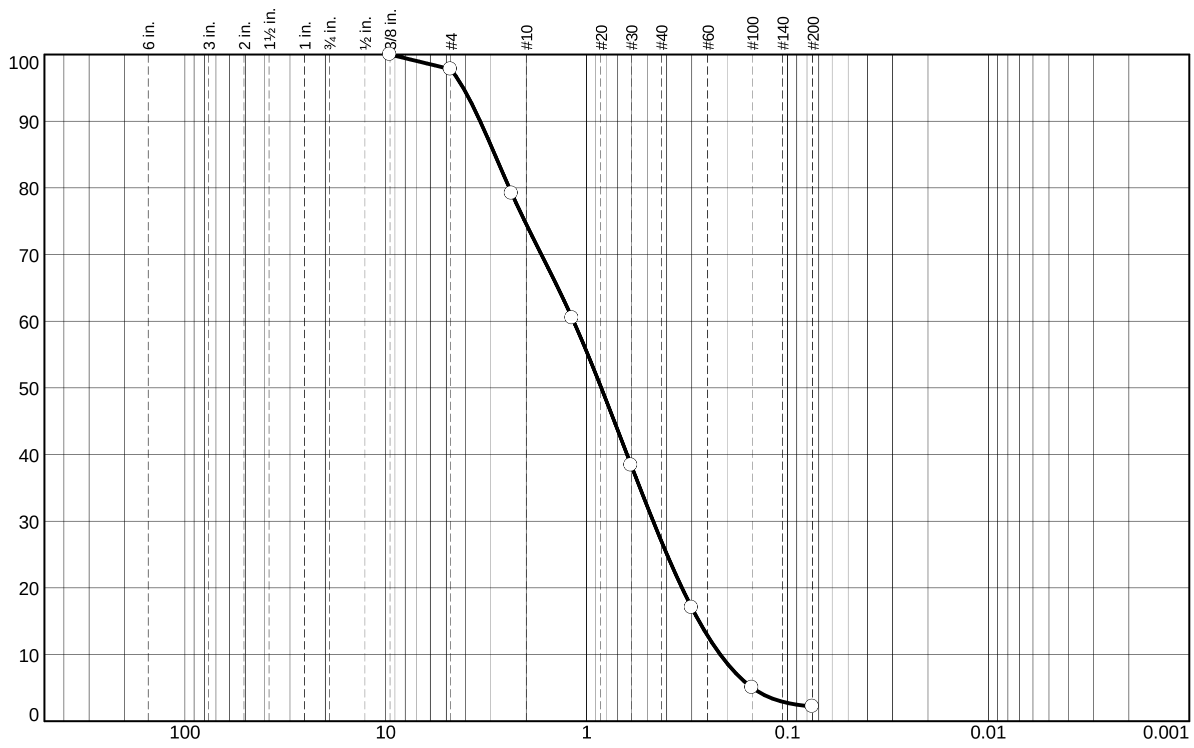
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: AS **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	2	23	48	25	2	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8"	100		
#4	98		
#8	79		
#16	60		
#30	38		
#50	17		
#100	5		
#200	2.2		

* (no specification provided)

Material Description

poorly graded sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SP AASHTO= A-1-b

Remarks

Location: On-Site
Sample Number: 7921

Date: 8-28-17

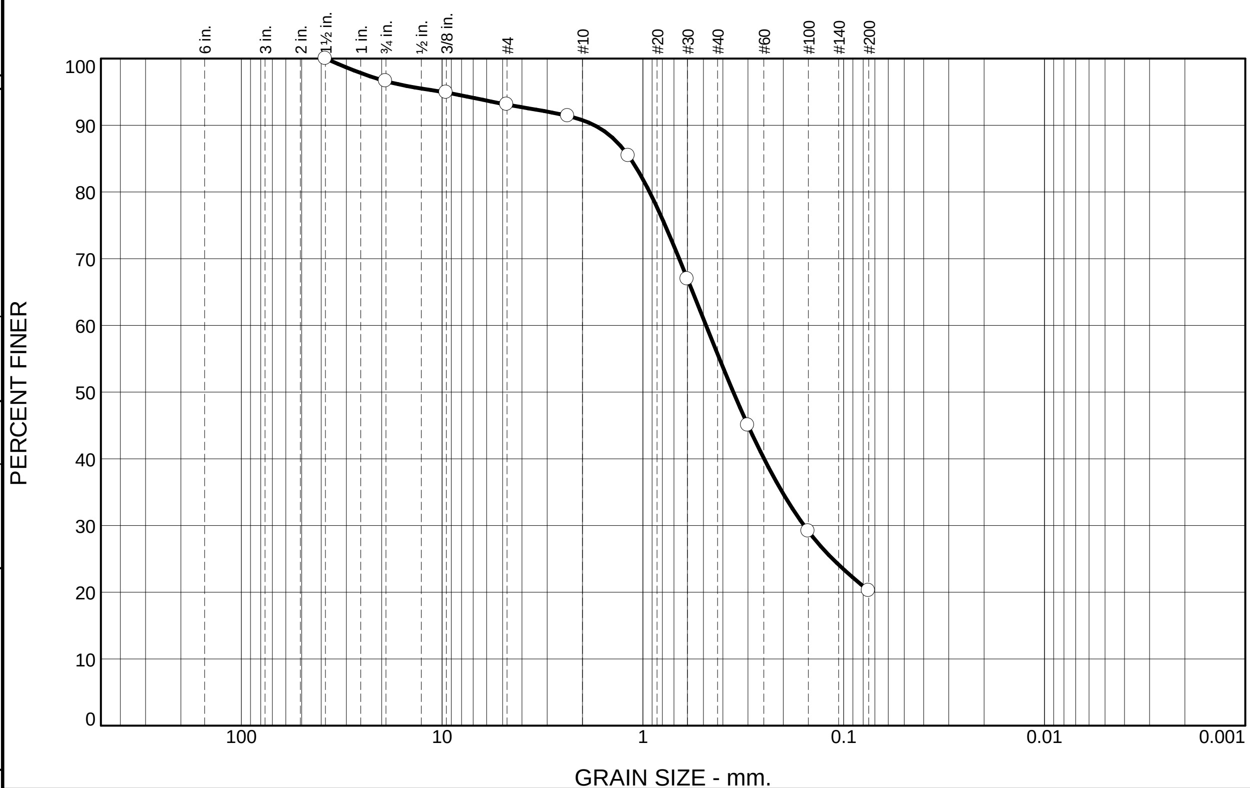
Kumar & Associates, Inc.

Denver, Colorado

Client:
Project: MacFarlane Dam
Project No: 17-1-463 **Figure**

Tested By: AS **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	3	4	2	35	36	20	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
3/4"	97		
3/8"	95		
#4	93		
#8	91		
#16	85		
#30	67		
#50	45		
#100	29		
#200	20		

* (no specification provided)

Material Description

silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Location: Borrow #2
Sample Number: 7963

Date: 9-21-17

Kumar & Associates, Inc.

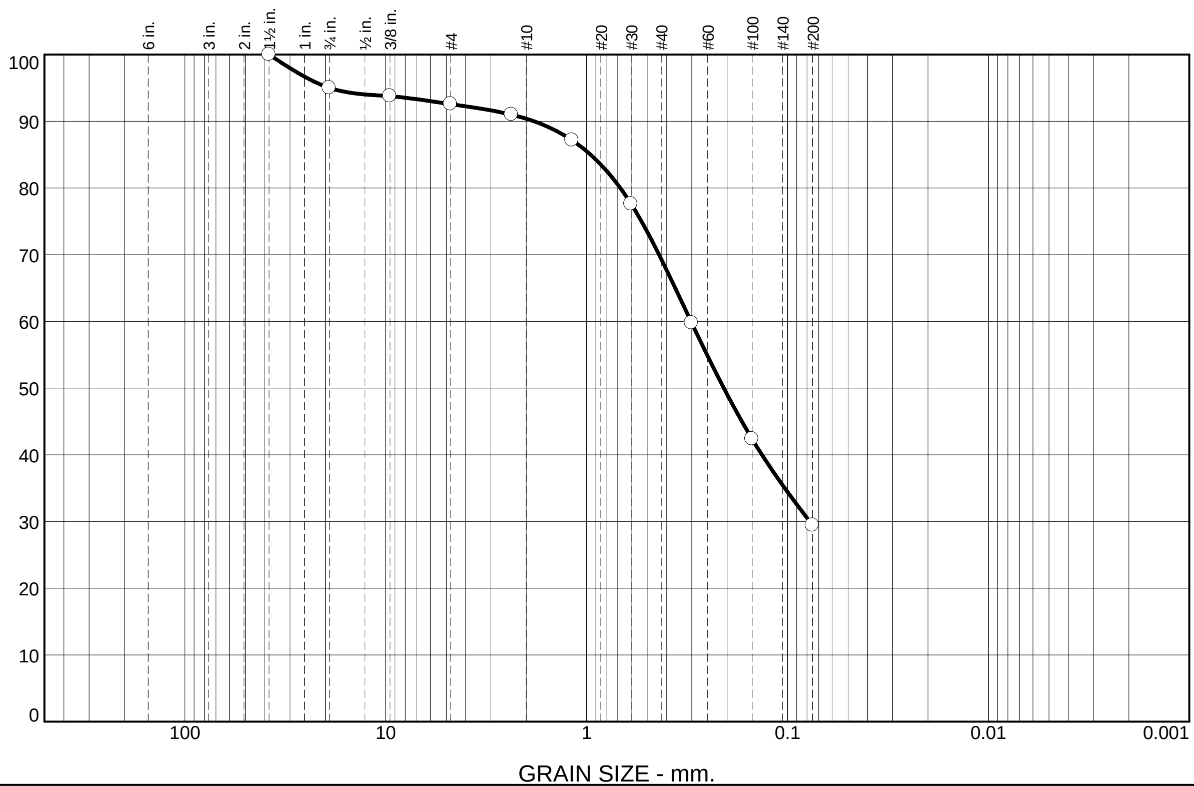
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: AS **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	5	2	3	21	40	29	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
3/4"	95		
3/8"	94		
#4	93		
#8	91		
#16	87		
#30	78		
#50	60		
#100	42		
#200	29		

* (no specification provided)

Material Description

Embankment Fill / silty sand

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Location: Borrow #2
Sample Number: 7964

Date: 9-21-17

Kumar & Associates, Inc.

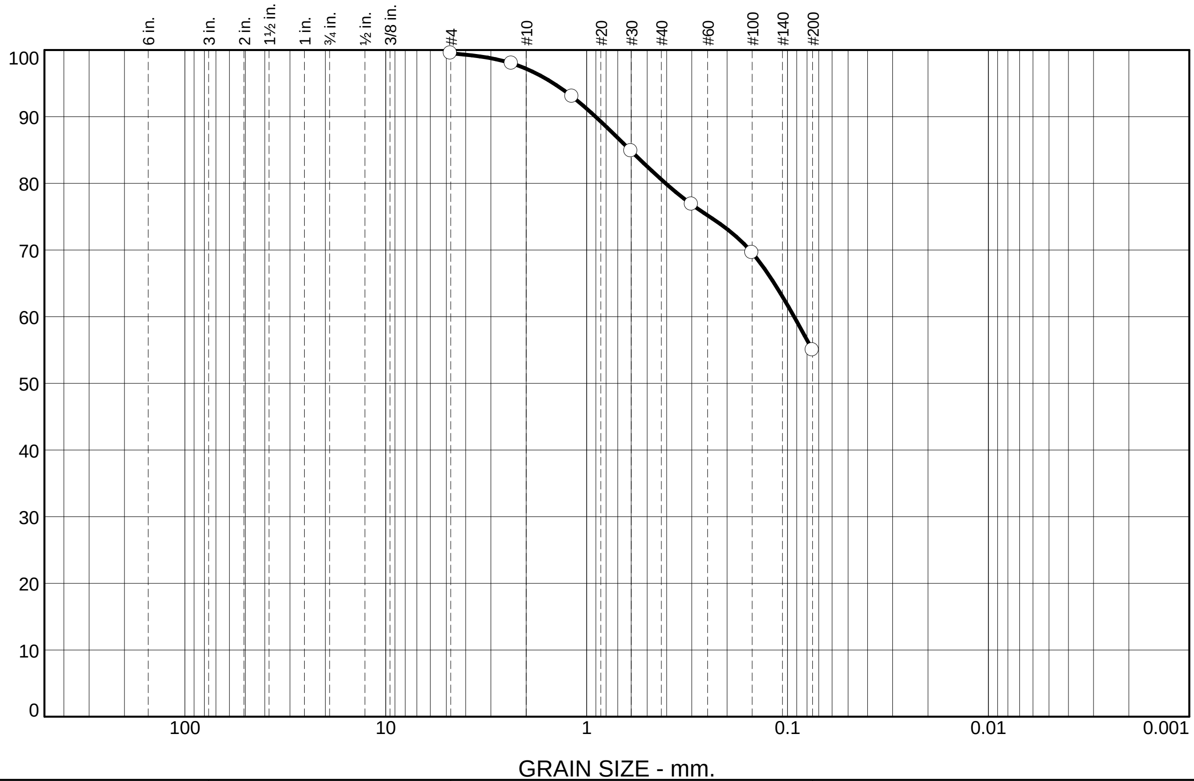
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: JP **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
			3	16	26	55	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100		
#8	98		
#16	93		
#30	85		
#50	77		
#100	70		
#200	55		

* (no specification provided)

Material Description

sandy silt

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= ML AASHTO= A-4(0)

Remarks

Location: Borrow #1
Sample Number: 7965

Date: 9-21-17

Kumar & Associates, Inc.

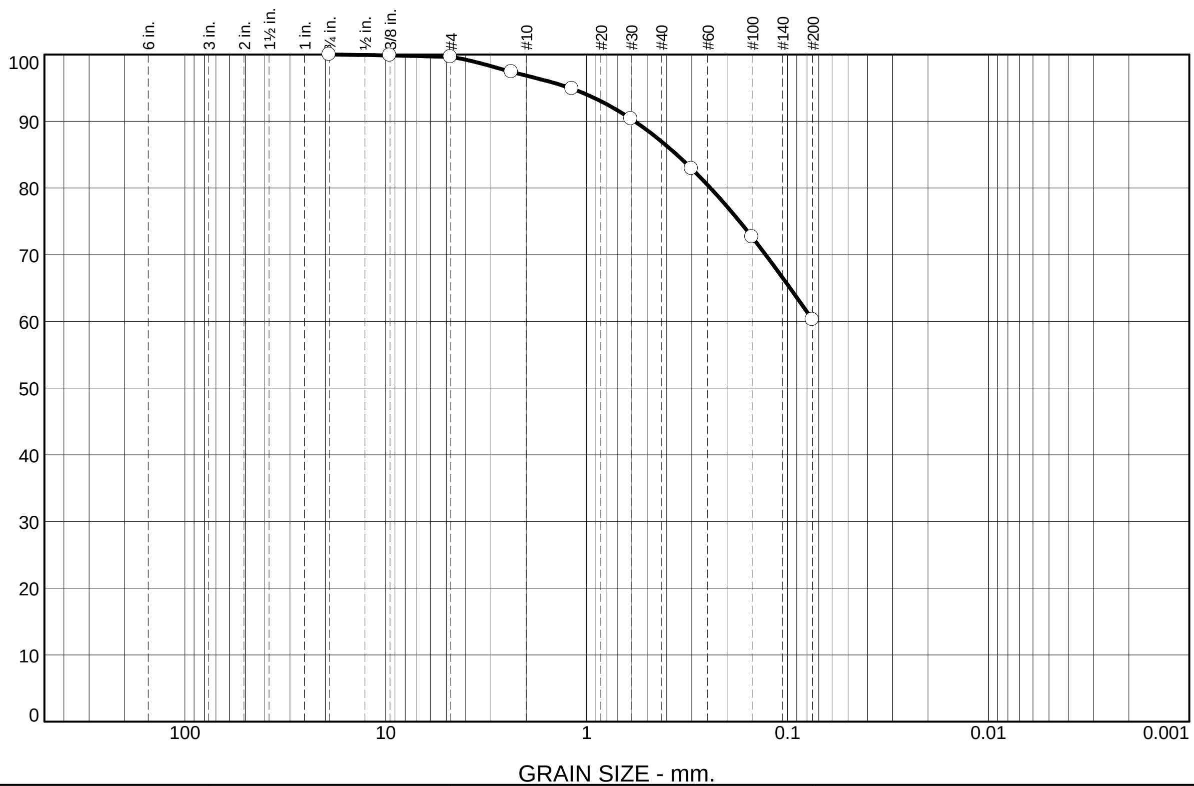
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: JP **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	3	10	27	60	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100		
3/8"	100		
#4	100		
#8	97		
#16	95		
#30	90		
#50	83		
#100	73		
#200	60		

* (no specification provided)

Material Description

Embankment Fill / sandy lean clay

Atterberg Limits

PL= 22 LL= 30 PI= 8

Classification

USCS= CL AASHTO= A-4(3)

Remarks

Location: Borrow #1
Sample Number: 7966

Date: 9-21-17

Kumar & Associates, Inc.

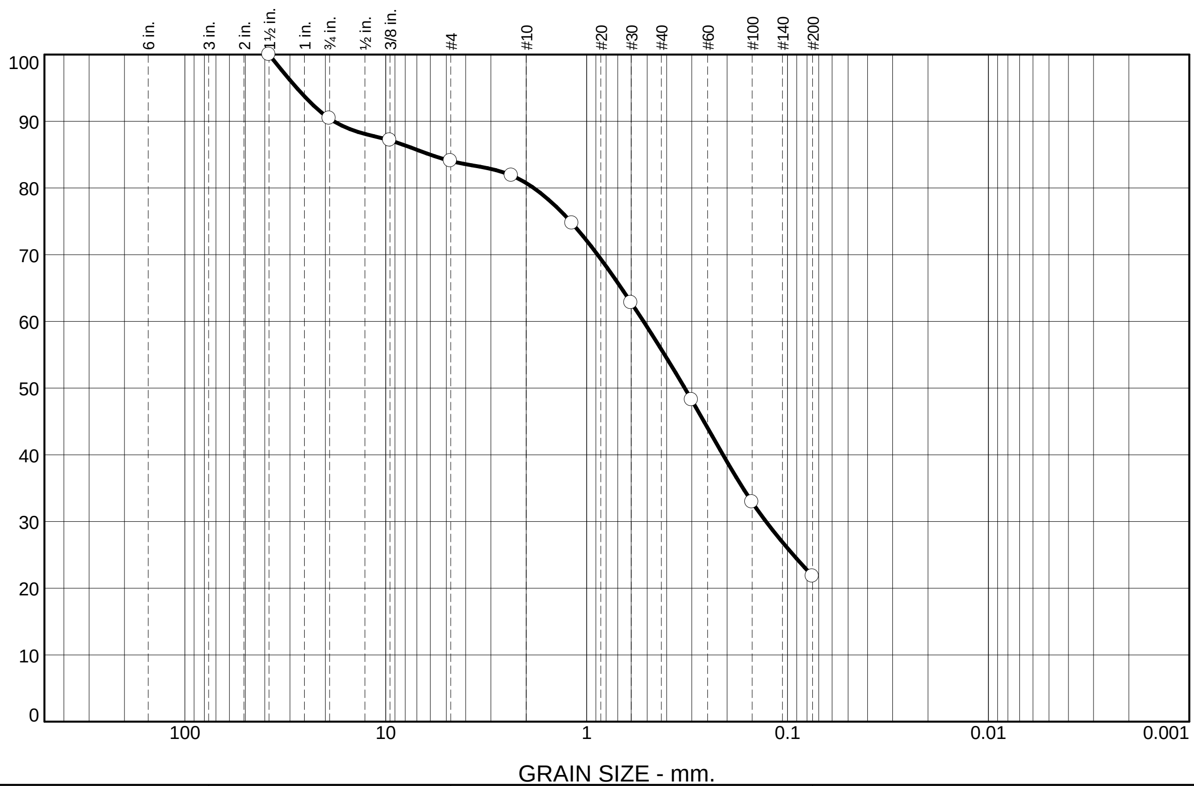
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: JP **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	10	6	3	25	34	22	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1-1/2"	100		
3/4"	90		
3/8"	87		
#4	84		
#8	82		
#16	75		
#30	63		
#50	48		
#100	33		
#200	22		

* (no specification provided)

Material Description

silty sand with gravel

Atterberg Limits

PL= NP LL= NV PI= NP

Classification

USCS= SM AASHTO= A-2-4(0)

Remarks

Location: On-Site
Sample Number: 7974

Date: 9-26-17

Kumar & Associates, Inc.

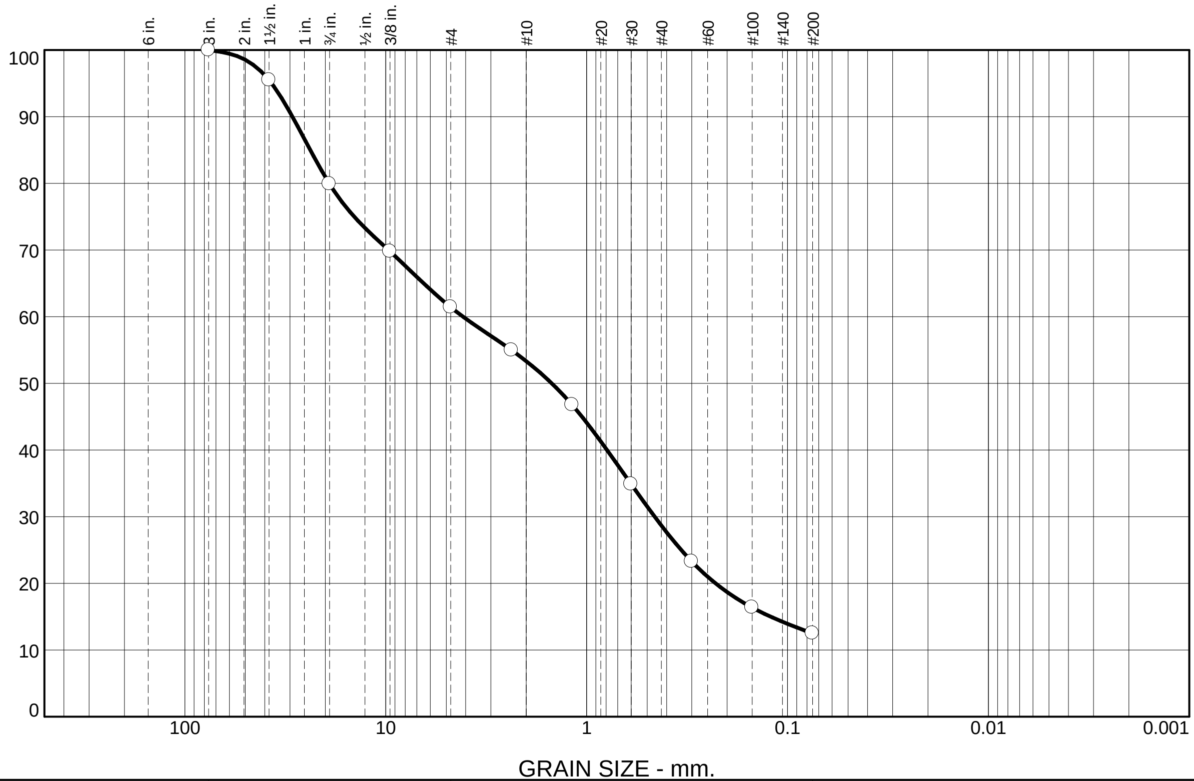
Denver, Colorado

Client:
Project: MacFarlane Dam

Project No: 17-1-463 **Figure**

Tested By: AS **Checked By:** DS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	20	19	8	24	16	13	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3"	100		
1-1/2"	95		
3/4"	80		
3/8"	70		
#4	61		
#8	55		
#16	47		
#30	35		
#50	23		
#100	16		
#200	13		

* (no specification provided)

Material Description

silty sand with gravel / Rip-Rap Bedding

Atterberg Limits

PL= 20 LL= 21 PI= 1

Classification

USCS= SM AASHTO= A-1-b

Remarks

Location: Refuge HQ Stockpile
Sample Number: 7982

Date: 9/28/17

Kumar & Associates, Inc.

Denver, Colorado

Client:
Project: MacFarlane Dam
Project No: 17-1-463 **Figure**

Tested By: JP **Checked By:** DS

APPENDIX C-3

Proctor Curves and Density Field Testing

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

Date	Test No.	Structure	Location	Depth/ Elev. (ft)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Dry Density (pcf)	Moisture Content (%)	Compaction (%)	Pass/ Fail	Material	Soil Type	Proctor Curve
8/3/2017	1.0	South Berm	Sta. 6+10, 30' S of CL	1.5 below existing grade	119.1	11.3	115.2	11.3	97	Y	Onsite borrow	SC	C181
8/3/2017	2.0	South Berm	Sta. 6+20, 20' S of CL	1' below exisiting grade	119.1	11.3	114	13.2	96	Y	Onsite borrow	SC	C181
8/4/2017	3.0	South Berm	Sta. 5+80, 20' S of CL	at exisiting grade	119.1	11.3	118.5	10.8	100	Y	Onsitit borrow	SC	C181
8/4/2017	4.0	South Berm	Sta. 5+75, 18' S of CL	4' Below grade	119.1	11.3	113.2	14.6	95	Y	Onsite borrow	SC	C181
8/4/2017	5.0	South Berm	Sta. 6+35, 25' S of CL	4' below grade	119.1	11.3	115.7	13.4	97	Y	Onsite borrow	SC	C181
8/4/2017	6.0	South Berm	Sta. 5+70, 16' S pf CL	3.5' below grade	119.1	11.3	117.5	11.3	98	Y	Onsite borrow	SC	C181
8/4/2017	7.0	South Berm	Sta. 6+10,, 28' S pf CL	3' below grade	119.1	11.3	120.1	10.7	100	Y	Onsite borrow	SC	C181
8/4/2017	8.0	South Berm	Sta. 5+40, 15' S of CL	2' below exisitng grade	119.1	11.3	112.7	14.1	95	Y	Onsite borrow	SC	C181
8/5/2017	9.0	South Berm	Sta. 5+90 20' S of CL	2.5' below grade	119.1	11.3	117.5	11.8	98	Y	onsite borrow	SC	C181
8/5/2017	10.0	North Berm	Sta. 5+60, 15 N of CL	6' below grade	119.1	11.3	113.7	13.5	95	Y	Onsite borrow	SC	C181
8/5/2017	11.0	South Berm	Sta. 5+00	2.5' below grade	119.1	11.3	113.8	11.5	96	Y	Onsite borrow	SC	C181
8/5/2017	12.0	North Berm	Sta. 5+40, 27' N of CL	5' below grade	119.1	11.3	113.7	14.6	95	Y	Onsite borrow	SC	C181
8/5/2017	13.0	North Berm	Sta. 6+40, 32' N of CL	5' below grade	119.1	11.3	113.9	14	95	Y	Onsite borrow	SC	C181
8/5/2017	14.0	North Berm	Sta. 4+80, 15' N of CL	4' below grade	119.1	11.3	117.2	13.7	98	Y	Onsite borrow	SC	C181
8/5/2017	15.0	North Berm	Sta. 5+70, 10' N of CL	4' Below grade	119.1	11.3	118	9.6	99	Y	Onsite borrow	SC	C181
8/5/2017	16.0	South Berm	Sta. 6+45, 10' S of CL	1.5' below grade	119.1	11.3	113.8	10.9	95	Y	Onsite borrow	SC	C181
8/5/2017	17.0	South Berm	Sta. 4+40, 12' S of CL	1' below grade	119.1	11.3	113.7	10.7	95	Y	Onsite borrow	SC	C181
8/7/2017	18.0	South Berm	Sta. 4+25, 2' S of S berm CL	1.5' below grade	119.1	11.3	115.2	10.9	97	Y	Onsite borrow	SC	C181
8/7/2017	19.0	South Berm	Sta. 5+60, 3' N of S berm CL	1.5' below grade	119.1	11.3	115.6	11.1	97	Y	Onsite borrow	SC	C181
8/7/2017	20.0	North Berm	Sta. 4+96, 1' S of N berm CL	.5 below grade	119.1	11.3	113.4	10.9	95	Y	Onsite borrow	SC	C181
8/7/2017	21.0	North Berm	Sta. 5+64, 4' N of N berm CL	.5 below grade	119.1	11.3	113.8	11.7	96	Y	Onsite borrow	SC	C181
8/7/2017	22.0	South Berm	Sta. 4+62, S berm CL	.5 below grade	119.1	11.3	115.6	11.5	97	Y	Onsite borrow	SC	C181
8/7/2017	23.0	South Berm	Sta. 5+50, 1' S of S berm CL	.5 below grade	119.1	11.3	114.9	11	97	Y	Onsite borrow	SC	C181
8/8/2017	24.0	North Berm	Sta. 5+00, 28' N of CL	3.5' below grade	119.1	11.3	117.2	9.3	98	Y	Onsite borrow	SC	C181
8/8/2017	25.0	North Berm	Sta. 6+00, 20' N of CL	3.5' below grade	119.1	11.3	116.2	9.3	98	Y	Onsite borrow	SC	C181
8/8/2017	26.0	South Berm	Sta. 4+65, 25' S of CL	2.5' below grade	119.1	11.3	111.6	16.8	94	N	Onsite borrow	SC	C181
8/8/2017	27.0	South Berm	Sta. 5+90, 30' S of CL	2.5' below grade	119.1	11.3	108.2	9.2	91	N	Onsite borrow	SC	C181
8/8/2017	28.0	North Berm	Sta. 4+70, 25' N of CL	3' below grade	119.1	11.3	113.3	11.2	95	Y	Onsite borrow	SC	C181
8/8/2017	29.0	North Berm	Sta. 6+21, 20' N of CL	3' below grade	119.1	11.3	113.7	11.5	95	Y	Onsite borrow	SC	C181
8/8/2017	26.1	North Berm	Retest, # 26	2.5' below grade	119.1	11.3	112.6	11.5	95	Y	Onsite borrow	SC	C181
8/8/2017	27.1	South Berm	Retest # 27	2.5' below grade	119.1	11.3	113.1	9.5	95	Y	Onsite borrow	SC	C181
8/8/2017	32.0	Spillway	Spillway Sta. 5+95, 32' N of Cl	2.5' below grade	119.1	11.3	114	15.7	96	Y	Onsite borrow	SC	C181
8/8/2017	33.0	Spillway	Spillway Sta. 4+65, 22' N of CL	2.5' below grade	119.1	11.3	116.1	13.3	97	Y	Onsite borrow	SC	C181
8/10/2017	34.0	Spillway	Sta. 4+88, 22' N of CL	2' below grade	119.1	11.3	116.1	14.1	97	Y	Onsite borrow	SC	C181
8/10/2017	35.0	Spillway	Sta. 6+20, 27' N of CL	1' below grade	119.1	11.3	119.1	10.5	100	Y	Onsite borrow	SC	C181
8/10/2017	36.0	Spillway	Sta. 2+90, 30' S of CL	4' Below grade	119.1	11.3	117.8	12.4	99	Y	Onsite borrow	SC	C181
8/10/2017	37.0	Spillway	Sta. 1+60, 27' S of CL	4' Below grade	119.1	11.3	118.7	9.9	99	Y	Onsite borrow	SC	C181

Date	Test No.	Structure	Location	Depth/ Elev. (ft)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Dry Density (pcf)	Moisture Content (%)	Compaction (%)	Pass/ Fail	Material	Soil Type	Proctor Curve
8/10/2017	38.0	Spillway	Sta. 1+30, 21' N of CL	3' below grade	119.1	11.3	113.8	13.9	96	Y	Onsite borrow	SC	C181
8/10/2017	39.0	Spillway	Sta. 2+20, 25' N of CL	3' below grade	119.1	11.3	115.8	12.3	97	Y	Onsite borrow	SC	C181
8/10/2017	40.0	Spillway	Sta. 3+45, 22' N of CL	3' below grade	119.1	11.3	119.2	10.7	100	Y	Onsite borrow	SC	C181
8/10/2017	41.0	Spillway	Sta. 5+30, 20' N of CL	1' below grade	119.1	11.3	119	12.5	100	Y	Onsitit borrow	SC	C181
8/10/2017	42.0	Spillway	Sta. 2+70, 29' S of CL	3' below grade	119.1	11.3	119	9.9	100	Y	Onsite borrow	SC	C181
8/10/2017	43.0	Spillway	Sta. 1+80, 22' S of CL	3' below grade	119.1	11.3	119.1	9.7	100	Y	Onsite borrow	SC	C181
8/10/2017	44.0	Spillway	Sta. 2+05, 30' N of CL	1' below grade	119.1	11.3	119	10	100	Y	Onsite borrow	SC	C181
8/10/2017	45.0	Spillway	Sta. 1+00, 20' N of CL	1' below grade	119.1	11.3	118	9.6	99	Y	Onsite borrow	SC	C181
8/10/2017	46.0	Spillway	Sta. 5+60, 30' N of CL	1' below grade	119.1	11.3	113.8	13.8	96	Y	Onsite borrow	SC	C181
8/10/2017	47.0	Spillway	Sta. 3+90, 28' N of CL	1' below grade	119.1	11.3	114.6	9.6	96	Y	onsite borrow	SC	C181
8/10/2017	48.0	Spillway	Sta. 2+65, 29' S of CL	2' below grade	119.1	11.3	120.1	6.3	101	N	Onsite borrow	SC	C181
8/10/2017	49.0	Spillway	Sta. 1+45, 30' S of CL	2' below grade	119.1	11.3	121	6.6	102	N	Onsite borrow	SC	C181
8/11/2017	48.1	Retest # 48			119.1	11.3	119.4	9.3	100	Y	Onsite borrow	SC	C181
8/11/2017	49.1	Retest # 49			119.1	11.3	115	11.2	97	Y	Onsite borrow	SC	C181
8/11/2017	50.0	Spillway	Sta. 3+40, 30' N of CL	Rough Grade	119.1	11.3	119	9.3	100	Y	Onsite borrow	SC	C181
8/11/2017	51.0	Spillway	Sta. 5+70, 27' N of CL	Rough Grade	119.1	11.3	113.7	11.4	95	Y	Onsite borrow	SC	C181
8/11/2017	52.0	Spillway	Sta. 2+10, 28' S of CL	1' below grade	119.1	11.3	114.8	8	96	N	Onsite borrow	SC	C181
8/11/2017	53.0	Spillway	Sta. 1+30, 24' S of CL	1' below grade	119.1	11.3	113.6	5.6	95	N	Onsite borrow	SC	C181
8/11/2017	52.1	Retest # 52			119.1	11.3	114.2	10.8	96	Y	Onsite borrow	SC	C181
8/11/2017	53.1	Retest # 53			119.1	11.3	117.8	11.2	99	Y	Onsite borrow	SC	C181
8/11/2017	54.0	Spillway	Sta. 2+40, 24' N of CL	1' below grade	119.1	11.3	113.5	15.3	95	Y	Onsite borrow	SC	C181
8/11/2017	55.0	Spillway	Sta. 2+75, 18' N of CL	1' below grade	119.1	11.3	113.2	15.1	95	Y	Onsite borrow	SC	C181
9/8/2017	56.0	North Embankment	Sta. 4+75, 3' N of CL	1.5' above exisiting grade	111.7	14.4	114.1	13.5	102	Y	Onsite borrow	CL	C213
9/8/2017	57.0	North Embankment	Sta. 2+25, CL	2.0' above exisiting grade	111.7	14.4	110.7	13	99	Y	Onsite borrow	CL	C213
9/8/2017	58.0	North Embankment	Sta. 1+00, 4' S of CL	2.5' above exisiting grade	111.7	14.4	106.8	14.3	96	Y	Onsite borrow	CL	C213
9/8/2017	59.0	Main Embanment	Sta. 3+75, CL	0.5' above exisiting grade	119.1	11.3	110.7	8.2	93	N	Onsite borrow	SC	C181
9/8/2017	59.1	Retest # 59			119.1	11.3	114.1	11	96	Y	Onsite borrow	SC	C181
9/8/2017	60.0	North Embankment	Sta. 4+27, CL	2.5 above exisiting grade	111.7	14.4	107.9	16.4	97	Y	Onsite borrow	CL	C213
9/8/2017	61.0	North Embankment	Sta. 3+00, 4' N of CL	3.0' above exisiting grade	111.7	14.4	111	14.9	99	Y	Onsite borrow	CL	C213
9/8/2017	62.0	North Embankment	Sta. 1+30, 4' S of CL	3.5' above exisiting grade	111.7	14.4	112.9	12.9	101	Y	Onsite borrow	CL	C213
9/8/2017	63.0	North Embankment	Sta. 4+80, 5' S of CL	3.0' above exisiting grade	111.7	14.4	112.8	13.7	101	Y	Onsite borrow	CL	C213
9/8/2017	64.0	North Embankment	Sta. 3+20, CL	3.5' above esisiting grade	111.7	14.4	113.8	12.9	102	Y	Onsite borrow	CL	C213
9/8/2017	65.0	North Embankment	Sta. 2+00, 4' N of CL	4.0' above exisiting grade	111.7	14.4	113.9	13	102	Y	Onsite borrow	CL	C213
9/11/2017	66.0	North Embankment	Sta. 4+75, CL	3.5 above exisiting grade	111.7	14.4	109.5	12.4	98	Y	Onsite borrow	CL	C213

Date	Test No.	Structure	Location	Depth/ Elev. (ft)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Dry Density (pcf)	Moisture Content (%)	Compaction (%)	Pass/ Fail	Material	Soil Type	Proctor Curve
9/11/2017	67.0	North Embankment	Sta. 3+87, 5' N of CL	4.0' above exisiting grade	111.7	14.4	108.9	12.7	97	Y	Onsite borrow	CL	C213
9/11/2017	68.0	North Embankment	Sta. 1+50, 2' S of CL	4.5' above exisiting grade	111.7	14.4	110.1	14.7	99	Y	Onsite borrow	CL	C213
9/12/2017	69.0	North Embankment	Sta. 4+50, 2' N of CL	4.0' above exisiting grade	111.7	14.4	110	13	98	Y	Onsite borrow	CL	C213
9/12/2017	70.0	North Embankment	Sta. 3+05, 4' S of CL	4.5' above exisiting grade	111.7	14.4	114.9	15.2	103	Y	Onsite borrow	CL	C213
9/12/2017	71.0	North Embankment	Sta. 1+80, 4' N of CL	5.0' above exisiting grade	111.7	14.4	108.9	16.2	98	Y	Onsite borrow	CL	C213
9/12/2017	72.0	North Embankment	Sta. 0+75, 3' N of CL	4.0' above exisiting grade	111.7	14.4	114.9	16.4	103	Y	Onsite borrow	CL	C213
9/12/2017	73.0	North Embankment	Sta. 1+90, 4' N of CL	5.5' above exisiting grade	111.7	14.4	112.2	12.6	101	Y	Onsite borrow	CL	C213
9/12/2017	74.0	North Embankment	Sta. 2+60, 3' S of CL	5.0' above exisiting grade	111.7	14.4	112.5	15.1	101	Y	Onsite borrow	CL	C213
9/13/2017	75.0	Main Embanment	Sta. 3+95	1.0' above exisiting grade	119.1	11.3	112.7	11.1	95	Y	Onsite borrow	SC	C181
9/13/2017	76.0	Main Embanment	Sta. 3+48	2.0' above exisiting grade	119.1	11.3	118.9	6.3	100	N	Onsite borrow	SC	C181
9/13/2017	76.1	Main Embanment			119.1	11.3	118.9	13.1	100	Y	Onsite borrow	SC	C181
9/21/2017	77.0	Main Embanment	Sta. 1+75	1.5' above exisiting grade	111.7	14.4	113.9	12.4	102	Y	Onsite borrow	CL	C213
9/21/2017	78.0	Main Embanment	Sta. 1+50	1.5' above exisiting grade	111.7	14.4	111	16.2	99	Y	Onsite borrow	CL	C213
9/21/2017	79.0	Main Embanment	Sta. 1+00	2.0' above exisiting grade	111.7	14.4	109	13.1	98	Y	Onsite borrow	CL	C213
9/21/2017	80.0	Main Embanment	Sta. 2+20	2.0' above exisiting grade	111.7	14.4	108.4	16.4	97	Y	Onsite borrow	CL	C213
9/22/2017	81.0	Main Embanment	Sta. 0+60	2.0' above exisiting grade	111.7	14.4	106.8	13.4	96	Y	Onsite borrow	CL	C213
9/22/2017	82.0	Main Embanment	Sta. 2+30	3.0' above exisiting grade	111.7	14.4	111.7	14	100	Y	Onsite borrow	CL	C213
9/23/2017	83.0	Main Embanment	Sta. 4+50	at exisiting grade	119.1	11.3	115	12.8	97	Y	Onsite borrow	SC	C181
9/23/2017	84.0	Main Embanment	Sta. 3+80	2.0' above exisiting grade	119.1	11.3	121.3	10.4	101	Y	Onsite borrow	SC	C181
9/25/2017	85.0	Main Embanment	Sta. 4+18	3.0' above exisiting grade	119.1	11.3	111.5	10.7	94	N	Onsite borrow	SC	C181
9/25/2017	85.1	Main Embanment	Retest	3.0' above exisiting grade	119.1	11.3	111.3	12.2	94	N	Onsite borrow	SC	C181
9/25/2017	85.2	Main Embanment	Retest	3.0' above exisiting grade	119.1	11.3	116.4	11	98	Y	Onsite borrow	SC	C181
9/25/2017	86.0	Main Embanment	Sta. 3+75	3.5' above exisiting grade	119.1	11.3	115.2	10.8	97	Y	Onsite borrow	SC	C181
9/26/2017	87.0	Main Embanment	Sta. 3+60	4.0' above exisiting grade	112.3	14.3	107	16.2	96	Y	Onsite borrow	SC	7966
9/26/2017	88.0	Main Embanment	Sta. 3+40	4.0' above exisiting grade	112.3	14.3	107.8	12.4	97	Y	Onsite borrow	SC	7966
9/26/2017	89.0	Main Embanment	Sta. 4+12	4.5' above exisiting grade	112.3	14.3	112.5	13.1	101	Y	Onsite borrow	SC	7966
11/9/2017	90.0	North Dam	Sta. 2+00 Centerline	Grade	112.3	14.3	107	20.1	95	N-Over OMC	Onsite borrow	SC	7966

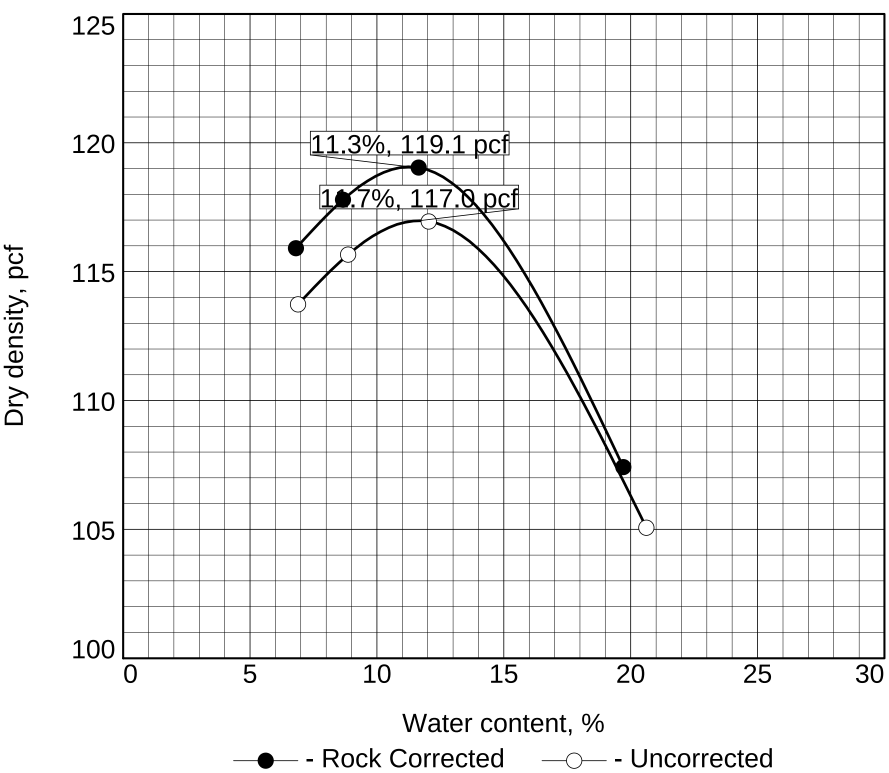
Date	Test No.	Structure	Location	Depth/ Elev. (ft)	Maximum Dry Density (pcf)	Optimum Moisture Content (%)	Dry Density (pcf)	Moisture Content (%)	Compaction (%)	Pass/ Fail	Material	Soil Type	Proctor Curve
11/9/2017	91.0	North Dam	Sta. 4+00 Centerline	Grade	112.3	14.3	107.9	20.4	96	N- Over OMC	Onsite borrow	SC	7966
11/9/2017	92.0	Main Dam, Left Side	Sta. 5+50, Centerline	Grade	112.3	14.3	107.7	16.4	96	Y	Onsite Borrow	SC	7966
11/9/2017	93.0	Main Dam, Left Side	Sta. 2+50, Centerline	Grade	112.3	14.3	106.9	13.6	95	Y	Onsite Borrow	SC	7966
11/9/2017	94.0	Main Dam, Rigth Side	Sta. 3+55, Centerline	Grade	112.3	14.3	112.5	14.3	100	Y	Onsite borrow	SC	7966
11/9/2017	95.0	Main Dam, Right Side	Sta. 4+51, Centerline	Grade	112.3	14.3	110	17.9	98	Y	Onsite Borrow	SC	7966

Type A Filter Sand
Field Density and Moisture Content Test Results
MacFarlane Dam Rehabilitation

Date	Test No.	Structure	Location	Depth/ Elev. (ft)	Maximum Density (pcf)	Minimum Density (pcf)	Dry Density (pcf)	Moisture Content (%)	Compaction (%)	Pass/ Fail	Material	Soil Type	Relative Density Curve
8/28/2017	1	Chimney Drain-Right Side	Sta. 2+60 East of Centerline	8281	119.4	88	105.6	7.3	63		Type A Filter Sand	C 33 Sand	7920
8/28/2017	2	Chimney Drain-Right Side	Sta. 2+60 West of Centerline	8281	119.4	88	108.1	9.3	71		Type A Filter Sand	C 33 Sand	7920
8/28/2017	3	Chimney Drain-Right Side	Sta. 2+60 East of Centerline	8281.5	119.4	88	109.2	7.9	74		Type A Filter Sand	C 33 Sand	7920
8/28/2017	4	Chimney Drain-Right Side	Sta. 2+60 West of Centerline	8281.5	119.4	88	107.7	6.8	70		Type A Filter Sand	C 33 Sand	7920
8/28/2017	5	Chimney Drain-Right Side	Sta. 2+60 East of Centerline	8282	119.4	88	108.7	6.4	72		Type A Filter Sand	C 33 Sand	7920
8/28/2017	6	Chimney Drain-Right Side	Sta. 2+60 West of Centerline	8282	119.4	88	107.2	7.2	68		Type A Filter Sand	C 33 Sand	7920
8/29/2017	7	Chimney Drain-Right Side	Sta. 2+60 East of Centerline	8268.8	119.4	88	107.2	8	68		Type A Filter Sand	C 33 Sand	7920
8/29/2017	8	Chimney Drain-Right Side	Sta. 2+60 West of Centerline	8268.8	119.4	88	107.8	10.7	70		Type A Filter Sand	C 33 Sand	7920
8/29/2017	9	Chiminey Drain-Right Side	Sta. 2+68 East of Centerline	8282	119.4	88	108	7.8	70		Type A Filter Sand	C 33 Sand	7920
8/29/2017	10	Chimney Drain-Right Side	Sta. 2+68 West of Centerline	8282.5	119.4	88	112.5	10	83		Type A Filter Sand	C 33 Sand	7920
8/29/2017	11	Chimney Drain-Right Side	Sta. 2+68 East of Centerline	8283	119.4	88	108.7	7.8	72		Type A Filter Sand	C 33 Sand	7920
8/29/2017	12	Chimney Drain-Right Side	Sta. 2+68 West of Centerline	8283.5	119.4	88	110.6	9.5	78		Type A Filter Sand	C 33 Sand	7920
8/31/2017	13	Chimney Drain-Right Side	Sta. 3+75 East of Centerline	8286.8	119.4	88	105.3	7.9	62		Type A Filter Sand	C 33 Sand	7920
8/31/2017	14	Chimney Drain-Right Side	Sta. 3+75 West of Centerline	8286.8	119.4	88	105.3	8.5	62		Type A Filter Sand	C 33 Sand	7920
8/31/2017	15	Chimney Drain-Right Side	Sta. 4+00 Centerline	8283	119.4	88	110.1	7.8	76		Type A Filter Sand	C 33 Sand	7920
8/31/2017	16	Chimney Drain-Right Side	Sta. 4+00 Centerline	8283.5	119.4	88	106.1	11.3	65		Type A Filter Sand	C 33 Sand	7920
8/31/2017	17	Chimney Drain-Right Side	Sta. 4+00 Centerline	8284	119.4	88	106.2	7.8	65		Type A Filter Sand	C 33 Sand	7920
9/8/2017	18	Chimney Drain-Left Side	Sta. 3+80 Centerline	8286	119.4	88	108.9	5.3	73		Type A Filter Sand	C 33 Sand	7920
9/8/2017	19	Chimney Drain-Right Side	Sta. 1+75 Centerline	8289.5	119.4	88	109.8	9.4	75		Type A Filter Sand	C 33 Sand	7920
9/14/2017	20	Chimney Drain-Right Side	Sta. 4+10 Centerline	2.0' above existing grade	119.4	88	110.5	6.1	77		Type A Filter Sand	C 33 Sand	7920
9/14/2017	21	Chimney Drain-Right Side	Sta. 2+98 Centerline	3.0' above existing grade	119.4	88	115.5	5.7	91		Type A Filter Sand	C 33 Sand	7920
9/14/2017	22	Chimney Drain-Left Side	Sta. 2+00 Centerline	Top of Sand	119.4	88	114.2	10.2	87		Type A Filter Sand	C 33 Sand	7920
9/14/2017	23	Chimney Drain-Left Side	Sta. 1+12 Centerline	Top of Sand	119.4	88	111.2	7.5	79		Type A Filter Sand	C 33 Sand	7920

COMPACTION TEST REPORT

Curve No. 2



Preparation Method: Dry Preparation Method
Rammer: Wt. 5.5 lb. Drop 12 in.
Type
Layers: No. three Blows per 56
Mold Size 0.075 cu. ft.
Test Performed on Material Passing 3/4 in. Sieve

%>3/4 in. 6 %<No.200 23
Atterberg (D 4318): LL 33 PI 10
NM (D 2216) Sp.G. (D 854)
USCS (D 2487) SC
AASHTO (M 145) A-2-4(0)
Date: Sampled 08/04/2017
Received 08/04/2017
Tested 08/07/2017
Tested By CH

COMPACTION TESTING DATA
ASTM D 698-12 Method C Standard
ASTM D4718-15 Oversize Corr. Applied to Each Test Point

	1	2	3	4	5	6
WM + WS	10074.3	10222.1	10396.0	10249.7		
WM	5938.5	5938.5	5938.5	5938.5		
WW + T #1	1158.7	1397.8	1186.6	1313.7		
WD + T #1	1096.5	1305.3	1077.3	1122.6		
TARE #1	194.7	262.3	169.5	195.5		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	6.8	8.7	11.6	19.7		
DRY DENS.	115.9	117.8	119.0	107.4		

SIEVE TEST RESULTS
ASTM D 422 ASTM D 1140

Opening Size	% Passing	Specs.
8"	100	
5"	100	
3"	100	
2"	98	
1-1/2"	97	
1"	96	
3/4"	94	
1/2"	89	
3/8"	85	
#4	72	
#8	71	
#16	68	
#30	60	
#50	45	
#100	32	
#200	23	

ROCK CORRECTED TEST RESULTS	UNCORRECTED
Maximum dry density = 119.1 pcf	117.0 pcf
Optimum moisture = 11.3 %	11.7 %

Material Description

clayey sand with gravel

Remarks:

Project No. 17-1-463 **Client:** WW Wheeler & Associates
Project: MacFarlane Dam, Walden

○ **Loc.:** On-Site Stockpile **Depth:** Composite **Sample No.:** C181

Kumar & Associates

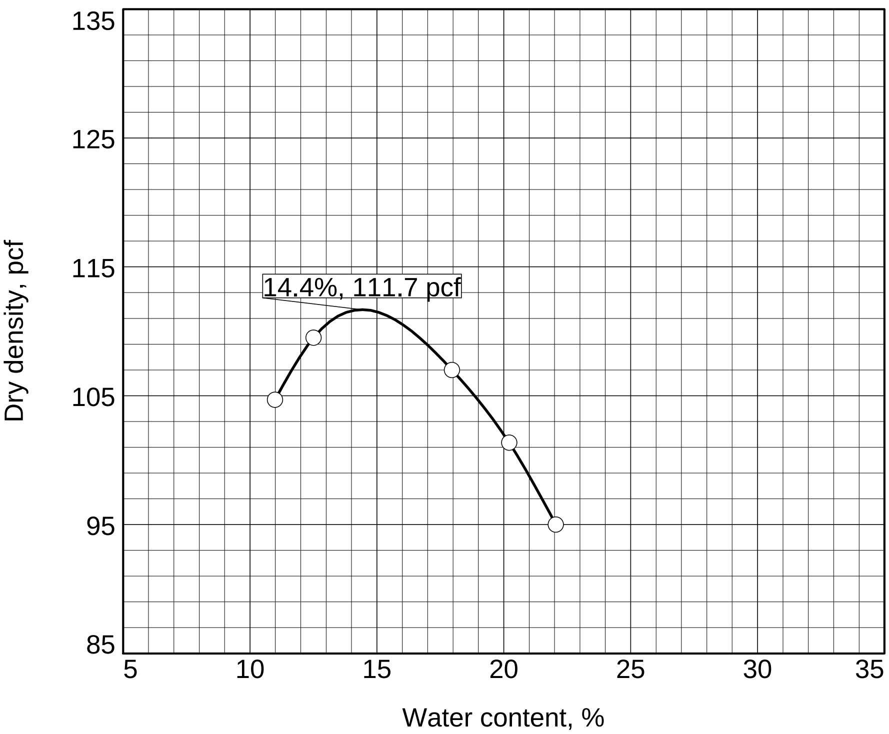
Silverthorne, CO

Checked by: JLC
Title: Lab Manager

Figure 4

COMPACTION TEST REPORT

Curve No. 5



Preparation Method: Dry Preparation Method
Rammer: Wt. 5.5 lb. Drop 12 in.
Type: automatic
Layers: No. three Blows per 56
Mold Size: 0.075 cu. ft.
Test Performed on Material Passing 3/4 in. Sieve

%>3/4 in. 0 %<No.200 72
Atterberg (D 4318): LL 37 PI 16
NM (D 2216) Sp.G. (D 854)
USCS (D 2487): CL
AASHTO (M 145): A-6(10)
Date: Sampled 08/29/2017
Received 08/30/2017
Tested 08/31/2017
Tested By: AMW

COMPACTION TESTING DATA
ASTM D 698-12 Method C Standard

	1	2	3	4	5	6
WM + WS	9887.2	10125.5	10228.2	10079.5	9879.4	
WM	5934.6	5934.6	5934.6	5934.6	5934.6	
WW + T #1	1455.3	1462.1	1402.1	1270.9	1379.1	
WD + T #1	1365.7	1355.9	1259.7	1143.0	1214.9	
TARE #1	550.2	506.4	466.8	510.2	470.3	
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	11.0	12.5	18.0	20.2	22.1	
DRY DENS.	104.7	109.5	107.0	101.4	95.0	

SIEVE TEST RESULTS
ASTM D 422 ASTM D 1140

Opening Size	% Passing	Specs.
1-1/2"	100	
1"	100	
3/4"	100	
1/2"	100	
3/8"	100	
#4	100	
#8	100	
#16	99	
#30	98	
#50	94	
#100	85	
#200	72	

TEST RESULTS

Maximum dry density = 111.7 pcf

Optimum moisture = 14.4 %

Material Description

lean clay with sand

Remarks:

Project No. 17-1-463 **Client:** WW Wheeler & Associates
Project: MacFarlane Dam, Walden

○ **Loc.:** On Site Soils **Depth:** Composite **Sample No.:** C213

Kumar & Associates

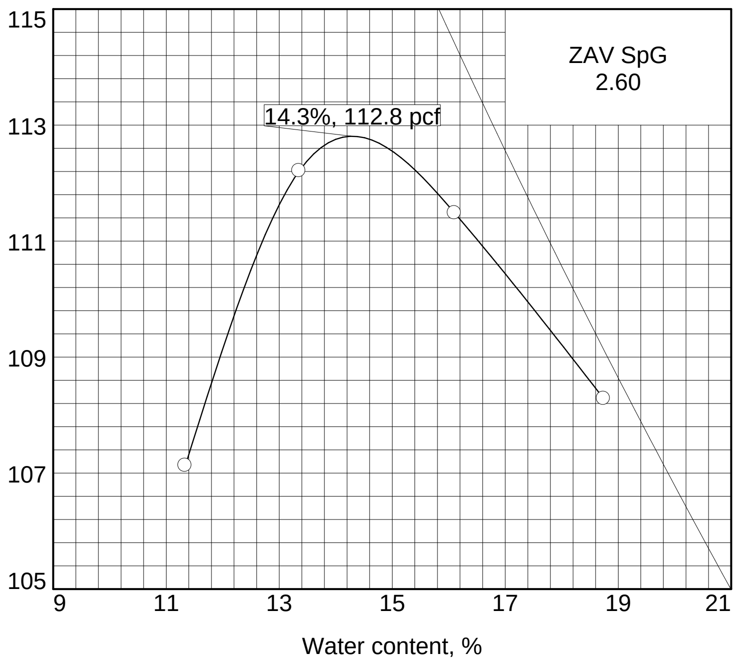
Silverthorne, CO

Checked by: JLC
Title: Lab Manager

Figure 10

COMPACTION TEST REPORT

Curve No. 7966



Preparation Method

Rammer: Wt. 5.5 lb. Drop 12 in.

Type Manual

Layers: No. 3 Blows per 25

Mold Size 0.03333 cu. ft.

Test Performed on Material Passing #4 Sieve

%>#4 0 %<No.200 60

Atterberg (D 4318): LL 30 PI 8

NM (D 2216) Sp.G. (D 854) 2.6

USCS (D 2487) CL

AASHTO (M 145) A-4(3)

Date: Sampled 9-21-17

Received 9-21-17

Tested 9-21-17

Tested By JP

COMPACTION TESTING DATA
ASTM D 698-12 Method A Standard

	1	2	3	4	5	6
WM + WS	3980.0	4100.0	4134.0	4121.0		
WM	2173.0	2173.0	2173.0	2173.0		
WW + T #1	615.6	584.9	585.5	525.1		
WD + T #1	568.7	533.1	525.2	468.3		
TARE #1	155.0	145.2	150.8	165.3		
WW + T #2						
WD + T #2						
TARE #2						
MOIST.	11.3	13.4	16.1	18.7		
DRY DENS.	107.1	112.2	111.5	108.3		

SIEVE TEST RESULTS
ASTM D-422 ASTM D-1140

Opening Size	% Passing	Specs.
3/4"	100	
3/8"	100	
#4	100	
#8	97	
#16	95	
#30	90	
#50	83	
#100	73	
#200	60	

TEST RESULTS

Maximum dry density = 112.8 pcf

Optimum moisture = 14.3 %

Material Description

Embankment Fill / sandy lean clay

Remarks:

Project No. 17-1-463 **Client:**

Project: MacFarlane Dam

Location: Borrow #1 **Sample Number:** 7966

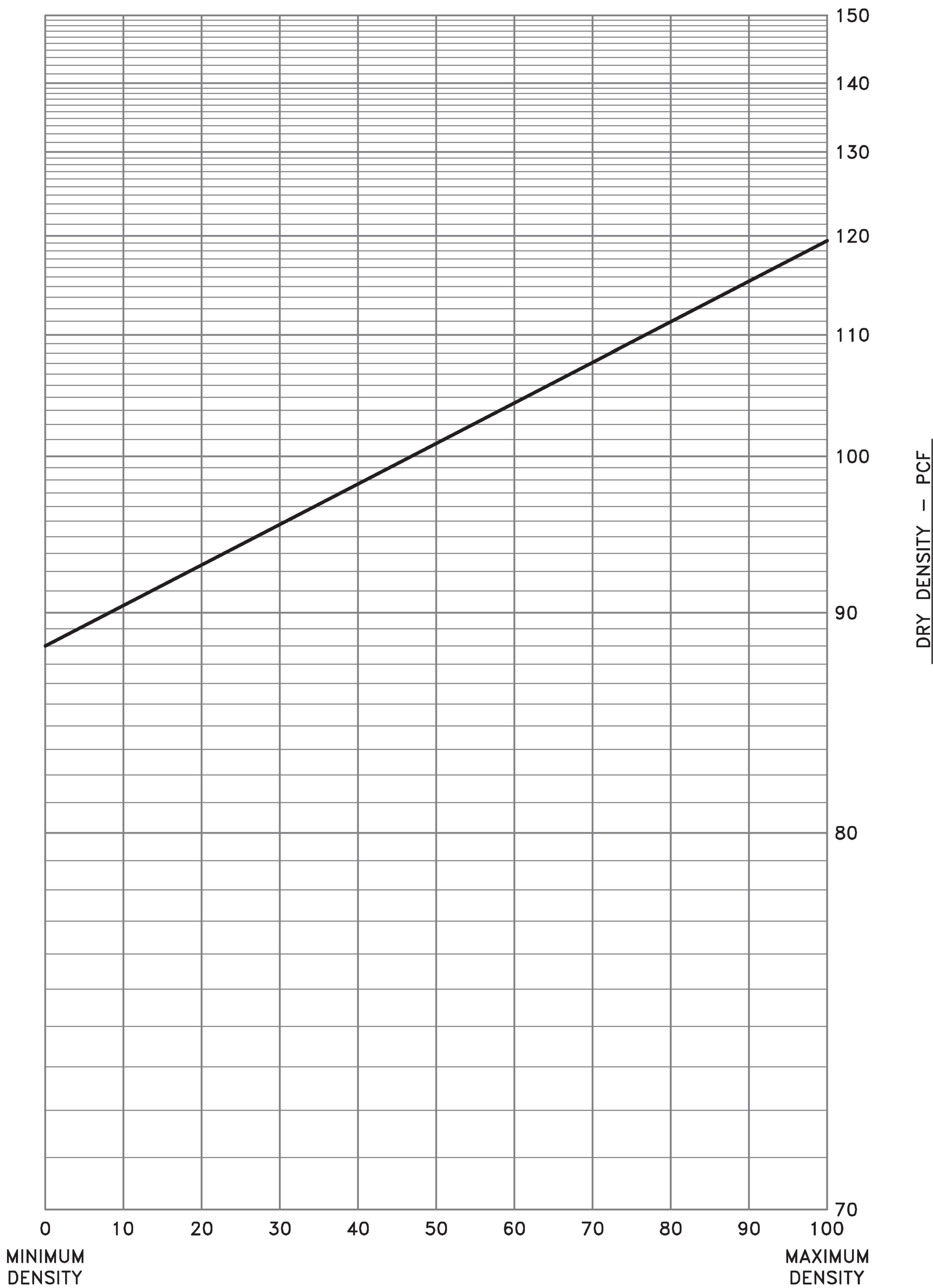
Kumar & Associates, Inc.

Denver, Colorado

Checked by: DS

Title: Lab Manager

Figure



SAMPLE DESCRIPTION:

LOCATION:

DATE SAMPLED: DATE RECEIVED: DATE TESTED: 08/30/17

MAXIMUM DENSITY (pcf): 119.4 MINIMUM DENSITY (pcf): 88.0

GRAVEL % SAND % SILT AND CLAY %

These test results apply only to the samples which were tested. The testing report shall not be reproduced, except in full, without the written approval of Kumar & Assoc., Inc. Relative density testing is performed in accordance with ASTM D4253 and D4254.

17–1–463	Kumar & Associates	RELATIVE DENSITY TEST RESULT	7920

August 31, 2017 – 10:05am
C:\Users\mromero\appdata\local\temp\AcPublish_6344\7920R MacFarlane Dam.dwg

APPENDIX D

DOCUMENTATION OF CONSTRUCTION CHANGES

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

APPENDIX D-1

Change Order No. 1
(HDPE Pipe SDR Thickness and Staff Gage)

W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

July 11, 2017

Jeremy Franz, P.E. Design Review Engineer
Colorado Dam Safety Branch
1313 Sherman Street, Suite 821
Denver, CO 80203

RE: Construction Change Order No. 1 for MacFarlane Dam Rehabilitation; Colorado DAMID: 470202, Water Division 1, Water District 6, Construction File Number: C-1031B; NATDAM No. CO-00997

Dear Jeremy:

This letter documents the basis for requesting your approval to change the required Standard Dimension Ratio (SDR) of the HDPE pipe liner for the above-referenced project from SDR 15.5 to SDR 17. This change order also requests your approval to change the staff gage design.

W. W. Wheeler & Associates, Inc. (Wheeler) is requesting this Change Order on behalf of our Client, the U.S. Fish and Wildlife (FWS), and the Contractor, Rocky Mountain Excavating (RME), for the following reasons. Due to a limited construction schedule and the approximate lead time for SDR 15.5 HDPE pipe, the Contractor has requested to change the pipe SDR from SDR 15.5 to SDR 17. The 20-inch-diameter SDR 17 HDPE is a more readily available pipe and will not impact the construction schedule. Changing to SDR 17 will increase the inside pipe diameter from 17.265 to 17.506 inches. This increase in diameter does not change the outlet discharge capacity. The SDR 17 HDPE pipe meets the required design load calculations. See the attached documentation for the design load calculations.

The contractor has also asked if there is an acceptable staff gage alternative to use instead of the designed customized Stevens Style E or equivalent staff gage. The lead time on a customized staff gage is several months following the final survey of the installed grade beam. It is our opinion that a sufficient alternative would be to install 4-inch by 6-inch figure plates at every 1-foot increment with a ½-foot marker. See the attached document for a schematic of the alternative staff gage. We have also attached a photo of a recent similar staff gage that was approved for installation at Beaver Park Dam in Division 3. It would be easy to interpolate 0,1-foot increments between each 0.5-foot mark on the proposed staff gage alternative. However, if a mark must be made at every 0.1-foot of reservoir elevation change we could have the contractor install a small concrete anchor at 0.1-foot increments in between each 0.5-foot mark.

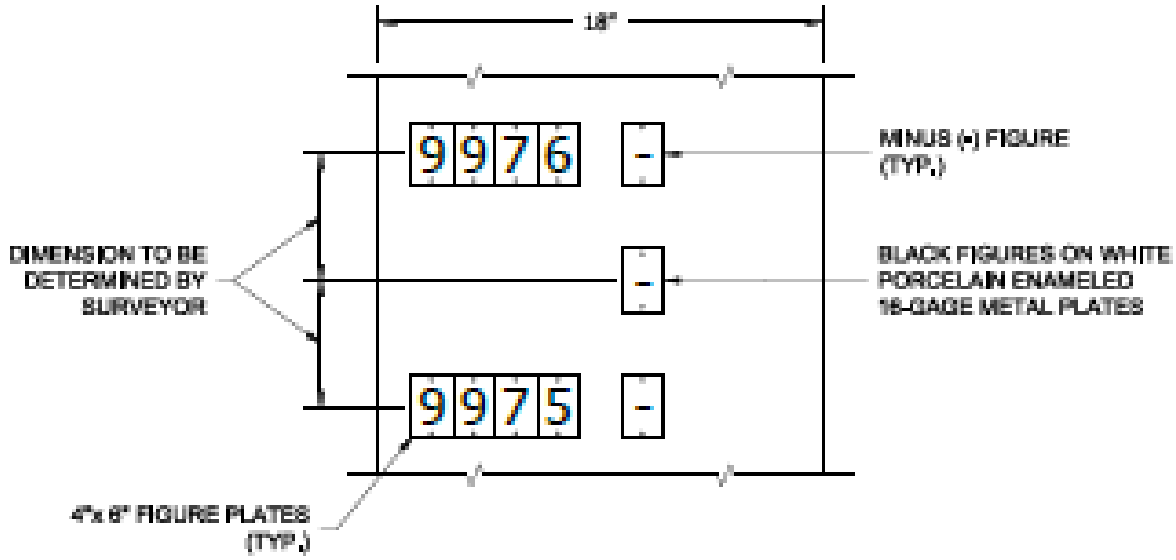
We trust that this letter adequately documents the technical details associated with proposed Construction Change Order No. 1. If you need any additional information please don't hesitate to give me a call at 303-761-4130.

Sincerely,
W. W. Wheeler & Associates, Inc.

John J. Treacy, P.E.

r:\1700\1772\1772.11.02_macfarlaneconstruction\construction\4_change orders\co#1\designco_1_final.docx

Cc: Dana Miller, Division 6 – Colorado Division of Water Resources
Lorri Harper, Civil Engineer – U.S. Fish and Wildlife Service
Jeremiah Kamp, Project Manager – Rocky Mountain Excavating



STAFF GAGE MOUNTED ON GRADE BEAM 1/02
TYPICAL DETAIL (N.T.S.)

MacFarlane Dam Outlet Works Lining
HDPE Pipe Load Design Calcs

Pipe Parameters:

DR =	**17**		pipe dimension ratio, d/t	
OD =	20	in	pipe outside diameter	ASTM D2737
t =	1.176	in	minimum wall thickness	
ID=	17.506	in	Manufacturer's Average Inside Pipe Diameter	

Working Pressure Rating (AWWA M55 Chapter 4):

$$PC = \frac{2(HDS)}{DR-1}*(DF)$$

[equation 4-1a] DF = 0.5 for water applications

HDS =	1000	psi	hydrostatic design stress (HDS) for PE4710 Pipe
PC =	62.5	psi	pressure class
$P_{max(RS)}$ =	93.75	psi	allowable system pressure w/ recurrent surge
$P_{max(OS)}$ =	125	psi	allowable system pressure w/ occasional surge

External Load Design (AWWA M55 Chapter 5):

$$P_E = wH/144$$ *[equation 5-1]*

$$P_{ES} = P_a + P_b + P_c + P_d$$ *[equation 5-4]*

$$P_L = \frac{I_f W_L}{144A}\left(1 - \frac{H^3}{(R^2+H^2)^{1.5}}\right)$$ *[Timoshenko]*

$$P_L = \frac{3 I_f W_L H^3/144}{2\pi(X^2+H^2)^{5/2}}$$ *[Boussinesq]*

	w =	130	pcf	unit weight of soil		
	H =	35.0	ft	soil height above pipe crown		
	P_E =	31.6	psi	earth pressure on pipe (see Equation 5.1)		
	P_{ES} =	0	psi	surcharge load pressure (see eq. 5-4)		
	I_f =	2.0		impact factor for vehicle live load		
	W_L =	16,000	lbs	wheel load	24,000	16,000
	A =	1.39	ft^2	contact area (tire footprint)	2.00	1.39
	P_L =	0.1	psi	live load (directly over pipe, Timoshenko)		
or	P_L =	0.2	psi	live load (two passing vehicles, Boussinesq)		
or	P_L =	0.8	psi	live load (AASHTO H20 Wheel Load, Table 5-3)		
		0.9	ft	soil height that produces equiv. live load pressure		

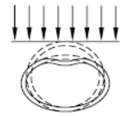
R:\1700\1772\1772.11.02_MacFarlaneConstruction\Construction\4_Change Orders\CO#1\[SDR Liner Design Calcs.xlsx]M55 Design Calcs DR17

External Load Design, continued:

Check ring deflection:

$$\delta = \frac{0.1(1.5P_E + P_L + P_{ES})}{\frac{2E}{3(DR-1)^3} + 0.061E'}$$

[equation 5-8]

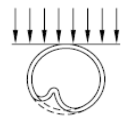


δ =	5.9	%	change in diameter over mean diameter	**O.K.**
E =	130,000	psi	modulus of elasticity PE4710 Short Term	
E' =	1000	psi	design modulus of soil reaction	

Check wall buckling:

$$P_{UA} = \frac{2E}{(1-\mu^2)}\left(\frac{1}{DR-1}\right)^3 \frac{f_o}{N}$$

[equation 5-14]

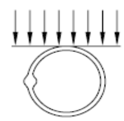


P_{UA} =	27.9	psi	allowable external pressure, unconstrained pipe
P_{VA} =	4.5	psig	allowable internal vacuum pressure in pipe
E =	130,000	psi	modulus of elasticity
μ =	0.35		Poisson's Ratio
f_O =	0.77		roundness factor (see figure 5-3)
N =	2.0		safety factor (generally 2.0)
h_{SA} =	13	ft H_2O	USBR-recommended min. subatmospheric head
=	-4.9	psig	USBR-recommended min. internal pressure

Check wall compressive stress:

$$S = \frac{P_E(DR-1)}{2}$$

[equation 5-15]



S =	252.8	psi	hoop compressive wall stress	**O.K.**

R:\1700\1772\1772.11.02_MacFarlaneConstruction\Construction\4_Change Orders\CO#1\[SDR Liner Design Calcs.xlsx]M55 Design Calcs DR17

From:	John Treacy, P.E.
To:	"Dana Miller"; Franz, Jeremy <Jeremy.Franz@state.co.us> (Jeremy.Franz@state.co.us)
Cc:	Stephen L. Jamieson, P.E.; Andrea D. Fasen; lorri_harper@fws.gov; Brad_Iarossi@fws.gov
Subject:	Change Order No. 1 Clarification
Date:	Wednesday, July 26, 2017 4:06:35 PM
Attachments:	image001.png

Jeremy & Dana,

We have looked at the guidelines discussed in FEMA 676 suggesting using the long term modulus of elasticity for the long-term static load. We agree with your assessment that by changing the modulus of elasticity, the Factor of Safety (FS) for the buckling pressure is less than the generally recommended 2.0 for an unconstrained flexible pipe.

FEMA 676 suggests that the total load (external hydrostatic pressure) must be less than the allowable buckling pressure. Using a modulus of elasticity of 30,000 lb/in^2, and using equation (3-20) from FEMA 676, the unconstrained buckling pressure = 2,644 lb/ft^2. The external hydrostatic pressure based on a maximum water surface elevation equal to the spillway crest = 1,996 lb/ft^2. Based on these calculations the buckling pressure of the pipe is greater than the hydrostatic pressure. The calculated FS would be 1.3.

FEMA 676 indicates that research has shown that for plastic pipes fully encased in concrete, the unconstrained buckling pressure can be increased by an enhancement factor of 4 to 5 depending on upon the pipe SDR and ovality.

Based on the guidelines documented in FEMA 676, it is our engineering opinion that using the SDR 17 pipe is sufficient for this slip lining application.

Following our weekly progress meeting today, it has been mutually agreed upon to use the SEO suggested staff gage alternative.

We trust that this clarification provides you with the information needed to approve Change Order No. 1 dated July 11, 2017. Please call if we need to discuss this further.

Thanks

John J. Treacy, III P.E.
W. W. Wheeler & Associates, Inc.
3700 South Inca Street, Englewood, CO 80110
303-761-4130 (O) | 720-313-3587 (M) | 303-761-2802 (F)
john.treacy@wwwheeler.com | www.wwwheeler.com

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

COLORADO
Division of Water Resources
Department of Natural Resources

Dam Safety

Mr. John Treacy, P.E.
W.W. Wheeler & Associates, Inc.
3700 S Inca St.
Englewood, CO 80110
via email: John.Treacy@wwwheeler.com

When replying, please refer to:
MACFARLANE DAM, DAMID 470202
Water Division 6, Water District 47
Construction File No. C-1031B

August 1, 2017

SUBJECT: Approval of Change Order No.1

Dear Mr. Treacy,

Thank you for submitting the Change Order request for the HDPE outlet liner pipe and staff gage for the MacFarlane Dam rehabilitation project for our review and approval in accordance with Rule 9.1.8 of the State of Colorado's "Rules and Regulations for Dam Safety and Dam Construction". This requested change includes increasing the SDR of the HDPE slipliner pipe and the re-configuring the reservoir gage rod. Based on our review of the Change Order request materials as presented in your letter dated July 11, 2017, and your subsequent clarification email dated July 26, 2017, we find this change in the approved plans and specifications to be acceptable and approved as of the date of this letter.

Please properly inform the general contractor of this change to the approved construction documents. As a result of this change, revisions to the approved plans, specifications, and construction report should be made prior to the submittal of "As-Constructed" documents to our office at the completion of the project.

If you have any questions concerning this matter, please do not hesitate to contact Jeremy Franz in our Denver Office at ext 8254 or Dana Miller in our Steamboat office at ext 6414.

Sincerely,

William T. McCormick III, P.E., P.G.
Chief, Colorado Dam Safety

ec: Erin Light, Division Engineer
Matt Blecha, WD 47 Water Commissioner
Dana Miller, Dam Safety Engineer
Jeremy Franz, Design Review Engineer
Stephen Jamieson, W.W. Wheeler & Assoc., Steve.Jamieson@wwwheeler.com
Lorri Harper, Project Manager for US Fish & Wildlife Service, lorri_harper@fws.gov
Brad Iarossi, US Fish & Wildlife Service, Brad_Iarossi@fws.gov
Blaine & Judy Evans, Evans Cattle Co., EvansCattleCo@gmail.com

APPENDIX D-2

Change Order No. 2
(CIPP Outlet Conduit Liner)

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

October 20, 2017

Jeremy Franz, P.E. Design Review Engineer
Colorado Dam Safety Branch
1313 Sherman Street, Suite 821
Denver, CO 80203

RE: Construction Change Order No. 2 for MacFarlane Dam Rehabilitation; Colorado DAMID: 470202, Water Division 1, Water District 6, Construction File Number: C-1031B; NATDAM No. CO-00997

Dear Jeremy:

This letter documents the basis for requesting your approval to change the designed 20-inch-diameter Standard Dimension Ratio (SDR) HDPE outlet works liner pipe to a 24-inch-diameter CIPP liner. The approximate inside diameter of the CIPP liner will be 23.5 inches. This Change Order is requested based on the video inspection after the existing outlet pipe was jet cleaned and the unsuccessful 20-inch-diamter HDPE test pull that occurred on September 29, 2017.

W. W. Wheeler & Associates, Inc. (Wheeler) is requesting this Change Order on behalf of our Client, the U.S. Fish and Wildlife (FWS) for the following reasons: During the HDPE test pull on September 29, 2017, a squashed section of the existing riveted steel host pipe was discovered approximately 76 feet upstream of the downstream end of the existing outlet works conduit at the transition from the CMP pipe to the riveted steel pipe. This squashed section of pipe has significantly reduced the host pipe diameter and the designed 20-inch-diameter HDPE liner cannot be installed. Due to a limited 2017 construction schedule and the approximate lead time for purchasing smaller, 18-inch-diameter HDPE pipe, the Contractor has requested to change the liner from HDPE to a 24-inch-diameter CIPP liner. The 24-inch-diameter CIPP Liner is a more readily available product that can be installed on approximately October 30 and will not significantly impact the construction schedule. Changing from the 20-inch-diameter HDPE liner to the 24-inch-diameter CIPP liner will not significantly change the outlet works discharge capacity because the outlet discharge capacity is still inlet controlled.

Due to the high entrance velocities at the intake, a 16-inch-diameter steel pipe and a 20-inch-dimaeter HDPE transition section will be installed in the intake as shown on the attached intake structure detail provided on Attachment B. The HDPE transition will allow the contractor to still install the air vent in the HDPE transition section as originally designed as well as providing a transition section to reduce flow velocities from the 16-inch-diameter steel insert to the new CIPP liner. The annular space between the new CIPP liner and the existing host pipe will be filled with the specified non-shrink grout and concrete bulkheads will be installed prior to grouting this annular space.

The 24-inch-diameter CIPP liner is a fiberglass pipe that is ultra-violet (UV) cured in place. The design thickness for this liner is 9mm and the fiberglass pipe meets the required design load calculations provided in Attachment C. Once the CIPP liner is installed an Insignia watertight seal will be inserted at the end of the pipe to prevent water flow between the host pipe and the new liner pipe. The CIPP liner will extend the entire length of the existing outlet works conduit and will end at the new downstream headwall. An approximately 10-foot-long section of 24-inch-diiameter CMP pipe will be installed added to the downstream end of the existing outlet works conduit to extend the outlet discharge pipe to the new headwall. The new CMP extension will be encased in concrete as designed.

The new CIPP liner and intake connection will slightly decrease the discharge capacity from that of the designed 20-inch-diameter HDPE liner. The revised maximum outlet discharge at the normal water level (8316.0) will decrease from 36.9 cfs to 35.3 cfs with the CIPP liner. Refer to the Attachment D for the revised outlet works discharge calculations and the updated discharge capacity table.

We trust that this letter adequately documents the technical details associated with proposed Construction Change Order No. 2. If you need any additional information please don't hesitate to give me a call at 303-761-4130.

Sincerely,

W. W. Wheeler & Associates, Inc.

John J. Treacy, P.E.

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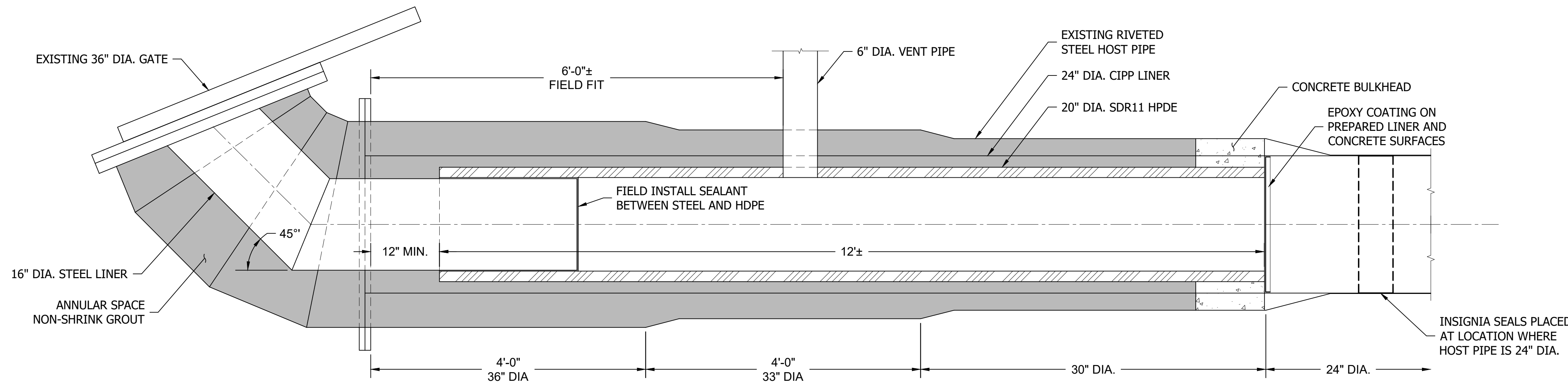
Cc: Dana Miller, Division 6 - Colorado Division of Water Resources
Lorri Harper, Civil Engineer – U.S. Fish and Wildlife Service
Brad Iarossi, Chief of Dam Safety – U.S. Fish and Wildlife Service
Jeremiah Kamp, Project Manager- Rocky Mountain Excavating

Attachment A
(Photos)

1. View looking upstream of the conduit at the transition between the CMP pipe and the riveted steel pipe. Note the squish in the pipe.

2. Close up view of the squished riveted steel pipe section located at the transition between the CMP pipe and the riveted steel pipe approximately 76 feet upstream of the outlet end of the discharge pipe.

Attachment B
(Intake Design Detail)



CIPP LINER & INTAKE STRUCTURE (1)

DETAIL

0 ½ 1 2 3
Scale in Feet

COLORADO LICENSED STEPHEN L. JAMIESON 25028 10/20/2017 PROFESSIONAL ENGINEER

C-1031B

REV.	DATE	DESCRIPTION	BY
1	10-20-2017	CHANGE ORDER NO. 2	JJT
0	2-26-2016	APPROVED FOR CONSTRUCTION	JJT

ARAPAHO N.W.R.

C9.1

MACFARLANE DAM REHABILITATION
CHANGE ORDER 2 - DETAILS

DESIGNED	DRAWN	CHECKED	DATE	SHEET NO.
JJT	SAA	SLJ	10-20-2017	

R:\1700\1772\1772.11.01_MacFarlaneDesign\Drawings\100% SUBMITTAL\2291-002-EX-141107 10-20-17 02:50pm Scott XREFS: MacFarlane Gate Inlet; SLJ2; Wheeler Logo;

Attachment C
(CIPP Design Calculations)

C & L WATER SOLUTIONS, INC.

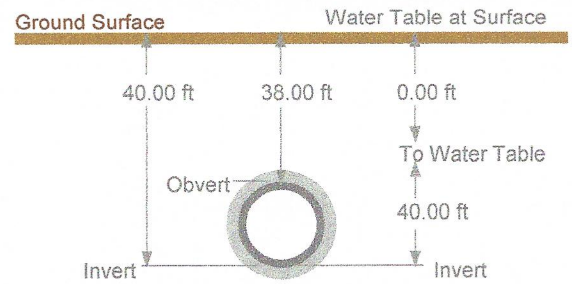
CIPP-DESIGN
CIPP Liner Thickness for Non-Pressure Pipes
By ASTM F1216-09 Appendix X1 Design Method

PROJECT INFORMATION **Design Date:** 12-Oct-2017

Macfarlane Dam Project
CIPP Liner Design Calculation
24" diameter pipe

Fully deteriorated host pipe conditions.
Fully structural CIPP liner design.

24" Diameter Tube
Calculated Design Thickness = 9.0 mm
Order Thickness = 9.0 mm Saertex S+ CIPP Liner



Size: 24 in Ovality: 2%
Fully Deteriorated Design
Required Liner Thickness: 9 mm

BY ASTM F1216 VERSION	F1216-09	CIPP liner design by ASTM F1216-09 Appendix X1 Method		
EXISTING PIPE PARAMETERS	ENTERED	**FACTOR SUMMARY - FULLY DETERIORATED**		
Existing Pipe Condition	Fully Det.	Flexural Modulus Design, E	1,610,000 psi	70% of Short-term
Inside Diameter, D	24 in	Flexural Strength Design, σ	21,000 psi	70% of Short-term
Depth to Invert	40 ft	Minimum Diameter for Existing Pipe	23.52 in	At 2% ovality
Water Table below Surface	0 ft	Maximum Diameter for Existing Pipe	24.48 in	At 2% ovality
Ovality of Existing Pipe, Δ	2.0%	Ovality Reduction Factor, C	0.836	
Soil Density, w	120 lb/ft3	Water Buoyancy Factor, Rw	0.670	Lower Limit
Soil Modulus, E's	1,000 psi	Coeffecient of Elastic Support, B'	0.7471	
Live Load, Ws	HS-20	Water Pressure, Invert	17.32 psi	40.00 ft Head
Other Load	0 psi	Vacuum Pressure, Invert	0.00 psi	
Vacuum Condition	0 psi	**Total Design Pressure, P, Invert**	**17.32 psi**	**For X1.1 & X1.2**
CIPP LINER PARAMETERS	ENTERED	Water Pressure, Obvert	16.45 psi	38.00 ft Head
Design Life	50 Years	Soil Pressure, Obvert	21.22 psi	38.00 ft Cover
Flexural Modulus short-term, Es	2,300,000 psi	Live Load Pressure Ws, Obvert	0.00 psi	Note 1
Retention for 50 Year Design E	70%	Other Load Pressure, Obvert	0.00 psi	
Flexural Strength short-term, σs	30,000 psi	**Total Design Pressure, qt, Obvert**	**37.67 psi**	**For X1.3**
Retention for 50 Year Design σ	70%	**NOTES**		
Enhancement Factor, K	7	Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.		
Poisson's Ratio, v	0.3			
Safety Factor, N	2			

FULLY DETERIORATED DESIGN REQUIRES SATISFYING F1216-X1 EQUATIONS X1.1, X1.2, X1.3 & X1.4

Equations X1.1, X1.2, X1.3 & X1.4		**Required Thickness, t**		**DR**
X1.1: P = [2KE/(1-v^2)] x [1/(DR-1)^3] x [C/N] For load due to groundwater at invert		0.282 in	7.2 mm	85.1
X1.2: (1.5Δ/100)(1+Δ/100)(DR)^2 - 0.5(1+Δ/100)DR=σ/(PN) For minimum thickness for ovality		0.161 in	4.1 mm	149.1
X1.3: qt=[1/N] x [32 x Rw x B' x E's x Cx (E x I/D^3)]^(1/2) For hydraulic, soil & live loads at obvert	Governs	0.353 in	9.0 mm	68.0
X1.4: (Es x I)/D^3 = Es/[12(DR^3)] ≥ 0.093 For minimum thickness fully deteriorated		0.189 in	4.8 mm	127.0
Required in Place Liner Thickness - Fully Deteriorated		**0.353 in**	**9.0 mm**	**68.0**

t in is rounded-up to 3 decimal places; t mm = t in x 25.4; DR = (Inside Diameter in)/(t in) NA - Not Available/Applicable

Required properties for installation test samples are Es ≥ 2300000 psi (D790) and σs ≥ 30000 psi (D790)

COMMENTS

Design assumes the following conditions: Soil modulus of 1,000 psi, 70% retention factor, 2% ovality, and water table to ground surface level. Liner design thickness may vary based on actual conditions.

COLORADO REGISTERED PROFESSIONAL ENGINEER
JEFFREY R. MAIER
38903

10/12/17

ASTM F1216 APPENDIX X1 CALCULATION DETAILS: FULLY DETERIORATED DESIGN **F1216-09**

Fully deteriorated design requires satisfying 4 F1216 equations: X1.1, X1.2, X1.3 and X1.4

Check Equation X1.1

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P is the maximum allowed external pressure on the liner from groundwater and any vacuum

Determine P for liner thickness of t = 0.353 in = 9.0 mm t is from summary page

K = Enhancement factor = 7 As entered

E_L = Flexural Modulus Design = (Flexural Modulus Short-term) x (Long-term Retention)

E = 2300000 x 70% = 1610000 psi

v = Poisson's ratio = 0.3 As entered

DR = D/t = 24/0.353 = 67.99 where D = inside diameter of existing pipe as entered

C = Ovality Reduction Factor = $([1-\Delta/100]/[1+\Delta/100]^2)^3$, where Δ is existing pipe % ovality Ovality = 2%

C = ([1- 2/100]/[1+2/100]^2)^3 = 0.836

N = Safety Factor = 2 As entered.

$P = [2KE_L/(1-v^2)] \times [1/(DR-1)^3] \times [C/N]$

P = [(2 x 7 x 1610000)/(1-0.3^2)] x [1/(67.99-1)^3] x [0.836/2] = 34.44 psi

Determine actual external pressure on liner, Pa

Pa = (Ground water pressure, Pgw) + (Vacuum pressure, Pv)

Pgw = 0.433 x H = 0.433 x 40 ft = 17.32 psi. Where H is height of water over invert.

Pv = -(0) = 0 psi As entered, 0 psi

Pa = Pgw + Pv = 17.32 + 0 = 17.32 psi

Compare Pa to P

Pa, Actual external pressure on liner = 17.32 psi

P, Allowed external pressure for 0.353 in liner by X1.1= 34.44 psi

Is P ≥ Pa? Yes. Equation X1.1 is satisfied by 0.353 in liner thickness

Check for DR ≤ 100 as per F1216 Appendix X1 Note X1.2

DR = 67.99 as calculated above

Is DR ≤ 100? Yes. Note X1.2 is satisfied by liner DR of 68

Check Equation X1.2

$[(1.5 \times \Delta/100) \times (1+\Delta/100) \times DR^2] - [0.5 \times (1+\Delta/100) \times DR] = (\sigma_L)/(P \times N)$

Check X1.2 for liner thickness of t = 0.353 in = 9.0 mm t is from summary page

Δ = 2 As entered.

DR, calculated above for X1.1 = 67.99

σL = Flex Strength Long-term = (Flex Strength Short-term) x (Long-term Retention) = 30000 x 70% = 21000 psi

P = External pressure on liner = Pa = 17.32 psi Calculated above for X1.1

N = safety factor = 2

Solve Eq. X1.2 for liner thickness, t. Where DR = (Liner OD)/(t)

$t = [3 \times (\Delta/100) \times D] / [0.5 + \{0.25 + (6 \times (\Delta/100)) \times [\sigma_L/(P \times N \times (1+(\Delta/100)))]\}^{.5}]$

t = [3 x (2/100) x 24] / [0.5 + {0.25 + (6 x (2/100)) x [21000/(17.32 x 2 x (1+(2/100)))]}^0.5] = 0.161 in

Compare liner t to t required by Equation X1.2

Liner t:	0.353 in	t is from summary page
Required t:	0.161 in	By Equation X1.2
Is Liner t ≥ Required t?		Yes. Equation X1.2 is satisfied by 0.353 in liner thickness.

Fully Deteriorated calculation details continued on next page

FULL FLOW CAPACITY COMPARISON BEFORE & AFTER LINING - Not Required

Flow = Q = Area x Velocity $=[(Pi \times D^2)/4] \times [(1.486/n) \times R^{2/3} \times S^{1/2}]$ Manning formula, imperial units

S = Slope = same before & after lining; R = Hydraulic Radius = D/4 for full flow (D in ft)

$Q2/Q1 = \{[(Pi \times (D_2^2)/4] \times [(1.486/n_2)] \times (D_2/4)^{2/3}\} / \{[(Pi \times (D_1^2)/4] \times [(1.486/n_1)] \times (D_1/4)^{2/3}\}$

Flow capacity comparison was not required.

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ASTM F1216 APPENDIX X1 FULLY DETERIORATED CALCULATION DETAILS CONT'D **F1216-09**

Check Equation X1.3

$q_t = [C/N] \times [32R_wB'E'_s(E_L I/D^3)]^{1/2}$ F1216-07a -

$q_t = [1/N] \times [32R_wB'E'_sC(E_L I/D^3)]^{1/2}$ F1216-09 **Using this equation**

Design is by F1216-09

Where q_t is the maximum allowed external pressure on the liner from cover, live loads and other loads

<u>Determine q_t for liner thickness of:</u> t = 0.353 in = 9.0 mm t is from summary page

C = Ovality Reduction Factor = 0.836 (calculated on page 1)

N = Safety Factor = 2

Rw = Water Bouyancy Factor (Min 0.67, Max 1.0) = 1-0.33(Hw/H) = 1-0.33(38/38) = 0.67 Lower Limit

Where Hw and H are height of water and height of soil over top of pipe. See F1216 X1.2.2

B' = Coefficent of elastic support = 1/(1+4e^[-0.065H]) = 0.7471 Where H = 38 and e = 2.718

E's = Modulus of soil reaction = 1000 psi. As entered.

EL = Long-term modulus for CIPP = 1610000 psi (calculated on page 1)

I = Moment of inertia for liner = (t^3)/12 = (0.353^3)/12 = 0.00366558

D = Inside diameter of existing pipe = mean OD of liner = 24 in

qt=[1/N] x [32 x Rw x B' x E's x Cx (E x I/D^3)]^(1/2) X1.3 for F1216-09

qt = [1/2] x [32 x 0.67 x 0.7471 x 1000 x 0.836 x (1610000 x 0.00366558/24^3)]^(1/2) = 37.8 psi

<u>Determine actual external pressure on liner, qa, due to existing pipe conditions</u>

qa = Ww + W + Ws + Wo

Ww = Water load = 0.433 x Hw = 0.433 x 38 = 16.45 psi Hw is water over top of pipe.

W = Soil Load = (w x H x Rw)/144 = (120 x 38 x 0.67)/144) = 21.22 psi H is soil height over top of pipe

Ws = Live load = 0 psi Note 1: AASHTO HS-20. Refer AWWA M11, M23, M55.

Wo = Other load = 0 psi, entered

qa = 16.45 + 21.22 + 0 + 0 = 37.67 psi

<u>Compare qa to qt</u>

qa =	37.67 psi	Actual external pressure on liner
qt =	37.80 psi	Allowed external pressure for 0.353 mm liner by Equation X1.3
Is qt ≥ qa?	Yes. Equation X1.3 is satisfied by 0.353 in liner thickness.	

Check Equation X1.4

$(Es \times I)/D^3 = Es/(12 \times (DR^3)) \geq 0.093$

<u>Determine for liner thickness t of:</u> t = 0.353 in = 9.0 mm t is from summary page

Es = initial (short-term) modulus = 2300000 psi

DR = liner dimension ratio = D/t = 24 / 0.353 = 67.99

Es / (12 x (DR^3)) = 2300000/(12 x 67.99^3) = 0.6098

Is Es / (12 x (DR^3)) ≥ 0.093? Yes. Equation X1.4 is satisfied by 0.353 in liner thickness

Summary for Fully Deteriorated Design

Fully Deteriorated design requires satisfying Eqs X1.1, X1.2, X1.3, X1.4

Eq X1.1	Satisfied by 0.353 in liner thickness
Eq X1.2	Satisfied by 0.353 in liner thickness
Eq X1.3	Satsified by 0.353 in liner thickness
Eq X1.4	Satisfied by 0.353 in liner thickness

Required liner thickness for fully deteriorated design is 0.353 in 9.0 mm

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Technical Data of SAERTEX-LINER®

Company

Certification	DIN EN ISO 9001:2000

Procedure

Product Name	SAERTEX-LINER®
Use of the procedure since	1994
Inflate procedure	Compressed air
Curing method	UV- or Steam Curing
Installation technique	Pull in
Impregnation	At manufacturers site

Liner

General	
Storage stability	Steam Curing: UP 44.6 - 64.4 °F ≤ DN 23.6″ 3 weeks 44.6 - 64.4 °F ≥ DN 23.7″ 2 weeks VE 44.6 - 64.4 °F all DN 1 week UV-Curing: UP 44.6 - 77.0 °F all DN 2 months 44.6 - 64.4 °F all DN 6 months VE 44.6 - 64.4 °F all DN 3 months
Chemical resistance	According to ASTM D 543
Abrasion test Abrasion resistance after 100.000 cycles	Darmstädter method 0.025″ or 0.64 mm
Specific density in relation to DIN EN ISO 1183-2	1.5 g/cm^3 ± 0.5 g/cm^3
Impact toughness according to DIN 53453	77 mJ/mm^2
Barcol hardness according to DIN EN 59	≥ 40
Time for depreciation / Lifetime of the Liner	70 years
Maximum rest styrene content after curing	≤ 3 %
Fire characteristic	F 1/4 ; K 2/4
Ring gap after curing	0.35%

SAERTEX-S-LINER®

Dimension range	4 - 48″ (100-1200 mm)
Special profiles up to circumference	148″ (3770 mm)
Wall thickness in cured condition	0.157 - 0.472″ (4 – 12 mm)
Number of layers	2
Square weight per mm wall thickness	950 g/m^2, tolerance: + 150 g/m^2 or - 100 g/m^2
Short-term E-Modul according to ASTM D 790 and DIN EN 1228	1,740,453 psi
Long-term E-Modul according to ASTM D 2990 and DIN EN 761	1,276,332 psi
Short-term flexural strength in relation to ASTM D 790 and DIN EN ISO 178	36,259 psi
Long-term flexural strength according to ASTM D 2990 and DIN EN 761	26,832 psi
Compressive strength according to ASTM D 695 and DIN EN ISO 604	30,458 psi
Poisson´s ratio	axial = 0.279 radial = 0.171
Reduction factor after 10.000 h in relation to ASTM D 2990 and DIN EN 761	1.35
Creep behavior after 24 h according to DIN EN ISO 899-2	< 10%

SAERTEX-M-LINER®

Dimension range	6 – 16″ (150 – 400 mm)
Special profiles up to circumference:	49.48″ (1260 mm)
Wall thickness in cured condition	0.118 and 0.157″ (3 and 4 mm)
Number of layers	2
Square weight per mm wall thickness	520 g/m^2, tolerance: + 150 g/m^2 or - 100 g/m^2
Short-term E-Modul according to ASTM D 790 and DIN EN 1228	1,015,264 psi
Long-term E-Modul according to ASTM D 2990 and DIN EN 761	551,143 psi
Short-term flexural strength in relation to ASTM D 790 and DIN EN ISO 178	29,008 psi
Long-term flexural strength according to ASTM D 2990 and DIN EN 761	15,954 psi
Compressive strength according to ASTM D 695 and DIN EN ISO 604	30,458 psi
Poisson´s ratio	axial = 0.320 radial = 0.274
Reduction factor after 10.000 h in relation to an DIN EN 761	1.80
Creep behavior after 24 h according to DIN EN ISO 899-2	< 10%

SAERTEX multiCom®

Reinforcement:

Supporting material	Glass fibre stitchbonded fabric, non crimped
Textile glass type according to DIN 61850	glass which is permanently resistant to chemical agents or corrosion
Specific density	2.62 g/cm^3
Allowed stretching in radial direction	4.6%
Stretching in axial direction	0%

Resin type:

UP resin group according to DIN 18820-1	3
UP resin type according to DIN 16946-2	1140
VE resin type according to DIN 16946-2	1310
Resin based on	Isophthalic acid / Neopentyl glycol
Curing agents	UV-Curing: UV-Initiators Steam Curing: peroxide
Reaction shrinkage of the pure resin	8%
Content of styrene before curing	approx. 45%

Filler:

Species	$Al(OH)_3$
Mass content based on the raw resin	Up to 25%

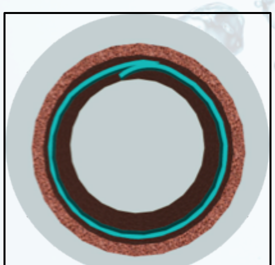
The Myth, the Fact, and the Legend: Insignia™ Hydrophilic Sealing System

Over the course of time, people have bought into stories that are believed to be true only later to be found that the story is nothing more than a myth. Dating back to the belief that the earth was flat, the demystifying of these supposedly all-pervading truths has always generated astonishment and awe in a society. A classic example of one such modern myth is the conviction among users of trenchless pipe renewal technologies in that cured-in-place pipe (CIPP) will not only structurally restore the pipe but that inflow and infiltration (I&I) will also be eliminated by bonding the liner to a host pipe preventing future leakage in a sewer collection system.

Before making our way through the distorted facts of I&I elimination, it is important that one understands the purpose and the long-term goals for sealing a collection system. In any given collection system, I&I can cause havoc for a few valid reasons. Consequently, if CIPP itself could really eradicate I&I, as the myth perpetuates, the results would be significant and would save a tremendous amount of time, effort, and tax dollars on municipal sewer renovation programs. However, truth be told, it is beyond conventional wisdom to install CIPP in a greasy sewer and expect the CIPP to bond and form a water tight seal for the designed 50 years, especially where hydrostatic loading is present. It is common knowledge that the standard industry practice for cleaning a sewer pipe in preparation for CIPP lining involves nothing more than hydraulic jetting to remove any debris in the pipe. The residual fats, oils, and grease (FOG) present on the walls of a host pipe are in no way diminished due to high pressure hydro cleaning. Additionally, shrinkage of CIPP occurs during polymerization resulting in an annulus where water can track behind the liner and migrate back into the collection system at manhole connections and service lateral connections.

- Requires additional energy which equates to additional tax dollars spent
- Overtaxing of the collection system whereby reducing capacity
- Sewer overflows that pollute our environment and adversely affects clean water

Effects of I&I on a collection system

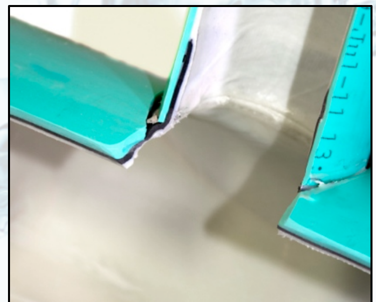


Overlap in Pipe

These problems have not gone unnoticed, and over the years there have been numerous attempts to correct these issues without notable success. The attempted remedies range from methods of injecting a chemical

End Seal Installation

grout post-lining, to packing of cementitious material at the liner/manhole interface, to the insertion of expanding end seals positioned in the pipe prior to lining. The concept of a compression gasket to form an engineered seal is an accepted industry practice used for years in the installation and joining of sewer pipes. Even though the engineering society understands that the best long-term solution is an engineered gasket seal, one must select the proper gasket, which is designed for CIPP applications. The use of a hydrophilic rope or belt shaped material commonly used in a cold-concrete-joint is not suitable for CIPP renewal works. Those who have attempted to use this type of seal will appreciate the challenges of effectively securing a penannular or non-monolithic gasket to the inside of a pipe. Some of the problems that occur with this method are the fact that gluing anything into a wet and greasy sewer pipe is a challenge in itself. If the gasket falls over during insertion of the liner, the result is a large bump at the invert of the pipe; or the contractor simply doesn't install the problematic gasket as required. Even if one were to assume the gasket could remain in-place as the liner is inserted, the ends of the gasket would have to abut or overlap. The belt type gasket creates a significant opportunity for separation or a gap in the gasket resulting in continued leakage where hydraulic loading is present. Furthermore, these belt shaped gaskets are fairly narrow, producing an insignificant sealing surface. They are also quite bulky in thickness, reducing the cross section of the pipe, which may hinder the insertion of robotic cutters, maintenance and lateral connection lining equipment.



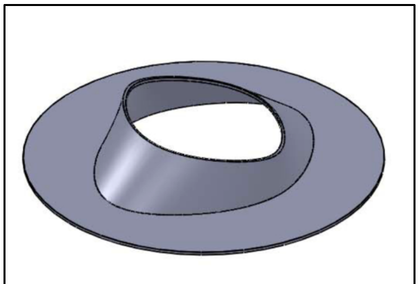
Gasket embedded at service connection

In order to correct these deficiencies, a considerable amount of research and development has been initiated to produce a truly engineered mechanical end seal which is simple to install, is effectively secured to the inside of the pipe, and has a significant sealing surface and a low profile that maximizes the cross section of the pipe opening.

Those who invested in the research and development could not put their checkbook away until the research project proved to conclude a total system seal that is compatible with all mainline CIPP systems, regardless if the mainline liner is pulled into place or inverted into place. To achieve the objective of a total sealed system, the team had to first identify additional locations for continued leakage post mainline CIPP rehabilitation. Identifying this source was quite simple, as the trenchless industry has widely accepted that a vast majority of infiltration is derived from service lateral pipes. Infiltration found at a service connection may have more than one source; where one source is

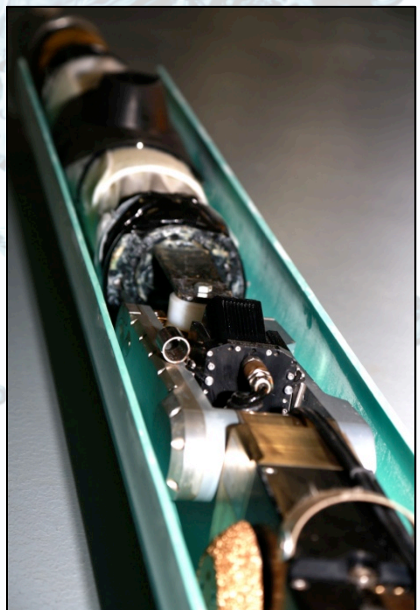
Hydrophilic End Seal

water that infiltrates through lateral pipe defects and another is water that tracks behind mainline linings and re-enters the collection system at service connections and manholes.



Hydrophilic Gasket for Service Connections

The renewal of lateral pipes and the main/lateral connection is typically performed by pressing a resin saturated mainline member against the interior of a mainline CIPP as a resin saturated liner tube is inverted into the lateral pipe. Most commonly, the lateral pipe is renewed to the public/private property line. The challenge is how to form a long-lasting seal between the lateral CIPP and the mainline CIPP. Long-term bonding to the interior surface of a mainline CIPP is problematic for a few practical reasons: 1) CIPP includes inner coatings made of materials that are incompatible for long-term thermoset bonding; 2) CIPP liners are lubricated with mineral oil, vegetable oil, cooking grease and similar lubricants to reduce friction during inversion (these materials are well-known release agents that actually prevent bonding); 3) Thermal expansion/contraction of plastic CIPP; and 4) If water is present, it is a relentless force working against any bonded connection.



Hydrophilic Hat Installation Equipment

The solution for obtaining a long-term seal starts by applying common engineering principles. The science of a compression gasket seal is where two structural materials are joined and during the joining process, the gasket is compressed resulting in a flexible seal that has been proven to be extremely effective in sealing pipes for many years in the pipeline industry. In the case of CIPP applications, the design team applied these same engineering principles. The research project concluded with a final solution for a mainline and service lateral collection system seal consisting of a high-strength, low-profile, short, full-hoop CIPP outfitted with a flange or hat-shaped, hydrophilic neoprene rubber gasket and a single-piece lateral liner tube assembly. The full-hoop mainline member provides a structural bridge as an opposing force from the swelling gasket occurs forming a compression seal that is comparable to that of new pipe. An added benefit of this sealing method is compatibility with all mainline CIPP lining systems and the peace of mind that an engineered structural mainline member combined with an engineered seal can be designed and stamped by professional engineers providing a true service life, and not simply relying on "let's hope it sticks."

Originally published in Trenchless International Magazine, October 2012
Authors: Sahar Hasan, Engineering; Kristina Kiest, Director of Marketing

LMK TECHNOLOGIES

SPECIFICATION

INSTALLATION PRACTICE
HYDROPHILIC END SEAL SLEEVE

INSTALLATION SPECIFICATION FOR HYDROPHILIC END SEAL SLEEVE

1. Intent

   It is the intent of this specification to detail a safe, efficient, cost-effective installation method of a hydrophilic pipe end sealing product called Insignia™ End Seal for the junction of a main or lateral pipe and a manhole. The Insignia™ End Seal provides a full-circle compression seal to a substantial area at the ends of a pipe rehabilitated by lining. This hydrophilic sealing product is intended for use in conjunction with most all pipe rehabilitation systems, including but not limited to: inverted CIPP liners, pull-in-place CIPP liners, and fold-and-form plastic pipe liners. The Insignia™ End Seal product shall be commercially available from LMK Technologies or a distributor for use as an adjunct to rehabilitative pipe lining projects on a price per kit basis.

2. Overview

   2.1 The Insignia™ End Seal product and process consists of providing a full-circle seal at the junction of a main or lateral pipe and a manhole by using a tubular sleeve of hydrophilic material specifically tailored to provide the most safe, efficient, cost-effective, watertight seal at the ends of a rehabilitated pipe. The Insignia™ End Seal product and process overcomes major deficiencies of other known products and methods used at the junction of a pipe at the manhole. For example, the use of a hydrophilic rope is commonly used near the ends of rehabilitated pipe. The use of such a hydrophilic rope may result in imprecise placement within the host pipe, as the flexible rope is prone to shift within the pipe or fall during installation of a pipe liner, resulting in an incomplete seal at the pipe ends. Another example of material used to seal pipe ends is a hydrophilic caulk. The use of such a caulk to seal the ends of a pipe at the manhole may result in inconsistent wall thickness and imprecise placement before and after a liner is installed. Since there are no structural elements to hold the caulk in place, the caulk is allowed to smear and spread throughout the pipe. Additionally, the use of either hydrophilic rope or caulk requires arduous cleaning of the pipe interior before application in an attempt to stick and retain the seal to the pipe as a liner is installed.

   2.2 The Insignia™ End Seal product and process overcomes these deficiencies by the use of a sealing product that provides a hydrophilic material that does not shift or move during installation of a rehabilitative pipe liner. Additionally, the Insignia™ End Seal product provides a uniform seal and consistent wall thickness around the pipe end after installation of a pipe liner. Furthermore, the Insignia™ End Seal product does not require arduous cleaning of the pipe end before installation.

   2.3 The Insignia™ End Seal product includes a tubular sleeve constructed of a hydrophilic polymeric material, designed with a specified length and wall thickness to provide a compression seal to the end of a pipe at the manhole. A mechanical fastener band is provided with the tubular sleeve that is specifically designed to hold the tubular sleeve in place during installation of a pipe liner. The mechanical fastener may utilize a double-sided adhesive to ensure that neither the tubular sleeve nor the fastener shift during installation.

2.4 The most common method utilized and associated with the Insignia™ End Seal includes placing the tubular hydrophilic sleeve within the pipe to be rehabilitated adjacent to the manhole. A mechanical fastener is placed against the inner wall of the tubular sleeve during installation, securing the tubular sleeve against the inner wall of the pipe. (For sizes 18" and larger, anchor screws should also be installed to assist in holding the mechanical fastening band in place.) After the mechanical fastener is secured in place, a liner is inserted through the tubular sleeve utilizing known installation methods. After the liner is set in place, the tubular sleeve will swell in the presence of water, creating a full-circle seal between the newly-installed liner and the host pipe for the entire length of the Insignia™ End Seal.

3. Material

3.1 The materials utilized for the Insignia™ End Seal shall be provided in kits that are designed to accommodate varying pipe diameters, manhole depths, junction configurations, and pipe liner products. The Insignia™ End Seal kits are compatible with most rehabilitative pipe liner products, including cured-in-place, and fold-and-form Additionally, the Insignia™ End Seal kit may be used with many different pipe liner installation and curing methods, including inversion, pull-in-place, hot water curing, steam curing, ultra violet curing, and ambient curing methods. The components of the Insignia™ End Seal include a tubular sleeve, and a mechanical fastener.

3.2 Tubular Sleeve: The member that creates the end seal is a hydrophilic neoprene rubber of approximately 50 Shore A durometer. The tubular sleeve has a uniform wall thickness of approximately 2 mm, a length of approximately 3.5 inches, and a diameter slightly less than the interior pipe diameter. The hydrophilic neoprene rubber has the following characteristics:

Characteristic	Unit	Value	Test Method
Shore A Hardness	point	50 +/- 5	ASTMD2240
Tensile Strength	psi	177	ASTMD412
Elongation at Break	%	523	ASTMD412
Specific Gravity		1.2	ASTMD297
Swell Capacity in Water Contact	%	200	GRCSC

3.3 Sizes: The Insignia End Seal Sleeve is available in sizes of 6", 8", 10", 12", 15", 18", 21", 24", 27", 30", 33", 36", 42", 48" and 54"

3.4 Mechanical Fastener: There are several mechanical fasteners available for use with the Insignia™ End Seal product. A first option is a shape-memory alloy that has been formed into a specific acute or other curvilinear configuration having an outer profile that is generally greater than the circumference of the pipe before insertion. This conformation allows the alloy to be bent into a configuration that fits inside of the tubular sleeve and the pipe. Once inside the pipe, the alloy is pressed against the wall of the tubular sleeve, thus pressing the tubular sleeve against the wall of the pipe. The shape memory characteristic of the fastener urges the fastener to return to its original profile. The alloy remains in a strained configuration, pressing the tubular sleeve against the pipe wall. A second option for a mechanical fastener is a ratcheting retaining ring. The ratcheted retaining ring includes a strip of material having a total length generally greater than the pipe diameter. A ratcheting worm gear is attached to the strip and the strip is formed into a ring shape of variable diameter. The ratcheting retaining ring allows an operator to manually adjust the outer profile of the mechanical fastener, allowing for a small initial diameter before placement into the pipe. After the ratcheting retaining ring is placed within the pipe, the diameter of the retaining ring may be expanded by actuation of the worm gear to tightly hold the tubular sleeve in place.

3.5 Dual-sided Adhesive Tape: For some mechanical fasteners, a dual-sided adhesive tape may be used to affix the mechanical fastener to the tubular sleeve before installation within the pipe. This feature encourages the mechanical fastener to remain within the tubular sleeve during installation of the tubular sleeve and the pipe liner. (For sizes 18" and larger, anchor screws should also be installed to assist in holding the mechanical fastening band in place.)

4. Installation Recommendations

4.1 Access to the ends of the pipe to be rehabilitated: Access a manhole where a main pipe or a lateral pipe connects. A technician may access the manhole interiors via conventional methods to access the main or lateral pipe to be rehabilitated. The pipe interior at the manhole shall be measured from 6:00 to 12:00 and from 3:00 to 9:00. The mean shall be the nominal inner diameter.

4.2 Cleaning and Inspection: All roots, deposits, and debris should be removed from the pipe with hydraulically powered equipment, high velocity jet cleaners, or mechanically powered equipment as per NASSCO recommended specifications for sewer collection system rehabilitation. Since the Insignia™ End Seal provides a seal based on compression instead of adhesion, extensive cleaning beyond obvious obstructions is optional. A full-circle seal at the ends of the pipe will be achieved regardless of the presence of fats, oils, and grease which is inherent in sewer pipes even after high velocity jet cleaning. It should be noted that the various pipe rehabilitation installation methods have different installation standards (such as ASTM standards and manufacturer's recommendations), and those installation standards should be observed during installation of the liner.

4.3 Placement of the Insignia™ End Seal Product: After the ends of the pipe have been accessed and cleaned and inspected, the Insignia™ End Seal product is placed inside the end of the pipe adjacent the manholes. The mechanical fastener is placed into a conformation such that the outer profile of the mechanical fastener is smaller than the diameter of the pipe to be rehabilitated, and the mechanical fastener is placed within the tubular sleeve. Dual-sided adhesive tape may be applied to the outer surface of the mechanical fastener to adhere the outer surface of the mechanical fastener to the inner surface of the tubular sleeve. (For sizes 18" and larger, anchor screws should be installed to assist in holding the mechanical fastening band in place.) The tubular sleeve is then placed inside the end of the pipe, and the mechanical fastener is placed into a conformation where the tubular sleeve is held to the pipe wall.

4.4 Installation of a Rehabilitative Liner: After the Insignia™ End Seal product has been placed into the ends of the pipe, a rehabilitative liner product shall be installed into the pipe. The Insignia™ End Seal product is intended for use in conjunction with most pipe rehabilitation systems, including but not limited to: cured-in-place pipe liners and fold-and-form pipe liners. The Insignia™ End Seal kit may be used with many different pipe liner installation and curing methods including, inversion, pull-in-place, hot water curing, steam curing, ultra violet curing, and ambient curing.. Since the Insignia™ End Seal product has a uniform wall thickness and is held firmly within the pipe to be rehabilitated, a compression seal will be provided to a large area of the pipe end adjacent the manhole. Since the Insignia™ End Seal product may be used with a variety of rehabilitative pipe liners, the standard installation practices of each individual pipe liner method should be closely followed. Therefore, procedures should be used that meet applicable NASSCO, ASTM, NACE and SSPC standards and provide quality assurance controls that meet the manufacturer's printed recommendations.

Patents:
8,240,340
8,240,341
8,567,451
8,636,036
8,561,145
8,640,737

Revised March 13, 2015
Document #1560 V. 4

Attachment D
(Outlet Discharge Capacity)

MACFARLANE DAM NEW CIPP OUTLET CAPACITY ANALYSIS

Outlet Capacity.

Pressurized Pipe Flow - Iterative Solver spreadsheet that uses the Initial lake level and solves for Discharge by changing the Total Hald Delta to Zero.
Assumes Downstream Boundary Condition at Pipe End is gravity flow

"1"	Intake Section - 16-inch Steel Pipe		"2"	20-inch HDPE		"3"	24-inch-diameter CIPP Liner	
	No Intake Trash Rack			20-inch HDPE transition section			New CIPP Liner Pipe	
AO1 =	1.33	Gate Open Area, Sq-Ft	D2 =	1.34	Diameter, Feet	D3 =	2.00	Diameter, Feet
A1 =	1.33	Typ Section Area, Sq-Ft		16.1	Diameter, Inches		24.0	Diameter, Inches
P1 =	4.18	Typ Section Perimeter, Feet	N2 =	0.0120	Manning 'N'	N3 =	0.0090	Manning 'N'
N1 =	0.0120	Manning 'N'	Ke2 =	0.00	Minor Losses	Ke3 =	0.30	Minor Losses
Ke1 =	0.61	Gate Entrance Loss	Km2 =	0.00	Other Minor Loss	Km3 =	0.00	Other Minor Loss
Km1 =	0.31	Minor Losses	Kec2 =	0.19	Expan/Contract Loss, 1-2	Kec3 =	0.51	Expan/Contract Loss, 1-2
L1 =	7.0	Intake Length, Feet	L2 =	12.0	Pipe Length, Feet	L3 =	240.0	Pipe Length, Feet
Q1 =	-35.26	Total Discharge, CFS	Q2 =	-35.26	Pipe Discharge, CFS	Q3 =	-35.26	Pipe Discharge, CFS
Ke1 =	Pipe intake at headwall, square		Ke2 =			Ke3 =	Exit Losses	
Km1 =			Km2 =	Expansion Losses		Km3 =		
			Kec2 =			Kec3 =	Expansion losses	
A1=	1.330	Gate Area, Feet	A2=	1.410	Pipe Area, Feet	A3=	3.142	Pipe Area, Feet
V1=	-26.51	Flow Velocity, Ft/Sec	V2=	-25.00	Flow Velocity, Ft/Sec	V3=	-11.22	Flow Velocity, Ft/Sec
Hf1 =	11.510	Total Head Loss, Ft	Hf2 =	2.330	Total Head Loss, Ft	Hf3 =	7.332	Total Head Loss, Ft
EGL =	8304.490	Ft	EGL =	8302.160	Ft	EGL =	8294.828	Ft
V*V/2g =	10.915	Ft	V*V/2g =	9.708	Ft	V*V/2g =	1.956	Ft
HGL =	8293.575	Ft	HGL =	8292.452	Ft	HGL =	8292.872	Ft

Initial Lake Level =	8,316.00	MSL - Operating Water Level
Minimum Downstream WL =	8,284.12	MSL -- Pipe Invert [S=0.0312]
Pipe Outfall dc =	0.00	inches (determined elsewhere)
Pipe Outlet Flow Depth (D5') =	1.00	Ft -- Water depth at pipe outfall ((D5+dc)/2)
Outfall WL =	8285.12	MSL -- Water surface at pipe outfall (D5+Min WL)
Alpha =	2.086	(Area function for not full pipe)
Outfall Area =	1.129	Sq. Ft.
Outfall Velocity =	-31.24	Ft/Sec
Outfall Velocity Head Loss =	9.71	Ft (= $1.0*V^2/2g$)
Total Head Loss =	30.88	Ft - Head loss from reservoir to pipe outfall end
Total Head Delta =	0.000	Ft -- adjust Q to minimize delta , (-) delta indicates too high Q

R:\1700\1772\1772.11.02_MacFarlaneConstruction\Construction\4_Change Orders\CO#2\[CIPP_Outlet_Capacity Analysis.xlsm]A
20-Oct-17

MacFarlane Dam New Outlet Works Discharge Capacity

1772.11.01

Reservoir Elevation (ft)	Culvert Discharge (cfs)	
8320	37.5	**Top of Dam**
8319	36.9	
8318	36.4	
8317	35.8	
8316	35.3	**Spillway Crest Elevation**
8315	34.7	
8314	34.1	
8313	33.5	
8312	32.9	
8311	32.3	
8310	31.7	
8309	31.0	
8308	30.4	
8307	29.7	
8306	29.0	
8305	28.3	
8304	27.6	
8303	26.8	
8302	26.1	
8301	25.3	
8300	24.5	
8299	23.6	
8298	22.8	
8297	21.9	
8296	20.9	
8295	19.9	
8294	18.9	
8293	17.8	
8292	16.6	
8291	15.4	
8290	14.0	
8289	12.5	
8288	10.8	
8287	8.7	
8286	6.0	
8285	2.5	
8284.12	0.0	**Invert Elevation**

From:	John J. Treacy, P.E.
To:	Franz, Jeremy <Jeremy.Franz@state.co.us> (Jeremy.Franz@state.co.us); Dana Miller; Brad_Iarossi@fws.gov; Lorri Harper
Cc:	Stephen L. Jamieson, P.E.; Jon Morse; Andrea D. Fasen; clarson@clwsi.com; Jeremiah Kamp; Trent Burns
Subject:	MacFarlane Dam CO #2 Clarifications
Date:	Thursday, October 26, 2017 11:40:08 AM
Attachments:	image001.png

Jeremey & Dana,

Per our conversation this morning, I am providing you with the requested follow up information to clarify your installation questions associated with Change Order No. 2. This email is considered to be an addendum to information previously submitted for Change Order No. 2.

1. *Provide an installation sequence of the liner and transition at the upstream intake.*
    a. C&L will jet and clean host pipe prior to CIPP liner installation,
    b. The insignia seals will be installed at both an upstream and downstream location in the 24-inch-diameter host pipe section prior to the liner installation,
    c. The CIPP liner is planned to be installed throughout the entire length of the pipe,
    d. The CIPP liner will be cut to an engineer approved location within the host pipe prior to HDPE installation,
    e. The 20-inch-diameter HDPE insert will be cut to fit and installed as far downstream as practical after the CIPP liner is cut.
    f. The 16-inch-diameter steel elbow will be inserted into the upstream end of the HDPE liner pipe.
    g. Bulkheads will then be installed by hand at the downstream transition section from the HDPE liner to the CIPP liner prior to grouting the annular space,
    h. 5,000 psi non-shrink grout will be placed in the annular space upstream of the bulkheads.
    i. The concrete bulkheads will be sealed with an epoxy coating to provide a smooth flow transition to the 24-inch-diameter CIPP liner.

2. *Is there a minimum temperature requirement prior to installation?*
    a. Yes, the ambient air temperature has to be above freezing prior to installation. The temperature within the host pipe is not a concern due to the heating of the liner pipe during the installation.

3. How will the CIPP liner maintain its circularity, and remain centered in the larger diameter host pipe at the upstream end?
    a. The CIPP liner will not remain centered in the larger diameter host pipe. The CIPP liner will drop to the bottom of the pipe once it transitions to this section. However this section of CIPP liner will be cut out in the field prior to installing the 20-inch HDPE pipe.

4. How will the non-shrink grout be installed in the annular space?
    a. The non-shrink grout will be installed trough a tremie pipe to fill grout from the downstream end to the upstream end.

5. What is the installation schedule?
    a. C&L will have Snowbridge Inc. clean and jet the pipe either 10/26 or 10/27.
    b. The CIPP liner will be installed on Monday 10/30.
    c. The CIPP liner will have a follow up video inspection on Tuesday 10/31
    d. The 20-inch-diameter HDPE and 16-inch-diameter steel elbow will be installed either Tuesday or Wednesday
    e. The bulkheads are planning to be installed on Tuesday or Wednesday
    f. Grouting the annular space is scheduled for either Wednesday or Thursday
    g. Follow up Inspection with SEO is tentatively scheduled for Thursday Nov. 2.

Hopefully our responses address your comments and concerns. Please let us know if you have any additional comments.

Thanks

John J. Treacy, III P.E.
W. W. Wheeler & Associates, Inc.
3700 South Inca Street, Englewood, CO 80110
303-761-4130 (O) | 720-313-3587 (M) | 303-761-2802 (F)
john.treacy@wwwheeler.com | www.wwwheeler.com

W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

From: John J. Treacy, P.E.
To: Andrea D. Fasen
Subject: FW: MacFarlane Bulkhead Construction
Date: Tuesday, July 31, 2018 4:13:02 PM

From: Dana Miller [mailto:dana.miller@state.co.us]
Sent: Friday, October 27, 2017 1:22 PM
To: John J. Treacy, P.E. <John.Treacy@wwwheeler.com>
Cc: Jeremy <Jeremy. Franz@state. co. us> Franz <Jeremy.Franz@state.co.us>
Subject: Re: MacFarlane Bulkhead Construction

John,

Please thank Chris for the clarification. This helps. As the drawing included with the original change order is not representative of what we will see in the final construction, please plan on providing a revised detail with the as-constructed documents. The main differences to which I'm referring are:

1. The CIPP will presumably end a short distance upstream of the transition to the 24-inch section of host pipe (once field cut).
2. The concrete bulkhead shown at the downstream end will only be placed between the CIPP and HDPE pipe; the grout shown by shading will extend to the location where the CIPP and host pipe are both 24 inches.
3. There will be a "bulkhead" or seal in the annular space between the steel insert and the HDPE pipe on the downstream end.
4. Finally, as noted during the recent phone conversation, the air vent has been located closer to the upstream end than currently shown.

We find this change acceptable. Official approval letter to follow.

Do you have an expected time for installation on Monday?

Thank you!

Dana

Dana Miller, PE
Dam Safety Engineer

P 970.879.0272, ext. 6414 | C 719.221.1227
505 Angler's Dr., Suite 101, Steamboat Springs, CO 80487
dana.miller@state.co.us | www.water.state.co.us

On Fri, Oct 27, 2017 at 10:30 AM, John J. Treacy, P.E. <John.Treacy@wwwheeler.com> wrote:

> Dana,

Here is some additional clarification from C&L on the Bulkhead Construction. Let me know if you need any additional information

Sent from my iPhone

Begin forwarded message:

From: Christopher Larson <clarson@clwsi.com>
Date: October 27, 2017 at 8:45:23 AM PDT
To: "John J. Treacy, P.E." <John.Treacy@wwwheeler.com>
Subject: RE: MacFarlane Bulkhead Construction

John,

The drawing you provided does a good job showing the layout. Essentially there has to be a bulkhead at every point there is a transition in pipe size/type.

Bulkhead 1: CIPP to Steel Pipe: the first bulkhead requires no grout as it will be naturally created at the point where the CIPP liner (24”) meets and fits tight with the steel pipe at the point it becomes 24” in diameter. A hydrophilic seal will be placed at this point. This is a compression seal and works under tight fit conditions. C&L is responsible for this installation.

Bulkhead 2: HDPE to CIPP: The second bulkhead will be installed where the HDPE terminates within the CIPP liner. The HDPE shall be shimmed up temporarily off the invert of the liner to center it in the 24” liner and a high compression, non-shrink grout shall be placed as a bulkhead approximately 18” to 2’ thick. After Curing, an epoxy topcoat shall be placed over the grout to provide protection. C&L is responsible for this installation.

Bulkhead 3: Stainless Steel to HDPE: The third bulk wall will be placed between the Stainless steel inlet gate insert and the inner wall of the HDPE pipe. A high compression, non-shrink grout shall be placed as a bulkhead between the two materials. RMEC is responsible for this scope.

After the bulkheads have cured the manufacturers recommended time, the annular spaces and voids shall be filled with the specified Flowable fill. RMEC is responsible for this scope.

Hopefully this helps?

Christopher Larson
Chief Operations Officer

MAINTENANCE · TRENCHLESS · EXCAVATION

12249 Mead Way

Littleton, CO 80125

(303) 791-2521 **Office**
(303) 931-1829 **Mobile**
clarson@clwsi.com

www.clwsi.com

From: John J. Treacy, P.E. [mailto:John.Treacy@wwwheeler.com]
Sent: Thursday, October 26, 2017 1:49 PM
To: Christopher Larson <clarson@clwsi.com>
Subject: MacFarlane Bulkhead Construction

Chris,

Per our conversation, can you please send me an explanation, sketch, etc. that I can send onto the SEO describing the installation process of the non-shrink bulkheads, the new seal you suggested etc.
The SEO is having a hard time seeing how the bulkhead will be installed as we have the host pipe, CIPP liner pipe, and the HDPE pipe. Based on our conversation I have a good idea of the plan but I think it would make a lot more sense coming from you the installer. In essence we have 3 pipes and we 2 annular spaces we need to get filled. After speaking with Dana again I think the main question to answer is how the bulkhead will be installed between the host, liner, and HDPE.
Hopefully this makes sense. If you have questions please call my cell phone as I will be out of the office tomorrow.

Thanks

John J. Treacy, III P.E.
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john.treacy@wwwheeler.com | www.wwwheeler.com

Mr. John Treacy, P.E.
W.W. Wheeler & Associates, Inc.
3700 S Inca St.
Englewood, CO 80110
via email: John.Treacy@wwwheeler.com

When replying, please refer to:
MACFARLANE DAM, DAMID 470202
Water Division 6, Water District 47
Construction File No. C-1031B

October 30, 2017

SUBJECT: Approval of Change Order No. 2

Dear Mr. Treacy,

Thank you for submitting the Change Order request for the Cured-In-Place Pipe (CIPP) liner pipe for the MacFarlane Dam rehabilitation project for our review and approval in accordance with Rule 9.1.8 of the State of Colorado's "Rules and Regulations for Dam Safety and Dam Construction".

This Change Order includes switching from an HDPE slipliner pipe to a CIPP based on the constriction found in the host pipe. The construction does not allow passage of the 20-in Outer Diameter HDPE liner proposed under approved Change Order No. 1. Based on our review of the Change Order as presented in your letter dated October 20, 2017, and your follow-up emails dated October 26 & 27, 2017, we find this change in the approved plans and specifications to be acceptable and approved as of the date of this letter.

Please properly inform the general contractor for this construction project of this change to the approved construction documents. As a result of this change, revisions to the approved plans, specifications, and design report should be made on the construction documents prior to submitting the "As-Constructed" documents to our office at the completion of the project.

If you have any questions concerning this matter, please do not hesitate to contact Jeremy Franz in our Denver Office at 303-866-3581 ext 8254 or Dana Miller in our Steamboat office at 970-879-0272 ext 6414.

Sincerely,

William T. McCormick III, P.E., P.G.
Chief, Colorado Dam Safety

ec: Erin Light, Division Engineer
Matt Blecha, WD 47 Water Commissioner
Dana Miller, Dam Safety Engineer
Jeremy Franz, Design Review Engineer
Stephen Jamieson, W.W. Wheeler & Assoc., Steve.Jamieson@wwwheeler.com
Lorri Harper, Project Manager for US Fish & Wildlife Service, lorri_harper@fws.gov
Brad Iarossi, US Fish & Wildlife Service, Brad_Iarossi@fws.gov
Blaine & Judy Evans, Evans Cattle Co., EvansCattleCo@gmail.com

APPENDIX E

ELECTRONIC CONSTRUCTION FILES
(Provided in a Separate DVD)

1. **Daily Reports**
2. **Weekly Progress Meeting Summaries**
3. **Construction Photos**
4. **Submittals**
5. **Inspection Videos**