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January 27, 2017

Jerred Hoffman, Superintendent
Fort Lyon Canal Company
750 Bent Avenue,
Las Animas, CO 81054

Subject: **Adobe Creek Dam Outlet Conduit and Seepage Evaluation,
Water Division 2, Water District 17, Dam ID 170101,
Wheeler Project No. 1830.04**

Dear Jerred,

This letter report summarizes our outlet conduit and seepage evaluations for Adobe Creek Dam. This report was prepared by W. W. Wheeler & Associates, Inc. (Wheeler) for the Fort Lyon Canal Company (FLCC). The subsurface investigations and seepage analyses were performed by Kumar and Associates, Inc. (Kumar) as a subconsultant to Wheeler. This report satisfies the reporting requirements of the Colorado Water Conservation Board (CWCB) Water Supply Reserve Account (WSRA) basin and statewide grant for the work (CWCB, 2016).

PROJECT BACKGROUND

Adobe Creek Dam is located in Bent County approximately 11 miles north of Las Animas, Colorado. The dam was originally constructed in 1904 by the FLCC as an off channel storage facility for Arkansas River water for agricultural use. In 1969, the dam was repaired and raised to provide further storage. It is classified as a high hazard, embankment dam with a height of about 32 feet and a crest length of 7,375 feet. The reservoir has a total storage capacity of nearly 77,400 acre-feet. During a March 2016 inspection by the Colorado State Engineer's Office (SEO), Division 2 Dam Safety Engineer (SEO,2016), uncontrolled seepage and the initial stages of a potential piping failure were observed in the downstream dam toe immediately left of the outlet works. Temporary repairs were made to the dam in March of 2016 with the goal of keeping the dam operational, without storage restrictions through the 2016 water year (Wheeler, 2016).

Recent review of the dam history by the SEO and Wheeler indicates a history of seepage issues at the dam when the reservoir is sustained at a high level. Since 2002, the reservoir has not stored water at near full levels for more than a year. With more water in the Arkansas River in 2015 and 2016, the reservoir has been filled at high levels for over a year and the previously documented seepage issues have resurfaced. It is apparent that uncontrolled seepage issues and have occurred at the dam for many years and will likely continue to be an issue in the future. The FLCC has made several temporary seepage repairs in 1984, 1996, 2008, and 2016, but these temporary drainage repairs are not considered to be effective nor consistent with modern dam safety practice. The Colorado Dam Safety Branch is also concerned about the condition of the 112-year-old, vitrified clay, outlet works conduits in the dam. The FLCC sealed more than 50 leaking joints in the conduits in 1984 and had to seal another 27 leaking joints in 2011. Sealing these joints are also considered temporary repairs.

In order to avoid future reservoir restrictions and maintain safe water storage in Adobe Creek Reservoir, the SEO strongly recommended that the FLCC undertake an outlet works rehabilitation project immediately (SEO, 2016). Wheeler was retained by the FLCC to perform the following evaluations as the initial stage of a dam rehabilitation project under the WSRA grant (CWCB, 2016):

1) Complete subsurface investigations in the dam including installation of additional piezometers;
2) Complete an outlet conduit inspection;
3) Perform dam seepage analyses;
4) Develop dam and outlet conduit rehabilitation or replacement alternatives;
5) Prepare cost opinions for the dam rehabilitation alternatives,
6) Preparation of a repair and rehabilitation feasibility assessment report.

GEOTECHNICAL SUMMARY

Wheeler contracted with Kumar to perform the subsurface investigations and seepage analysis. The results of Kumar's evaluations are provided in a separated report provided in Attachment A (Kumar, 2016). The key results of Kumar's evaluations are summarized below.

Subsurface Investigations

Kumar drilled six exploratory borings in the dam from November 14 to 16, 2016. Three borings were completed along the downstream edge of the dam crest and three were completed along the downstream toe of the dam embankment. All six boreholes were converted into piezometers. There were three functional piezometers located within or near the dam prior to this study. These piezometers are what remain of four piezometers installed, from six boreholes, in June 1984 (Kumar, 2016). The boring logs and piezometer data for the new holes were used to complement data from the existing piezometers and supplement past boring log data. With data from the new piezometers, three cross sections of the phreatic surface through the dam near the outlet works were developed.

The subsurface conditions observed from the new boring logs are consistent with the previous boring logs. In general, the dam is constructed of lean clay with sand that varies in depths from about 28 to 32 feet at the dam crest. A consistent 6.5-foot to 9.5-foot-thick, layer of medium dense to dense, well-graded sand with silt, generally underlies the lean clay in the foundation of the dam. The sand layer is underlain by a hard to very hard claystone bedrock that is generally located at a depth of about 45 feet below the dam crest. The existing outlet works conduit appears to have been founded on the claystone bedrock. The sand layer also appears to be in direct contact with the outlet works conduits.

Seepage Analysis

Preliminary two-dimensional seepage analyses were performed to evaluate existing seepage conditions through the dam embankment and foundation in the vicinity of the outlet works. Potential dam rehabilitation measures were also modeled to evaluate the effects on reduced seepage flow and exit gradients where uncontrolled seepage exits into the excavated outlet works channel downstream of the dam.

The clay embankment material, native clay foundation material, and claystone bedrock have relatively low hydraulic conductivities when compared to the alluvial sand, therefore the preliminary results of the model indicate that the sand layer controls seepage flow and gradients in the foundation of the dam. The modeled uncontrolled exit of seepage through the foundation sand layer is consistent with field observations of seepage flows exiting the side slopes of the outlet works channel.

The preliminary seepage analysis indicates that seepage exit gradients from the dam near the outlet works are higher than the SEO allowances, which could lead to a piping failure of the dam. Piping failure occurs when the internal or exit seepage gradients are sufficiently high enough that the velocities of the uncontrolled seepage cause movement or erosion of embankment material. This process can occur at the seepage exit on the dam's downstream face or internally along an outlet works conduit. The erosion can work backwards upstream through the dam creating a continually larger opening or "pipe" that can lead to failure of the dam. The uncontrolled seepage face observed in March of 2016 was an example of the early stages of the initiation of piping.

Kumar evaluated three alternatives for rehabilitation of the embankment to reduce the seepage gradients included a soil-bentonite wall, jet-grout columns and a chimney drain. The preliminary seepage analysis results suggest that the construction of a chimney drain system would provide the most effective seepage mitigation for the uncontrolled foundation seepage in the sand layer. The jet-grout columns were the least effective of the alternatives considered. Additional information on the subsurface investigations and preliminary seepage analyses is provided in Attachment A.

OUTLET INSPECTION & ANALYSIS SUMMARY

Outlet Inspection

An inspection of the interior of the four 36-inch-diameter, vitrified clay pipe (VCP) outlet works conduits, downstream of the control gates, was performed by Wheeler on November 9, 2016. This inspection was performed to assess the overall condition of the conduits and the condition of past repairs. In summary, the inspection provided visual confirmation that the conduits have exceeded their design life and are in poor condition. Significant horizontal and vertical displacement and deterioration of the pipe was observed. Significant longitudinal and circumferential cracks were observed throughout the conduits. Large gaps were also observed at pipe joints.

Previous repairs to mitigate leakage at cracks and pipe joints are no longer considered to be effective. Significant leakage was observed entering the conduits through joints and cracks, which could initiate piping in the dam foundation or embankment. Significant leakage of water at the control gates was also observed. In addition to the outlet conduit interior inspection, it was also observed that the concrete on the outlet works intake structure and the terminal structure had significant deterioration and are in need of repair. A summary of the internal inspection findings, including representative photos are provided in Attachment B.

Drawdown Capacity Analysis

Alternatives for design or rehabilitation of dam outlet works requires an evaluation of the hydraulic capacity of the conduits to make normal and emergency releases. The head, or height of water above the outlet works conduits, is dependent on reservoir storage level or stage. The rate that reservoir head drops during a release through the outlet works is dependent on the stage-storage relationship for the reservoir behind the dam and the size and corresponding capacity of the outlet conduits. The most recent topographic survey of the reservoir was performed by Nixon and Associates, Inc. in 2011 (Nixon, 2011). The survey provided an area-capacity curve used in the stage storage relationship calculations for drawdown capacity. The spillway crest is at Elevation 4126.9 feet, 32.3 feet above the outlet works intake at Elevation 4094.6 feet. The storage capacity of the reservoir at the spillway crest, or the normal high water level, is 77,339 acre-feet.

Existing Outlet Works Capacity

The existing outlet works consists of four conduits with approximately 200 feet of 36-inch-diameter VCP pipe. Wheeler performed hydraulic calculations to develop the outlet works rating curve for the existing outlet works conduits using Bernoulli’s equation applied between the reservoir surface and the downstream end of the outlet conduits. The combined drawdown capacity of the four existing outlet works conduits was calculated as 535 cubic feet per second (CFS) with the reservoir level at the spillway crest.

Liner Capacity

A common method to rehabilitate existing outlet conduits for dams is to slip-line a smaller liner pipe inside the existing conduit. This is commonly done with a high density polyethylene (HDPE) liner pipe. The smaller outlet works conduit lining will decrease the discharge capacity from that of the existing outlet works. The minimum observed inside diameter of the existing VCP conduit during the inspection was 33 inches. As discussed on the next page, a nominal outside diameter of 28 inches for the liner pipe was used for capacity calculations after allowing for annular grout space between the liner pipe and the VCP and factoring in loading calculations. The DR 11 HDPE liner pipe was assumed to have an approximate inside diameter of 22.8 inches, and the Manning's "n" value is estimated to be 0.009. Hydraulic calculations were performed to develop the outlet works rating curve for the lined outlet conduit using Bernoulli's equation. The resulting combined outlet works capacity of the four lined outlet conduits with a reservoir water surface at the spillway crest is approximately 213 CFS.

Reservoir Drawdown Capacity

Rule 5.9.6.2.1 of the State of Colorado Rules and Regulations for Dam Safety and Dam Construction (SEO, 2007) states: "The outlets for High Hazard dams shall be capable of releasing the top five feet of the reservoir capacity in five days." This rule is intended to provide adequate outlet works capacity to quickly lower the reservoir water surface during an emergency at the dam. This rule is required to be addressed by the SEO for new dam construction or outlet works replacement and repair work. Calculations were performed to determine that the maximum flow rate of 2,360 CFS is required to drawdown the reservoir five feet from the spillway crest in five days.

Using the Army Corps of Engineers HEC-1 computer program, the current outlet conduits were estimated to have the capability to drawdown the top five feet of the reservoir in 24 days. The capability of the lined outlets were estimated to have the capability to drawdown the reservoir five feet in 59 days. Neither the existing conduits nor the lined conduits have the capacity to meet the SEO reservoir drawdown rule.

CONCEPTUAL REHABILITATION ATERNATIVES

Wheeler developed conceptual level dam rehabilitation alternatives that address outlet works rehabilitation and seepage control in Adobe Creek Dam. Using the data gathered from the geotechnical investigations and analysis and the outlet inspection two outlet works rehabilitation and two dam seepage control concepts were developed. There was limited existing survey data in the area of the outlet works, so field observations and aerial photos were used in developing the design concepts.

Outlet Works Rehabilitation

The two options considered for rehabilitation of the outlet works were to line the existing conduits with a smaller diameter HDPE pipe or completely replace the existing conduits with new, larger concrete box culvert conduit.

Colorado Dam Safety Rule 5.9.6.2.3 states: "Outlet conduits for all dams, except for dams with un-gated outlets, shall have a guard gate installed at the upstream end of the conduit." The existing outlet does not have guard gates; therefore, both the liner and replacement options include the provision to construct a new concrete gate tower. FLCC could apply for a waiver for this rule, but it may be unlikely to achieve approval from the SEO. The necessity for access to the new structure at all reservoir water levels required additional fill and a short access bridge from the dam crest to the new gate tower in our conceptual design. The new gate tower conceptual design also includes a steel trash rack.

HDPE Outlet Liner

Our outlet conduit liner concept assumed that a 28-inch-diameter, DR 11 HDPE pipe would be used to line the existing outlet works conduits. The annular space between the new liner and the existing outlet conduit would be grouted. The conceptual design of the new outlet works gate tower for a liner includes eight new 36-inch-square sluice gates. Four of the gates would be guard gates mounted on the upstream wall of the new gate tower and four of the gates would be control gates mounted on the downstream wall of the structure. All gates were assumed to be provided with a mobile electric or hydraulic actuator. The existing control gate tower was assumed to be abandoned by backfilling with lean concrete and left in place. Refer to Figure 1 of Attachment C for plan and profile views of the conceptual design components for the HDPE liner outlet works rehabilitation alternative.

Complete Outlet Works Replacement

A 12-foot-wide by 10-foot-tall concrete box culvert was selected for the replacement outlet works conduit using the calculations performed in the capacity analysis. The conceptual design of the new outlet works gate tower for a replacement conduit includes eight new three-foot-wide by 10-foot-tall square sluice gates. Four of the gates would be guard gates mounted on the upstream wall of the new gate tower and four of the gates would be control gates mounted on the downstream wall of the structure. All gates were assumed to be provided with a mobile electric or hydraulic actuator. The existing control gate tower would be demolished as a part of the excavation in the dam for the outlet works conduit replacement. The replacement of the conduits necessitates demolition of the existing terminal structure and replacement with a new reinforced concrete terminal structure. Refer to Figure 2 of Attachment C for plan and profile views of the conceptual design components for the complete replacement outlet works rehabilitation alternative.

For either option it is recommended that work be performed to regrade and reinforce the outlet channel downstream of the terminal structure to prevent erosion at the dam toe during controlled water releases from the dam. Wheeler proposes to lay back the outlet channel side slopes to three horizontal to one vertical and to line the side slopes and channel bottom with soil cement for a distance of about 30 feet downstream of the outlet works terminal structure.

The increased discharge capacity resulting from the outlet works replacement conduit alternative is larger than the capacity of the Fort Lyon Canal downstream of the dam. As a result, the replacement alternative includes provisions for armoring about 1,000 feet of the canal dike crest and downstream slope with roller compacted concrete to act as an overflow spillway in the canal bank. This work would occur in the approximate location of the existing filled in spillway.

Temporary Reservoir Control

Temporary reservoir control during construction would be required with either outlet works rehabilitation concept to control inflows and provide temporary reservoir releases. Two concepts were considered: a large cofferdam built to the elevation of the dam crest, and a small cofferdam built to the elevation of the top of the sides of the approach channel. Both concepts would include temporary pumping facilities to provide limited bypass flows during construction. The large cofferdam would allow for reservoir storage levels up to the normal high water line during construction. The smaller cofferdam would allow storage up to about five feet below the top of the approach channel during construction. The cofferdams were assumed to be earthfill construction with a ten-foot-wide crest and three horizontal to one vertical side slopes. Refer to Figure 3 of Attachment C for plan and profile views of the conceptual design alternatives for temporary reservoir control.

Seepage Control Systems

Two of the three seepage control rehabilitation alternatives considered in the geotechnical report were incorporated into the conceptual design: a soil-bentonite cutoff wall and a chimney drain system. The jet-grout columns were not evaluated because this approach would be more expensive and less effective than the other alternatives.

Soil Bentonite Cutoff Wall

The soil bentonite cutoff wall concept is expected to significantly reduce the seepage through the embankment. The cutoff wall would extend through the entire sand layer into bedrock. The conceptual design for this seepage control mechanism includes a three foot wide by approximately 40 foot deep excavation of the embankment material from the crest with replacement by backfill of a soil-bentonite mixture. The cutoff wall is designed to extend along the crest approximately 400 feet in either direction from the outlet works. A shallow bury toe drain is also included in this design to replace the existing seepage drains and catch any seepage not blocked by the cutoff wall.

Chimney Drain

The chimney drain design concept would replace the existing toe drains with a two filter material collection system. The chimney drain design includes a fine sand filter material which extends vertically through most of the embankment toe down through the sand layer to bedrock, and a coarse drain gravel material that surrounds and collects flows from the filter into a drain pipe. The coarse drain gravel and the drain pipe would be located within the fine filter sand material just above bedrock. The chimney drain is designed to extend along the dam toe approximately 400 feet in either direction from the outlet works and is intended to collect and control seepage through the natural sand layer in the dam's foundation.

A shallow bury toe drain to collect seepage in the lower embankment sections located from 400 feet to the left and right of the outlet works to the dam abutments is also included as a part of both seepage control concepts. Past SEO inspection reports from the late 1990s, when the reservoir level was high for a long period, contain sketches of seepage observed at the dam toe for several hundred feet on either side of the outlet works conduits. Kumar observed an interface between native clay and embankment fill in the new boring logs. The interface may be the cause of seepage surfacing at the dam toe in these areas. A shallow bury toe drain would be designed to collect and control seepage in these areas when the reservoir is full for extended periods of time.

Refer to Figure 4 of Attachment C for plan and profile views of the conceptual design alternatives for seepage control rehabilitation alternatives.

ALTERNATIVES COMPARISON

Wheeler developed an itemized cost opinion for the conceptual dam rehabilitation and seepage control system alternatives designs. The cost opinions were generated utilizing the Wheeler database of similar dam construction bid items and the R.S. Means Heavy Civil Estimating Guide. The costs are considered Class 4 cost opinions under the Association for the Advancement of Cost Engineering (AACE) Accuracy Matrix (USSD, 2012). AACE Estimate Class 4 identifies projects as up to 15% of complete definition with an expected accuracy that could be vary the estimated costs by -30% or +50%.

The cost opinion for a large cofferdam and temporary bypass pumps and pumping for temporary reservoir control was estimated to be approximately $2,300,000, while the cost opinion for a small cofferdam and temporary bypass facilities was estimated to be $600,000. The cost for both included limited capacity pumping of water from the reservoir for a short period of time, which are well below the flow rate and volumes of normal reservoir releases. Wheeler considered the cost to construct the large cofferdam to be cost prohibitive for the FLCC. Therefore, a side-by-side cost comparison of the two outlet rehabilitations options using the small cofferdam temporary reservoir concept is provided in Table No. 1 below.

The chimney drain, with a cost opinion of $274,000, is included in both options below as it provides the better alternative for uncontrolled seepage mitigation and is also more cost effective than the soil-bentonite cutoff wall, with a cost opinion of $348,000.

Table No. 1: Rehabilitation Alternatives Cost Comparison

Outlet Works Conduit Lining		**Outlet Works Conduit Replacement**	
Small Cofferdam	$615,000	Small Cofferdam	$615,000
Line Outlet Works	$1,599,000	Replace Outlet Works	$3,448,000
Chimney Drain	$274,000	Chimney Drain	$274,000
Miscellaneous Work	$540,000	Miscellaneous Work	$540,000
Construction Subtotal	**$3,634,000**	**Construction Subtotal**	**$5,852,000**
Indirect Costs	$1,251,000	Indirect Costs	$1,972,000
Total Costs	**$4,885,000**	**Total Costs**	**$7,824,000**

The second row of the table, the rehabilitation method of the outlet works, is the key difference between the two alternatives. The total cost of the outlet lining alternative with seepage control, small cofferdam temporary reservoir control, miscellaneous work, and indirect costs is estimated to be about $4.9 million dollars. The total cost of the outlet replacement alternative with seepage control, small cofferdam temporary reservoir control, miscellaneous work, and indirect costs is estimated to be approximately $7.8 million dollars.

Miscellaneous work includes outlet channel reinforcement, which was recommended in the geotechnical report, as well as the inclusion of a shallow bury toe drain along a 6,300 foot length of the dam toe outside of the chimney drain. Along with other conceptual design components, the miscellaneous work will require further discussion with the FLCC and the Colorado Dam Safety Branch. There are some indirect costs associated with final design and construction that have been included in this cost opinion that may also vary with further refinement.

Refer to Attachment D for the detailed cost estimate for all of the components and the two primary alternatives considered.

REFERENCES

1. Colorado Office of the State Engineer (SEO, 2007) *Rules and Regulations for Dam Safety and Dam Construction*, January 1, 2007.
2. Colorado Office of the State Engineer (SEO, 2014) *Project Review Guide, June 27, 2014.*
3. Colorado Office of the State Engineer (SEO, 2016) *Engineer's Inspection Report for Adobe Creek Dam,* inspection date March 22, 2016.
4. Colorado Water Conservation Board (CWCB, 2016) *WSRA Grant for Evaluation of Seepage and Outlet Conduit Issues at Adobe Creek* Dam, 2016
5. Nixon and Associates, P.A. (Nixon, 2011) *Adobe Creek Reservoir Survey*, September 2005, Revised June 2011
6. Kumar & Associates, Inc. (Kumar, 2016) *Geotechnical Engineering Study, Adobe Creek Dam Seepage Evaluation*, December 21, 2016.
7. United States Society on Dams (USSD, 2012) *Guidelines for Construction Cost Estimating for Dam Engineers and Owners*, May 2012.
8. W.W. Wheeler & Associates, Inc. (Wheeler, 2016) *March 2016 Uncontrolled Seepage Repair*, April 7, 2016.

CONCLUSIONS AND RECOMMENDATIONS

Based upon the presented findings, Wheeler offers the following conclusions and recommendations:

1. The subsurface investigations and seepage analysis identified an alluvial sand layer near the foundation bedrock for the dam that is considered to be the controlling factor in the historic seepage issues near the outlet works at the toe of the dam. Preliminary analyses for existing seepage have calculated higher than acceptable exit gradients in this sand layer.

2. A chimney drain system was preliminarily identified as the best alternative considered, in terms of both effectiveness and cost, for rehabilitation of the seepage control at Adobe Creek Dam.

3. The outlet works conduit interior inspection identified significant deficiencies in the existing conduits that confirms the SEO opinion that the outlet works at Adobe Creek Dam has exceeded its design life and requires rehabilitation.

4. Two alternative concepts were considered for outlet works conduit rehabilitation: line the existing outlet works conduits with HDPE pipe, thereby reducing outlet works capacity; or replace the existing outlet works with a concrete box culvert designed to meet SEO capacity requirements.

5. Cost opinions were generated for both outlet works rehabilitation concept alternatives. Wheeler's opinion of total project costs for the outlet works lining and replacement alternatives was approximately $4.9 million and $7.8 million, respectively. These cost opinions were developed in 2016 and the costs will increase in future years.

Sincerely,

W. W. Wheeler & Associates, Inc.

Stephen L. Jamieson

Stephen L. Jamieson, P.E.
Principal

Trevor E. Mugele, P.E.
Project Engineer

Cc: Mark Perry, Dam Safety Engineer, Colorado Division of Water Resources, Division 2

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Attachment A

Geotechnical Investigations Report

Kumar & Associates, Inc.
Geotechnical and Materials Engineers
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GEOTECHNICAL ENGINEERING STUDY
ADOBE CREEK DAM SEEPAGE EVALUATION
NEAR LAS ANIMAS, COLORADO
WATER DIVISION 2, WATER DISTRICT 17
DAM ID 170101

Prepared By:

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ATTENTION: Mr. Steve Jamieson

Project No. 16-1-695

December 21, 2016

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PURPOSE AND SCOPE OF WORK

This report presents the results of a geotechnical engineering study performed to evaluate conditions contributing to uncontrolled seepage at the downstream toe of Adobe Creek Dam. The dam is for an off-channel water storage facility for the Fort Lyon Canal Company (FLCC) located about 11 miles north of Las Animas, Colorado. The work summarized in this report was performed under subcontract to W.W. Wheeler & Associates, Inc. (Wheeler) in accordance with the scope of services presented in our Proposal P-16-751 dated November 8, 2016.

PROJECT DESCRIPTION

Adobe Creek Dam is classified as a high-hazard homogenous earthen embankment dam with a dam height of 32 feet and a crest length of 7,375 feet. The dam was originally constructed in 1909, and raised in 1969. Toe drains were installed in the maximum section of the dam around the outlet works in 1984, 1996 and 2008. The locations of the toe drains are not well known. The reservoir that is impounded by the dam has remained low for several years but was filled and retained at a high level for the first time in many years in early 2016. During an inspection in March 2016, uncontrolled seepage was observed exiting the downstream toe of the dam immediately to the left of the outlet conduit terminal structure. Temporary repairs consisting of excavation of the uncontrolled seepage area and installation of a 6-inch diameter slotted Contech A-2000 pipe imbedded in ASTM C-33 fine aggregate to filter and control the uncontrolled seepage in that area (Wheeler, 2016).

Due to continuing concerns regarding seepage issues, Wheeler recommended that the FLCC perform subsurface investigations and preliminary seepage analyses to better assess seepage conditions through the dam, and to assess the feasibility of possible alternatives for mitigating uncontrolled seepage and potential internal erosion through the dam and foundation associated with seepage.

SUBSURFACE CONDITIONS

General: A subsurface exploration program consisting of 6 exploratory borings was performed from November 14 to 16, 2016. The locations of the exploratory borings are shown on Fig. 1. Three borings (KB-7, KB-9 and KB-12) were completed along the downstream edge of the dam crest and extended to depths ranging from 44.5 to 45 feet. Three borings (KB-8, KB-10 and KB-11) were completed along the downstream toe of the dam embankment and extended to depths ranging from 25 to 30 feet. The borings were made to supplement information on subsurface conditions presented by the logs of exploratory borings completed along the crest and downstream toe of the dam in 1984, presented in the report by Tipton and Kalmbach (1984). The logs of exploratory borings completed for our study are presented on Figs. 2 and 3, and a legend and notes are presented on Fig. 4. The logs of the 1984 exploratory borings are included in Appendix A.

Following exploration, the borings were completed as six permanent piezometers, P-7 to P-12, as shown on Fig. 1. Well completion logs for each piezometer are presented on Fig. 5. The piezometers will be used to supplement water level monitoring in existing piezometers P-2, P-3 and P-6 (which were completed as piezometers in Exploratory Borings 2, 3 and 6 by Tipton and Kalmbach). The locations of the pre-existing piezometers are also shown on Fig. 1.

<u>Subsurface Conditions</u>: Subsurface conditions encountered in dam crest Borings KB-7, KB-9 and KB-12 generally consisted of existing embankment fill composed of lean clay with sand that extended from the surface to depths ranging from about 15.5 to 24 feet. The existing fill was underlain by naturally deposited stiff to very stiff lean clay with sand and sandy lean clay extending to depths ranging from about 28.5 to 32 feet. The clay contained calcite crystals that appeared to increase in frequency with depth. The calcite was deposited in isolated near-vertical hairline fractures in the clay deposit and did not appear to be associated with continuous lateral calcite seams or layers.   Those deposits may have precipitated from the transient groundwater or clay soil over time to form the infilled material. The naturally deposited clay soil was in turn underlain by medium dense to dense, well graded sand with silt in Borings KB-9 and KB-12, and by clayey sand in Boring KB-7. The naturally deposited sand ranged from about 6.5 to 9.5 feet in thickness and extended to depths ranging from about 37 to 38.5 feet. The sand was underlain by hard to very hard claystone bedrock that extended to the explored depths of 44.5 to 45 feet.

Subsurface conditions encountered in toe Borings KB-8 and KB-11, located near the downstream toe of the dam within about 230 feet right and 180 feet left of the outlet conduit, generally consisted of naturally deposited soft to very stiff lean clay with sand and sandy lean clay similar to that described above for the crest borings. The clay extended to depths ranging from about 14 to 20 feet and was underlain by naturally deposited, medium dense to dense well graded sand with silt that ranged from about 5 to 6.5 feet in thickness, and to depths ranging from about 20.5 to 24 feet. The naturally deposited sand was underlain by hard to very hard claystone bedrock that extended to explored depths ranging from about 25 to 30 feet.

Boring KB-10 was located immediately to the left of the outlet conduit. Based on the elevation that bedrock was encountered in the borings compared to the approximate invert elevation of the outlet conduit, the conduit is founded on the claystone bedrock and is surrounded and overlain by embankment fill material. Subsurface conditions encountered in that boring generally consisted of existing embankment fill composed of clay materials similar to the crest borings. The clay fill was underlain by a layer of well graded sand with silt. The color of the aggregate was dark brown to black that was significantly different than the light gray-brown color of the naturally deposited sand encountered in other borings. Although the sand has a gradation similar to surrounding naturally deposited sands, we believe it is possibly drain aggregate based on the different color of that material. The apparent drain aggregate was underlain by hard to very hard claystone bedrock that extended to the explored depth of about 30 feet.

Groundwater was measured in completed Piezometers P-7 to P-12 at elevations ranging from 4097.4 to 4106.4 feet when measured two to four days after drilling and completion of the piezometers. Of note, the water levels measured in pre-existing crest Piezometers P-2 and P-5 (Elevations 4405.2 and 4405.4, respectively) are slightly more than 1 foot lower than the level measured in Piezometer P-11, located downstream of those piezometers. With the exception of Piezometer P-10, all piezometric levels are within the foundation soils, and may be influenced by other groundwater sources in addition to the reservoir, which was drawn down to several feet below the upstream dam embankment toe at the time of exploration.

Interpreted Geologic Profiles and Sections: Two geologic profiles along the dam crest and downstream toe of the dam, and three geologic sections through the outlet conduit and in the dam embankment to the left and right of the conduit, were prepared using the exploration information to help interpret subsurface conditions. The locations of interpreted geologic profiles and sections are shown on Fig. 1, and the profiles and sections are presented on Figs. 12 and 13.

Profile A on Fig. 12 shows interpreted geologic conditions along the dam crest and generally indicates an approximately 16-foot thick embankment section underlain by a relatively uniform thickness of naturally deposited clay that is in turn underlain by a continuous layer of alluvial sand that ranges from about 6.5 to 11 feet in thickness and appears to thicken and slope slightly down to the left (southeast). The high-permeability alluvial sand rests on the low-permeability claystone bedrock. In the area of the outlet conduit, we assume that foundation soils were excavated to found the outlet conduit on the claystone bedrock. Profile A shows approximately 36 feet of embankment fill above the conduit. We have assumed that the excavation to extend the embankment down to bedrock in the vicinity of the outlet conduit was sloped approximately 1H:1V as shown on Fig. 1.

Profile B on Fig. 12 shows interpreted geologic conditions along the downstream toe of the dam upstream of the outlet terminal structure. The profile generally indicates that the alluvial sand layer reduces in thickness in the downstream direction in comparison to the crest Profile A, and slopes slightly down to the left similar to that shown by Profile A. The existence of apparent drain aggregate material to the left of the outlet conduit is also shown on Profile B, based on the material encountered in Boring KB-10. The drain material is similar in gradation in comparison to the natural alluvial sand, and is therefore anticipated to have a hydraulic conductivity that is generally similar but less anisotropic compared to the alluvial sands.

Interpreted geologic conditions in Sections C, D and E, located to the left, through and to the right of the outlet conduit, respectively, are presented on Fig. 13. We have assumed that up to about 6 feet of reservoir sediment has been deposited against the upstream slope of the dam, as shown on Sections C and E; however, this has not been substantiated by field exploration. Although the alluvial sand varies in thickness to the left and right of the outlet conduit, it appears to be of generally uniform thickness in the vicinity of the outlet conduit, as shown by Section D. Outside the downstream channel, the relatively permeable alluvial sand is overlain by relatively low-permeability, stiff to very stiff clay as shown by Sections C and E. The alluvial sand appears to daylight into the excavated channel downstream of the outlet terminal structure.

PRELIMINARY SEEPAGE EVALUATION

General: Preliminary seepage analyses were performed to evaluate existing seepage conditions through the embankment dam and foundation in the vicinity of the outlet works, and possible rehabilitation measures to reduce seepage and exit gradients where uncontrolled seepage exits into the excavated downstream channel downstream of the dam. The analyses were performed using the two-dimensional finite element analysis program SEEPW (Geo-Slope International, 2004).

The location of the seepage analysis section used in the analysis is shown on Fig. 1, and the modeled section is presented on Fig. 14. We assumed that the critical seepage condition occurs when the reservoir is at the normal high water level Elevation 4126.9 feet and the outlet conduit is closed or allowing only a small release of water into the downstream channel, corresponding to a downstream tailwater at Elevation 4097 feet. The section shows a seepage path along the left side of the outlet conduit, but we would expect seepage flows to primarily occur through the alluvial sand to the left and right of the outlet conduit. Seepage flowing around the left and right wing walls would encounter the alluvial sand layer bank slopes, and predominantly flow through the alluvial sand, and to a significantly lesser extent through the clayey embankment, clay soil and claystone bedrock, until exiting at the left and right side of the end walls for the outlet terminal structure.

The hydraulic conductivity values were developed considering a range of possible conductivities based on: published ranges of horizontal and vertical hydraulic conductivity for natural soils and compacted embankment fills developed by the U.S. Bureau of Reclamation (USBR, Standard No. 13, Chapter 8, 1987); calculated hydraulic conductivity using empirical methods, and our experience with similar materials. The values for the saturated water content and the residual water content were based on the sample ranges presented on Fig. 4-3 in Seepage Modeling with Seep/W (Geostudio, 2015) and other published correlations between material type and water content.

The Hazen Formula was one empirical method used to estimate the range of hydraulic conductivities for the alluvial sand. The Hazen Formula ($k=C*D_{10}{}^{\wedge 2}$) uses the D_{10} (mm) grain size multiplied by a coefficient “C” (assumed to be 1) to calculate a hydraulic conductivity and is intended for use with uniformly graded clean sands. Based on those analyses, we calculated hydraulic conductivity values ranging from about 400 ft/yr to 90,000 ft/yr. Vertical hydraulic conductivity and horizontal hydraulic conductivity of 1,000 ft/yr and 100,000 ft/yr, respectively, were used in the analyses.

Three seepage mitigation alternatives were developed based on discussion with Wheeler. These concepts were intended to mitigate uncontrolled seepage and reduce exit gradients of seepage exiting at the downstream end of the dam, particularly where seepage exits into the channel downstream of the dam. The sections are shown on Fig. 15 and include:

- Construction of a 3-foot-wide soil-bentonite seepage cutoff wall along the crest of the dam that extends through the embankment and foundation soils and is keyed 3 feet into the claystone bedrock. A hydraulic conductivity of 0.1 ft/yr (1.0 x 10 $^{-7}$ cm/sec) was used for the soil-bentonite grout.

- Construction of overlapping 5-foot-diameter jet grout columns in the alluvial sand layer. A hydraulic conductivity of 1 ft/yr (1.0 x 10^{-6} cm/sec) was used for columns of 5-foot diameter jet-grouted alluvial sand, which would overlap each other by about 6 inches to 1 foot to form a continuous barrier in the alluvial sand layer.

- Construction of a chimney drain at the downstream toe of the embankment. Based on discussion with Wheeler about outlet works rehabilitation concepts, we assumed that the outlet conduit and terminal structure would be extended farther downstream to prevent excavation for the toe drain from intersecting the downstream slope of the embankment dam above about Elevation 4119 feet, as shown on the section on Fig. 15. Hydraulic conductivity values for the toe drain filter sand were based on the Hazen formula and assuming the material is composed of ASTM C33 fine aggregate, and our experience with similar filter material on other projects.

The hydraulic conductivity values used in the seepage analyses are presented below and are also presented on Figs. 14 and 15.

MATERIAL	Ksat (ft/yr)	Kh (ft/yr)	Kv/kh	Kv (ft/yr)	Saturated Water Content	Residual Water Content
Shale Claystone	10	10	0.1	1	0.3	0.1
Alluvial Sand	100,000	100,000	0.1	1,000	0.35	0.04
Clay Soil	100	100	0.1	10	0.5	0.15
Existing Embankment Fill	50	50	0.2	10	0.5	0.15
New Embankment Fill	50	50	0.2	10	0.5	0.15
Filter Sand	200,000	200,000	0.5	100,000	0.35	0.02
Soil-Bentonite Wall	0.1	0.1	1	0.1	0.5	0.15
Jet-Grout Column	1.0	1.0	1	1.0	0.1	0.02

Due to the limited scope and budget of this preliminary evaluation, field and laboratory permeability tests were not performed to better evaluate hydraulic conductivities for the above materials. It was also not possible to calibrate the seepage analysis section using changes in the new piezometers with changes in reservoir level over time. In addition, the locations and condition of the existing downstream toe drains, which would influence the calibration model, are not known. The seepage analyses results presented below should be considered preliminary for those reasons. If seepage rehabilitation measures are further developed for final design, we recommend that supplemental exploration and testing be performed. We also recommend that calibration seepage analyses be performed once adequate monitoring information has been obtained on stabilized piezometric readings from the recently installed piezometers when the reservoir is at or near the normal high water level.

<u>Seepage Analyses of Existing Condition</u>: Using the hydraulic conductivity values presented above, seepage analyses were performed to evaluate seepage flows and the phreatic surface through the existing dam at the normal high water level (NHWL), Elevation 4126.9 feet. The analysis results for that condition are presented on Fig. 14. For the existing dam condition, a calculated seepage rate obtained from SEEP/W for seepage through the vertical face representing the terminal outlet structure was calculated to be about 0.8 gpm per foot width of the model (gpm/ft). We understand that a flow of approximately 50 gpm to 70 gpm was estimated to be exiting the left toe drain outfalls during the March 2016 inspection. We anticipate that the flows are being intercepted by the toe drains to some extent, but it is difficult to assess the reasonableness of the calculated flow per foot with the concentrated flow

observed exiting through and around the toe drains because the location, length and condition of the toe drains is not well known.

Internal seepage gradients approaching about 0.12 were calculated for seepage flows occurring through the existing embankment and natural foundation soils. The gradient flows are relatively low, reducing the potential for internal erosion between embankment and foundation soils that may not be filter-compatible. A maximum horizontal exit gradient at the vertical face was calculated to be about 0.55 and a maximum exit gradient downstream of the toe of embankment slope was calculated to be about 0.31. A critical horizontal gradient of 1.1 was calculated for flows exiting the alluvial sand layer, which was based on U.S. Bureau of Reclamation and ASDSO procedures (USBR, 2013; ASDSO, 2005) and assumed that the face of the alluvial sand at the exit slope was inclined 1.5H:1V, and an internal friction angle of 34 degrees for the alluvial sand material. The calculation is presented in Appendix B. A critical vertical gradient of 1.0 was also considered, and factors of safety for exceeding those critical gradients were calculated by dividing the above maximum exit gradients by their corresponding critical exit gradient. A factor of safety of 1.1 was estimated for the maximum horizontal exit gradient, and 3.2 for the maximum vertical exit gradient. A minimum factor of safety of at least 5.0 is typically required for exit gradients for new dam construction.

Seepage Analyses of Rehabilitation Alternatives: The results of seepage analyses performed to evaluate the three rehabilitation alternatives described above are presented on Fig. 15. A summary of calculated seepage flows, internal gradients, maximum horizontal and vertical exit gradients and factors of safety for the three alternatives are summarized below. Values for the existing condition are also presented in the table for comparison purposes.

Dam Condition	Exit Seepage Flow (gpm/ft)	Maximum Internal Seepage Gradient	Maximum Horizontal Exit Gradient at Vertical Face	Horizontal Exit Gradient Factor of Safety	Maximum Vertical Exit Gradient Downstream of Toe of Embankment	Vertical Exit Gradient Factor of Safety
Existing Dam	0.8	0.14	0.24	1.1	0.31	3.2
Soil-Bentonite Wall	0.001	5.0	0.04	12.5	0.21	4.8
Jet-GroutColumns	0.026	3.0	0.10	3.6	0.22	4.5
Chimney Drain	0.88	0.33*	0.05	4.9	0.21	4.8

*Internal Seepage Gradient at transition from Alluvial Sand to Filter Sand.

GEOTECHNICAL CONSIDERATIONS

The preliminary seepage analysis results suggest that construction of a chimney drain system along the downstream toe of the maximum dam section on both sides of the outlet conduit would provide the most effective seepage mitigation for the uncontrolled foundation seepage in the sand layer.

It is important to note that the preliminary analyses are based on two-dimensional seepage analyses and do not account for end effects. For both the soil-bentonite cutoff wall and jet-grouted column barrier, seepage will flow around the left and right ends of the barrier and eventually exit the alluvium into the downstream channel. The amount of flow will depend in part on the length of the wall. Given the high hydraulic conductivity of the alluvial sand, a barrier extending several hundred feet to the left and right side of the outlet conduit would likely be required, which may be cost prohibitive. Disadvantages of the above two seepage cutoff alternatives include providing a seepage tight connection around the outlet conduit, and disposal of bentonite-mixed or grout-mixed spoils.

A downstream chimney drain system is anticipated to be most effective method for controlling exit gradients. It could also be incorporated into the design of a filter diaphragm constructed around the outlet conduit using similar filter sand materials, and used to mitigate the potential for internal erosion along the conduit.

Armoring of the downstream channel slopes downstream of the outlet works terminal structure could also be used to mitigate erosion on the slope face caused by high exit gradients in the alluvial sands that daylight above the claystone bedrock in the channel.

LIMITATIONS

This study has been conducted in accordance with generally accepted geotechnical engineering practices in this area for exclusive use by the client for design purposes. The conclusions, preliminary analyses and considerations submitted in this report are based upon the data obtained from the exploratory borings at the locations indicated on Fig. 1, and the intent of providing a preliminary assessment of seepage conditions and possible seepage rehabilitation measures. This report may not reflect subsurface variations that occur between the exploratory borings, and the nature and extent of variations across the site may not become evident until site grading and excavations for selected rehabilitation measures are performed. Kumar & Associates, Inc. is not responsible for liability associated with interpretation of subsurface data by others.

GJM/CAJ/jw
Rev: AFC
cc: Book, file

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2. Geo-Slope International (Geo-Slope, 2012), *SEEP/W Software*, 2012.
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5. Tipton and Kalmbach (1984), “Adobe Creek Dam, Replacement of Toe Drain”, As-Built Drawing, DWR Construction Drawing C-1270A, October.
6. U.S. Army Corps of Engineers (1986), *Seepage Analysis and Control for Dam*s, EM 1110-2-1901, September 30.
7. U.S. Bureau of Reclamation (2005), “Best Practice in Dam and Levee Safety Risk Analyses”, Publication No. I-0-20150612, December.
8. U.S. Bureau of Reclamation (1987) *Seepage Analysis and Control*, Design Standards Embankment Dams No. 13, Chapter 8, March 20.
9. W.W. Wheeler & Associates, Inc. (2016), “Adobe Creek Dam March 2016 Uncontrolled Seepage Repair”, April 7, 2016.

LEGEND:

● LOCATION OF EXPLORATORY BORING AND PIEZOMETER COMPLETED BY KUMAR & ASSOCIATES FOR THIS STUDY.

⊙ LOCATION OF BORINGS AND PIEZOMETER COMPLETED BY TIPTON AND KALMBACH, INC IN 1984.

NOTES:

1. PREVIOUSLY INSTALLED PIEZOMETER P-4 WAS LOST DURING TOE DRAIN WORK IN 1984.
2. BORING B-1 AND B-3 WERE BACKFILLED AND NOT COMPLETED AS PIEZOMETER.

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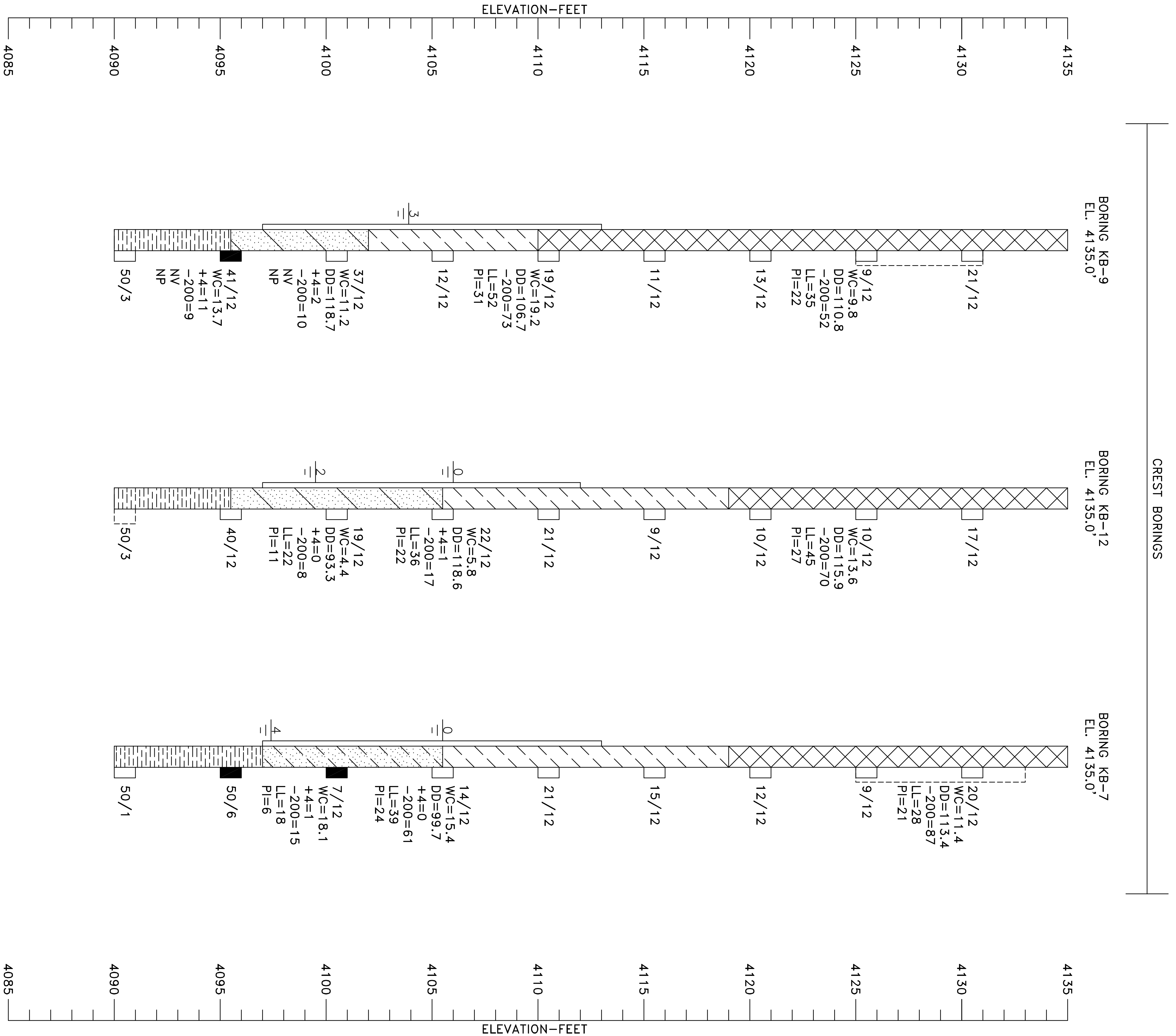
16-1-695 | Kumar & Associates | ADOBE CREEK DAM | LOCATION OF EXPLORATORY BORINGS | Fig. 1



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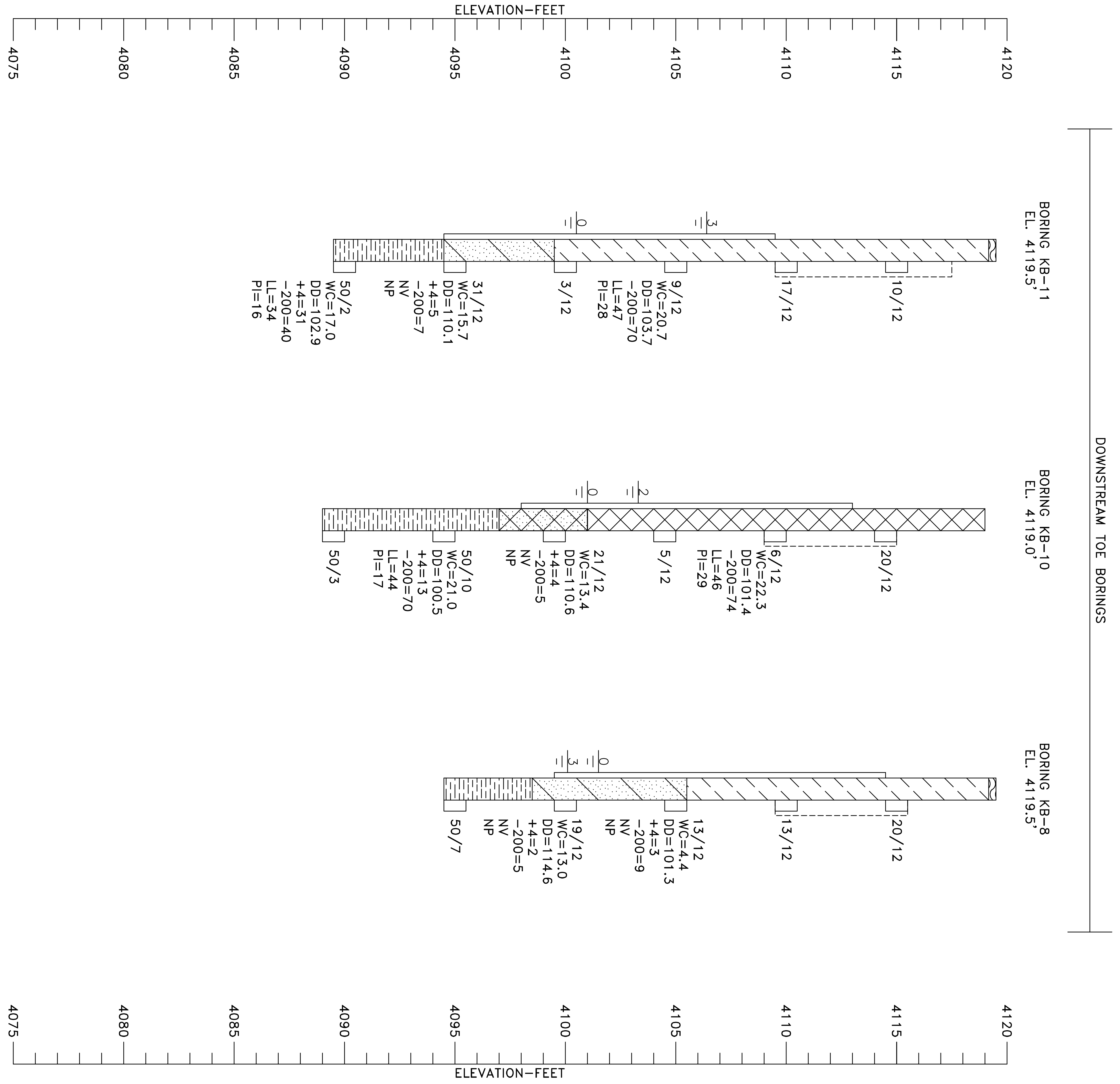
16-1-695	Kumar & Associates	ADOBE CREEK DAM	LOGS OF EXPLORATORY BORINGS	Fig. 2



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16–1–695	Kumar & Associates	ADOBE CREEK DAM	LOGS OF EXPLORATORY BORINGS	Fig. 3

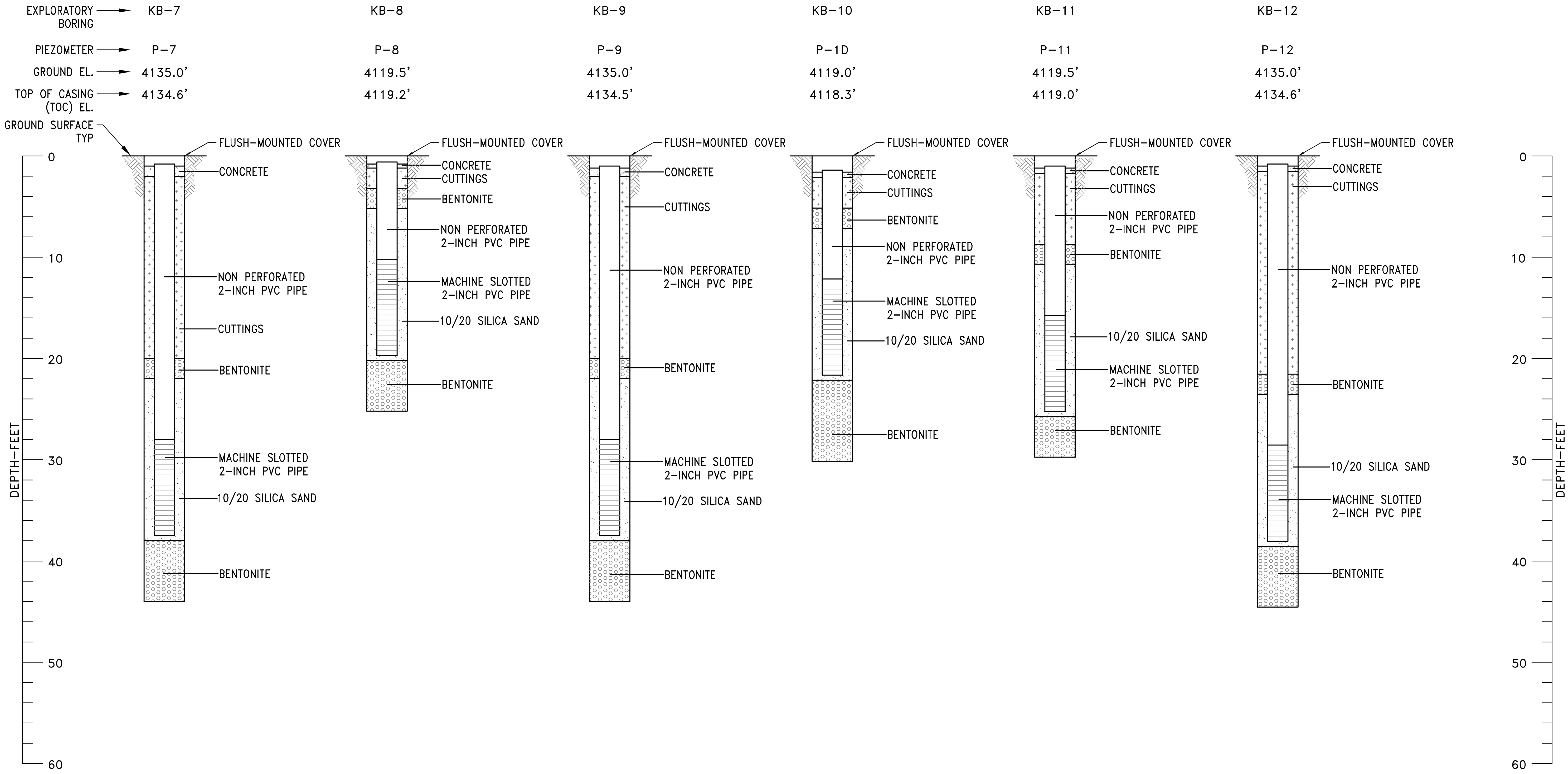
LEGEND

≋	TOPSOIL, CLAYEY SAND AND SANDY CLAY WITH ORGANICS.
☒	FILL: LEAN CLAY WITH SAND (CL), LEAN CLAY (CL) AND SANDY LEAN CLAY (CL), SILTY SAND POCKETS, INCREASING CALCITE DEPOSITS WITH DEPTH, LIGHT TO DARK BROWN, MOIST.
☒	FILL: WELL GRADED SAND WITH SILT (SW-SM) (APPARENT DRAIN MATERIAL) DARK BROWN TO BLACK, MEDIUM TO COARSE SAND (ENCOUNTERED ONLY IN BORING KB-10).
▨	LEAN CLAY WITH SAND (CL) AND SANDY LEAN CLAY (CL), SOFT TO VERY STIFF, BROWN, DARK BROWN AND BLACK, THINLY INTERBEDDED WITH FINE SAND, MOIST TO WET, INCREASING CALCITE DEPOSITS WITH DEPTH.
▨	CLAY SAND (SC) AND CLAYEY SAND WITH GRAVEL (SC), LOOSE TO MEDIUM DENSE, MOIST TO WET, BROWN.
▨	WELL GRADED SAND WITH SILT (SW-SM), MEDIUM DENSE TO DENSE, MOIST TO WET, LIGHT GRAY-BROWN.
▤	CLAYSTONE BEDROCK, WITH CLAYEY SANDSTONE INTERBEDS, HARD TO VERY HARD, DARK GRAY TO BLACK, DRY TO MOIST.
□	DRIVE SAMPLE, 2-INCH I.D. CALIFORNIA LINER SAMPLE.
■	DRIVE SAMPLE, 1 3/8-INCH I.D. SPLIT SPOON STANDARD PENETRATION TEST.
⬚	DISTURBED BULK SAMPLE.
21/12	DRIVE SAMPLE BLOW COUNT. INDICATES THAT 21 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE THE SAMPLER 12 INCHES.
4	DEPTH TO WATER LEVEL ENCOUNTERED, AND THE NUMBER OF DAYS AFTER DRILLING THAT MEASUREMENT WAS MADE.
▯	INDICATES PERFORATED PVC PIPE INSTALLED IN BORING TO DEPTH SHOWN.

NOTES

1. THE EXPLORATORY BORINGS WERE DRILLED ON NOVEMBER 14 TO 16, 2016 WITH A 7-INCH DIAMETER CONTINUOUS FLIGHT HOLLOW STEM POWER AUGER.
2. THE LOCATIONS OF THE EXPLORATORY BORINGS WERE STAKED IN THE FIELD BY THE CLIENT PRIOR TO EXPLORATION.
3. THE ELEVATIONS OF THE EXPLORATORY BORINGS WERE MEASURED BY KUMAR & ASSOCIATES AND THE CLIENT USING AN INSTRUMENT LEVEL.
4. THE EXPLORATORY BORING LOCATIONS AND ELEVATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
5. THE LINES BETWEEN MATERIALS SHOWN ON THE EXPLORATORY BORING LOGS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES AND THE TRANSITIONS MAY BE GRADUAL.
6. GROUNDWATER LEVELS SHOWN ON THE LOGS WERE MEASURED AT THE TIME AND UNDER CONDITIONS INDICATED. FLUCTUATIONS IN THE WATER LEVEL MAY OCCUR WITH TIME.
7. 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);
    NV = NO LIQUID LIMIT VALUE (ASTM D 4318);
    NP = NON-PLASTIC (ASTM D 4318).

16-1-695	Kumar & Associates	ADOBE CREEK DAM	LEGEND AND NOTES	Fig. 4



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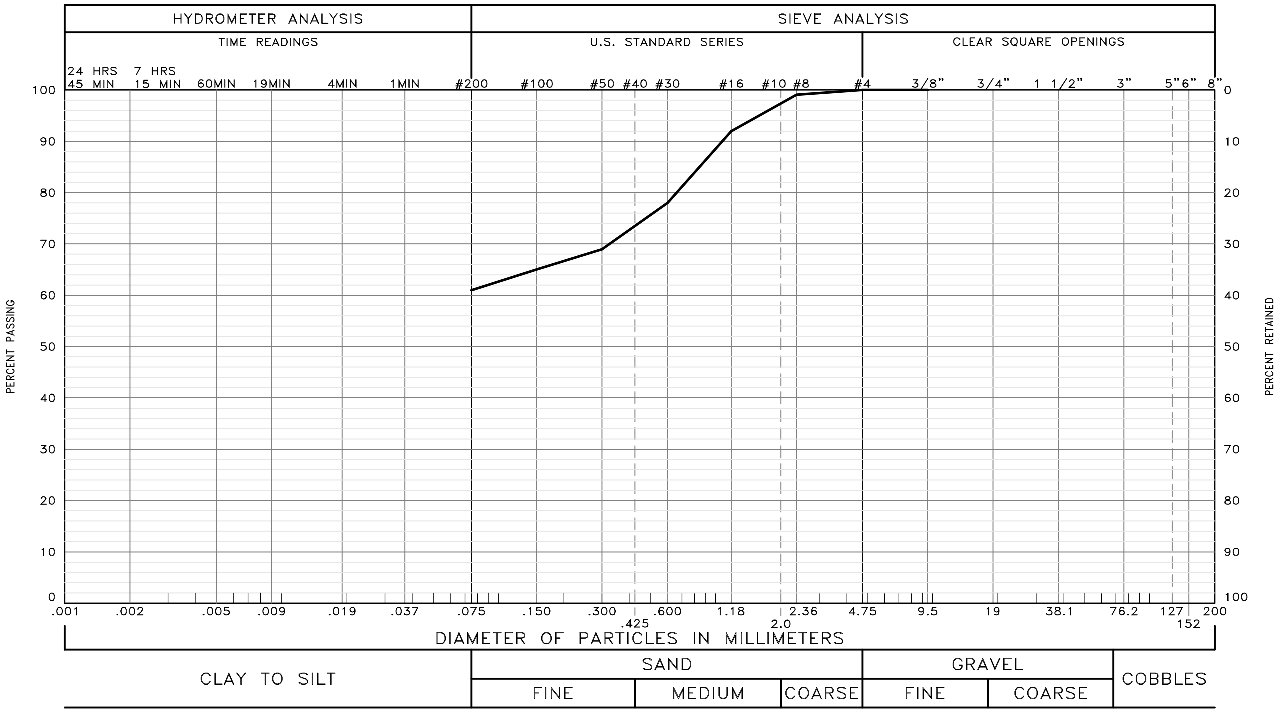
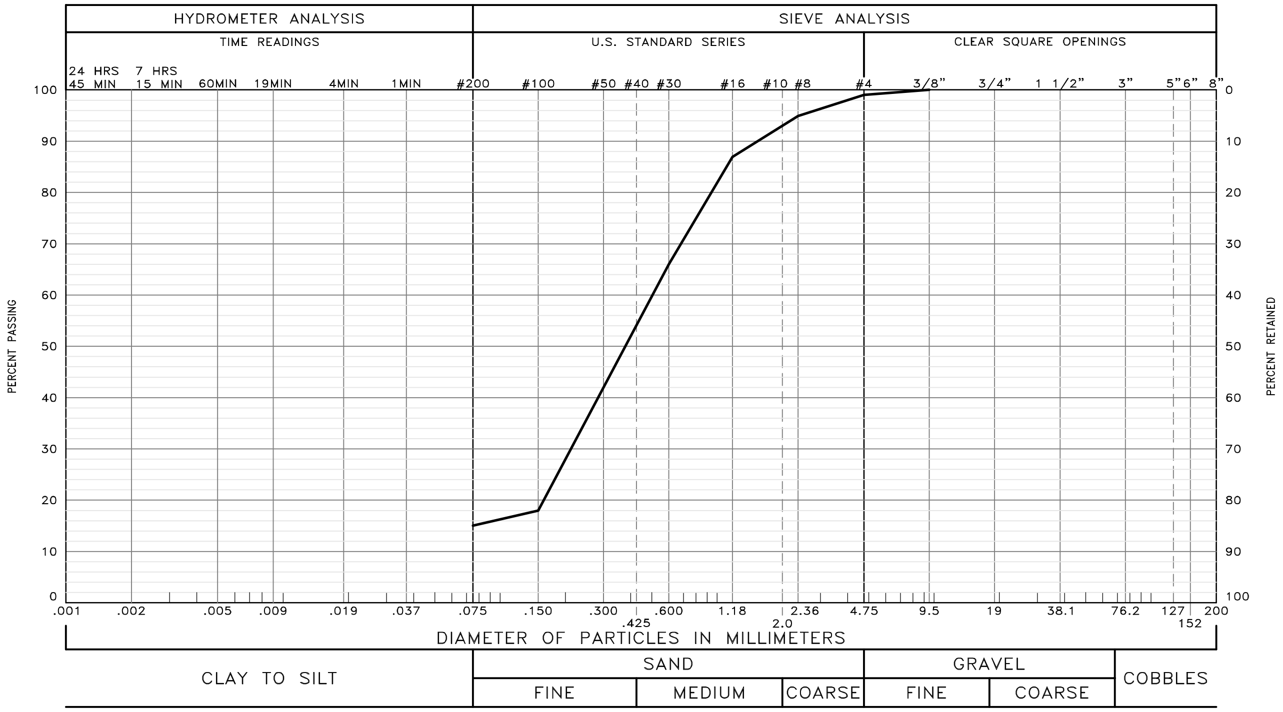
16-1-695	Kumar & Associates	ADOBE CREEK DAM	PIEZOMETER WELL COMPLETION LOGS	Fig. 5



GRAVEL **0** %   SAND **39** %   SILT AND CLAY **61** %

LIQUID LIMIT **39**   PLASTICITY INDEX **24**

SAMPLE OF: **Sandy Lean Clay**   FROM: **Boring KB-7 @ 29'**

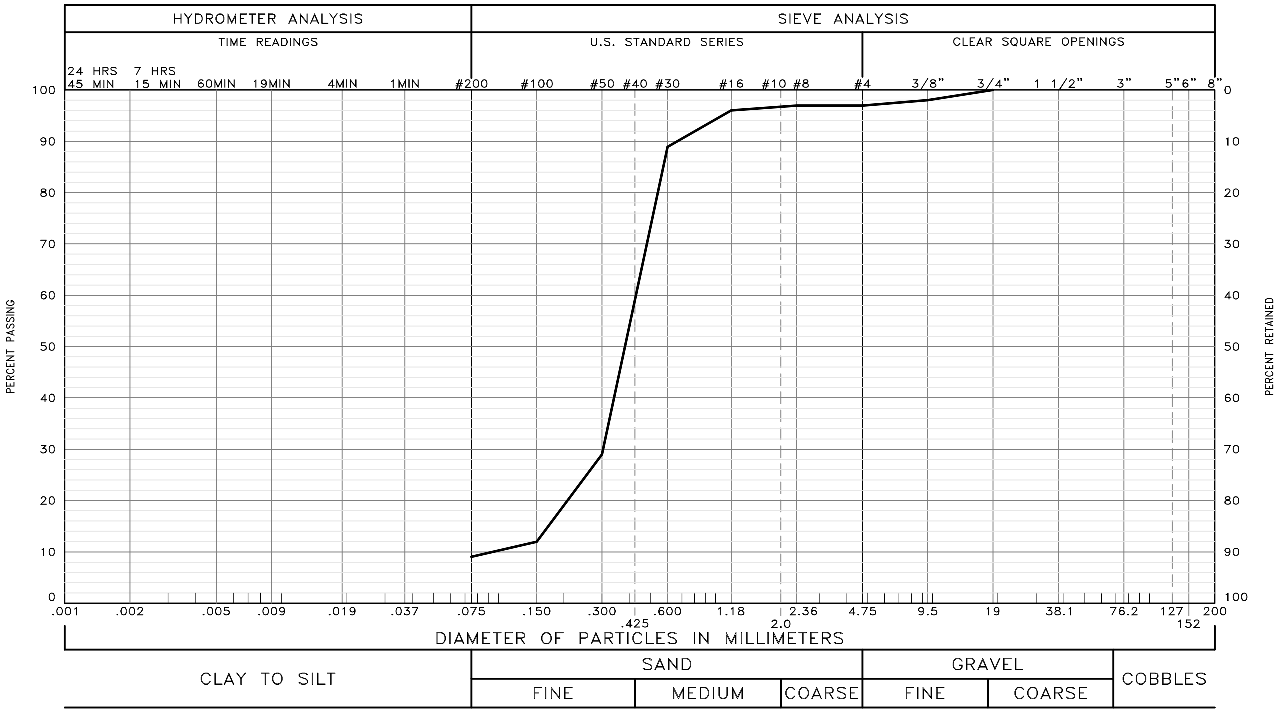


GRAVEL **1** %   SAND **84** %   SILT AND CLAY **15** %

LIQUID LIMIT **18**   PLASTICITY INDEX **6**

SAMPLE OF: **Silty to Clayey Sand**   FROM: **Boring KB-7 @ 34'**

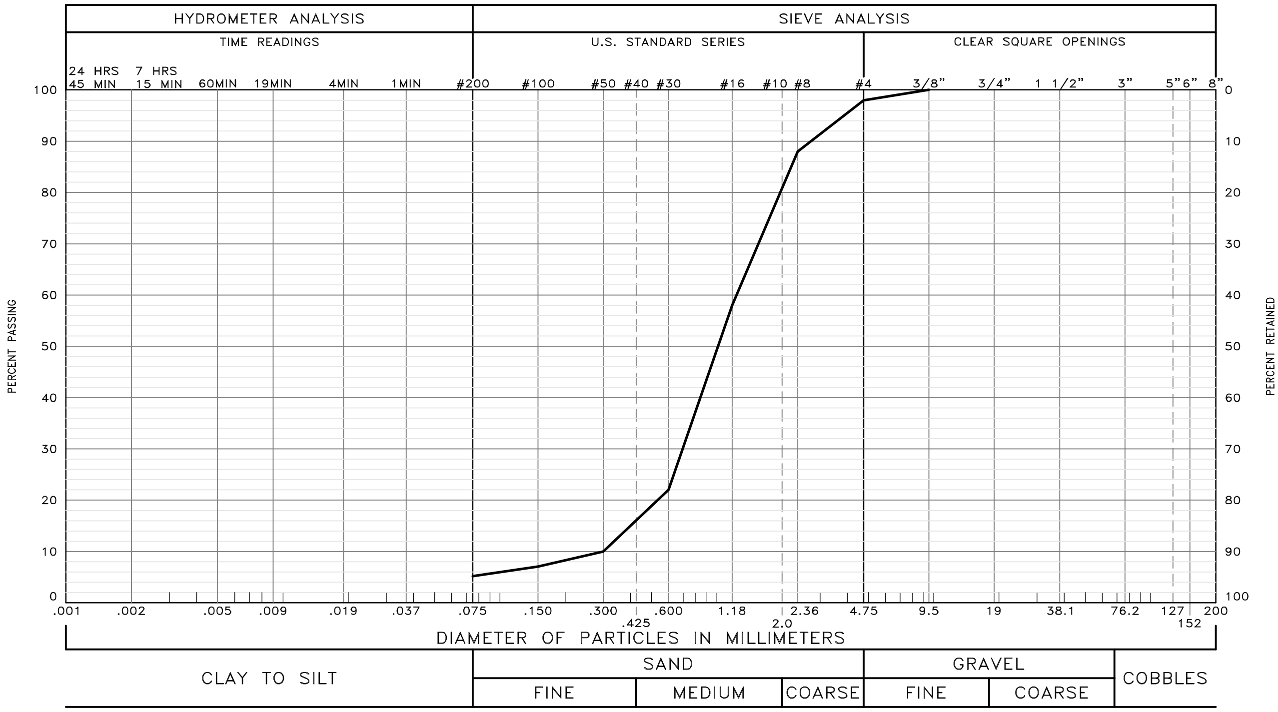
16-1-695	Kumar & Associates	GRADATION TEST RESULTS	Fig. 6



GRAVEL **3** %　　SAND **88** %　　SILT AND CLAY **9** %

LIQUID LIMIT **NV**　　PLASTICITY INDEX **NP**

SAMPLE OF: **Well Graded Sand with Silt**　　FROM: **Boring KB-8 @ 14'**



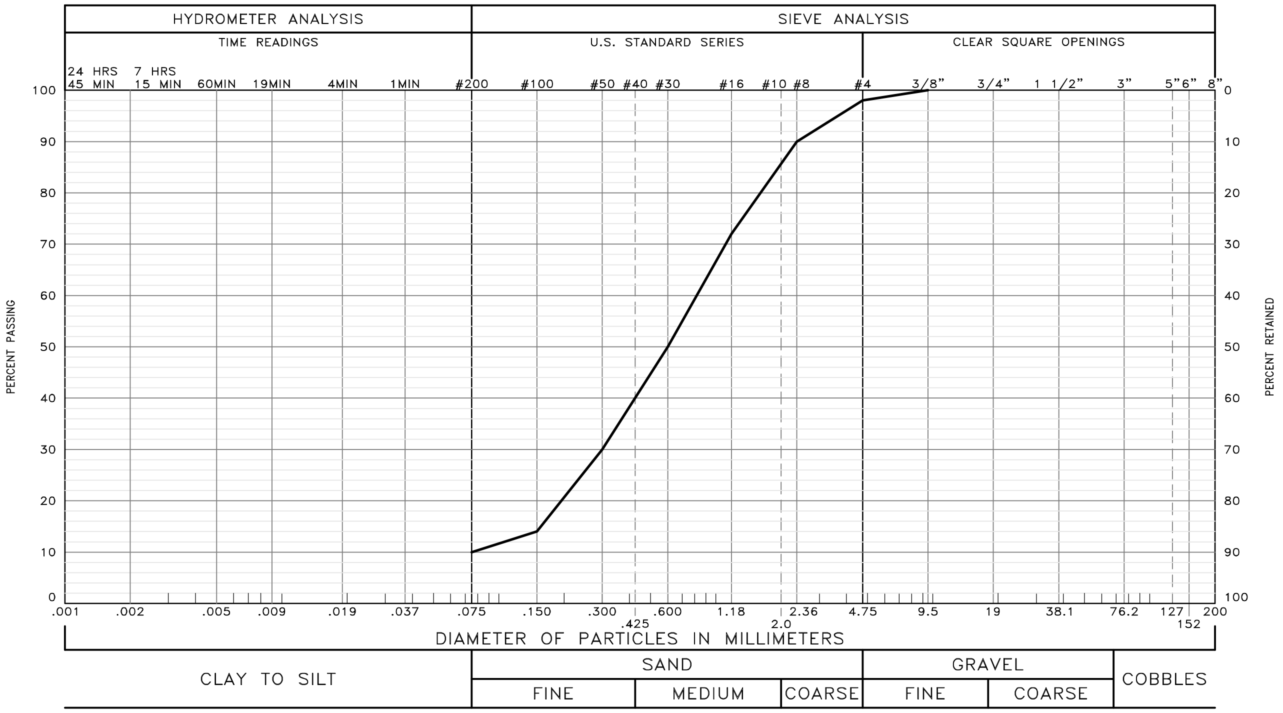
GRAVEL **2** %　　SAND **93** %　　SILT AND CLAY **5** %

LIQUID LIMIT **NV**　　PLASTICITY INDEX **NP**

SAMPLE OF: **Well Graded Sand with Silt**　　FROM: **Boring KB-8 @ 19'**

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 & Associates, Inc. Sieve analysis testing is performed in accordance with ASTM D422, ASTM C136 and/or ASTM D1140.

16-1-695	Kumar & Associates	GRADATION TEST RESULTS	Fig. 7



GRAVEL **2** % SAND **88** % SILT AND CLAY **10** %

LIQUID LIMIT **NV** PLASTICITY INDEX **NP**

SAMPLE OF: **Well Graded Sand with Silt** FROM: **Boring KB-9 @ 34'**

GRAVEL **11** % SAND **80** % SILT AND CLAY **9** %

LIQUID LIMIT **NV** PLASTICITY INDEX **NP**

SAMPLE OF: **Well Graded Sand with Silt** FROM: **Boring KB-9 @ 39'**

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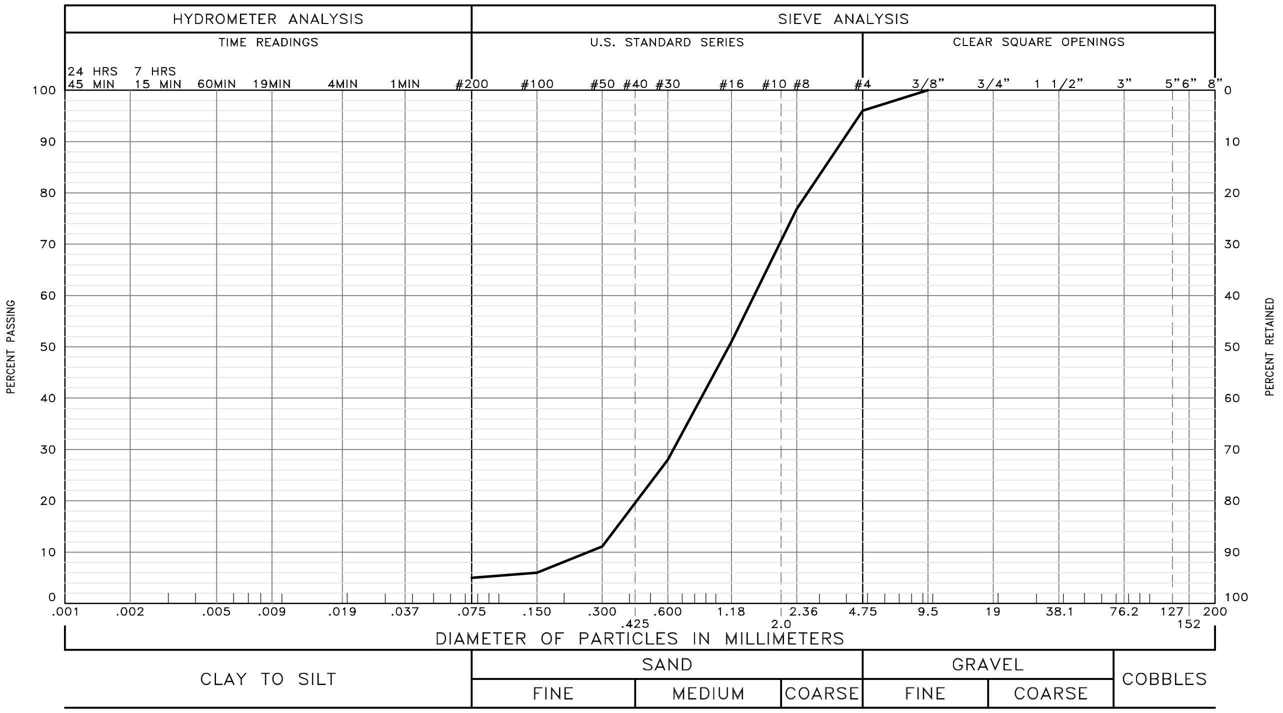
16-1-695	Kumar & Associates	GRADATION TEST RESULTS	Fig. 8



GRAVEL **4** % SAND **91** % SILT AND CLAY **5** %

LIQUID LIMIT **NV** PLASTICITY INDEX **NP**

SAMPLE OF: **Fill: Well Graded Sand with Silt** FROM: **Boring KB-10 @ 19'**

GRAVEL **5** % SAND **88** % SILT AND CLAY **7** %

LIQUID LIMIT **NV** PLASTICITY INDEX **NP**

SAMPLE OF: **Well Graded Sand with Silt** FROM: **Boring KB-11 @ 24'**

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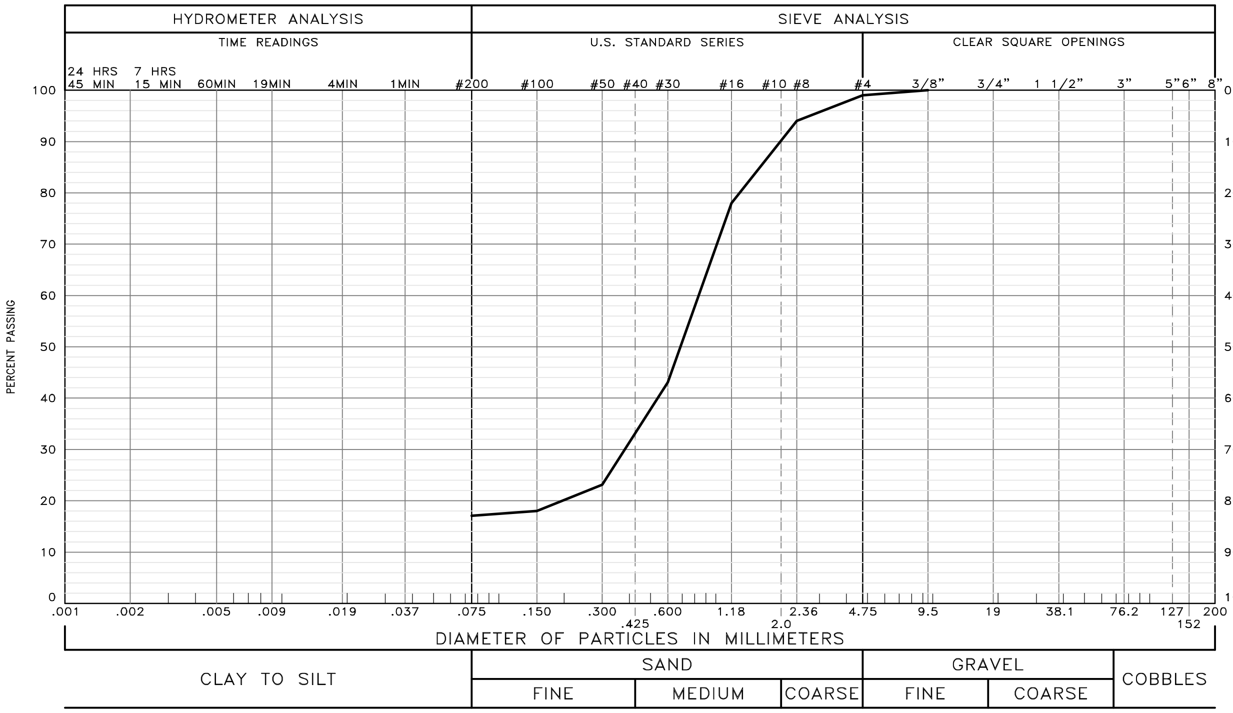
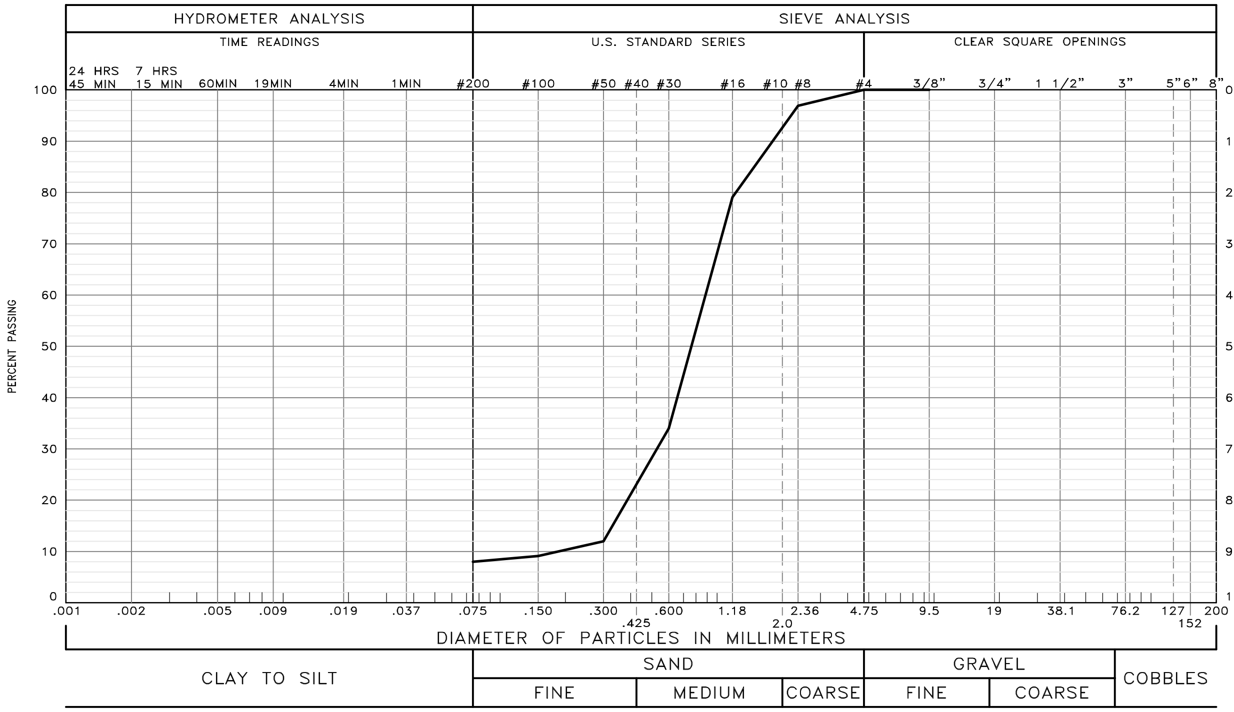
16-1-695	Kumar & Associates	GRADATION TEST RESULTS	Fig. 9



GRAVEL 1 % SAND 82 % SILT AND CLAY 17 %

LIQUID LIMIT 36 PLASTICITY INDEX 22

SAMPLE OF: **Clayey Sand** FROM: **Boring KB-12 @ 29'**



GRAVEL 0 % SAND 92 % SILT AND CLAY 8 %

LIQUID LIMIT 22 PLASTICITY INDEX 11

SAMPLE OF: **Well Graded Sand with Clay** FROM: **Boring KB-12 @ 34'**

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 & Associates, Inc. Sieve analysis testing is performed in accordance with ASTM D422, ASTM C136 and/or ASTM D1140.

16-1-695	Kumar & Associates	GRADATION TEST RESULTS	Fig. 10

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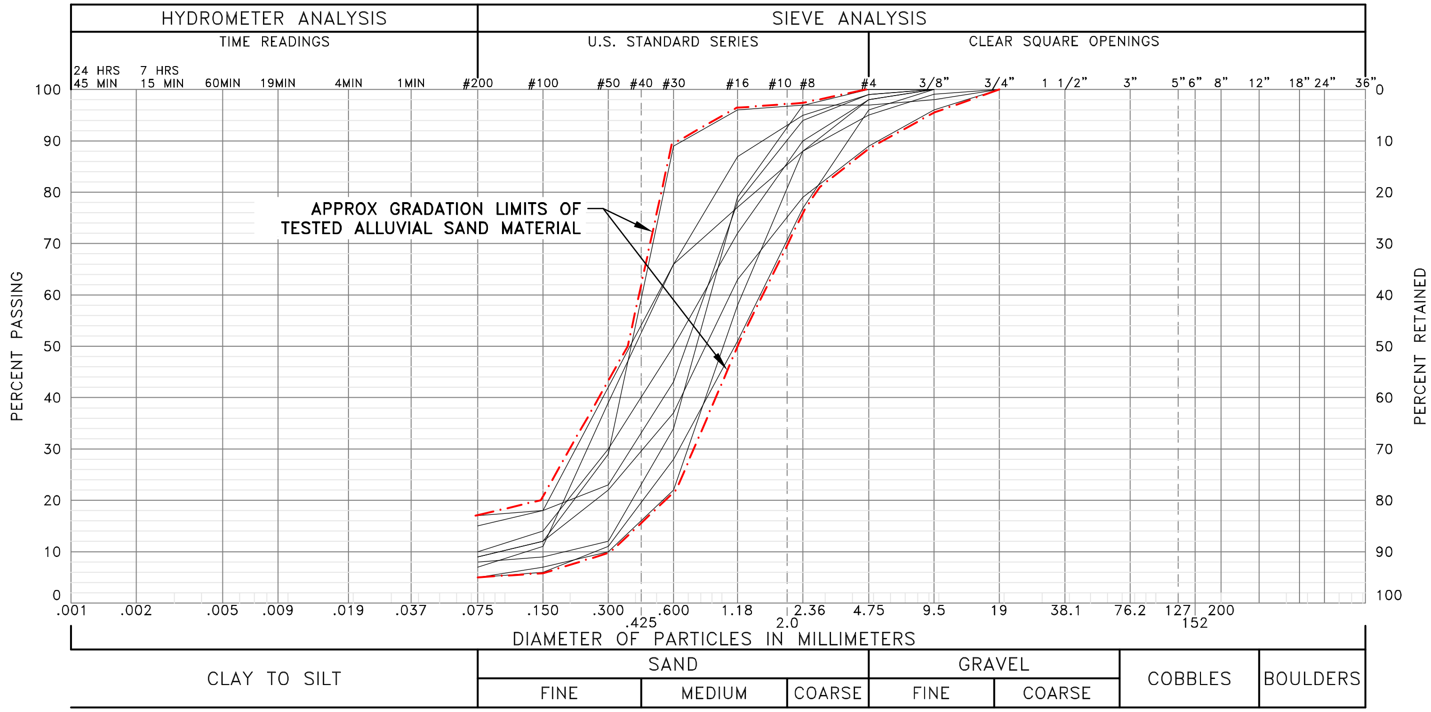

APPROX GRADATION LIMITS OF TESTED ALLUVIAL SAND MATERIAL

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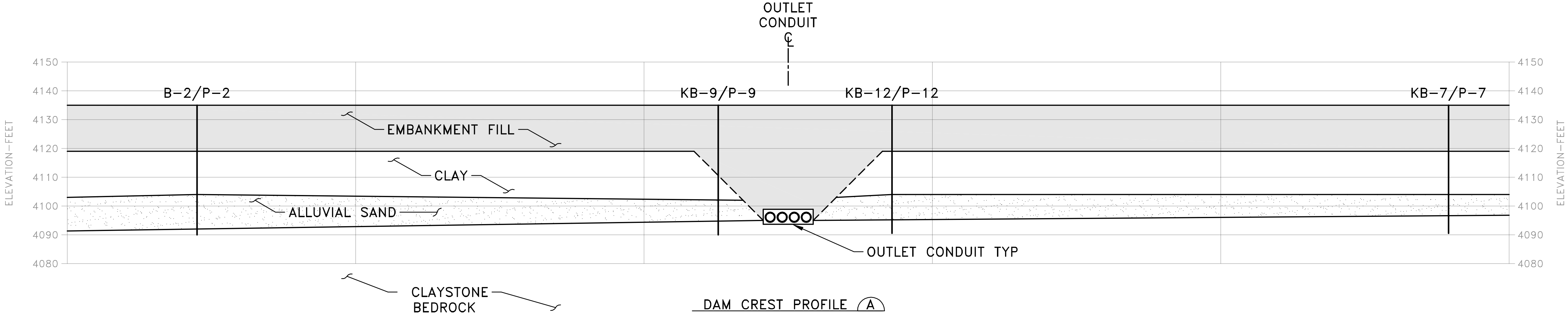
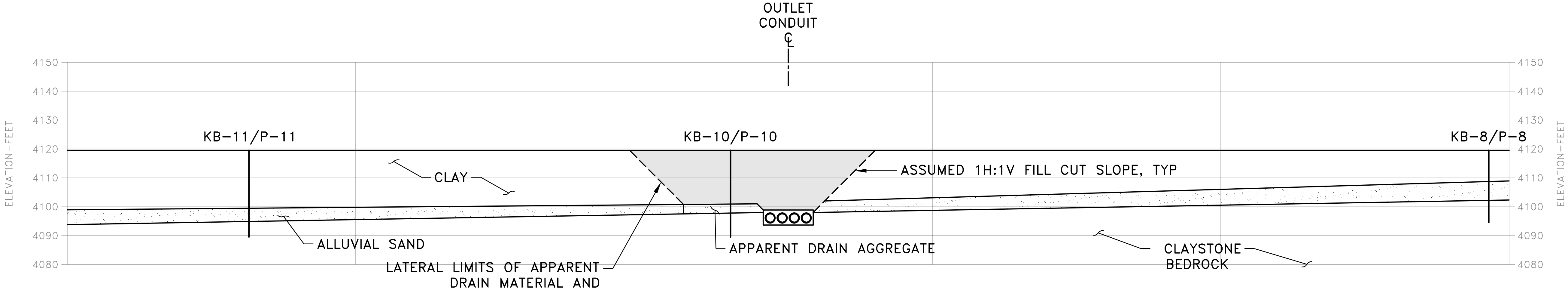
16-1-695	Kumar & Associates	GRADATION LIMITS OF ALLUVIAL SANDS	Fig. 11



DAM CREST PROFILE (A)

20 0 20 40

APPROXIMATE SCALE–FEET



DOWNSTREAM TOE PROFILE (B)

20 0 20 40

APPROXIMATE SCALE–FEET

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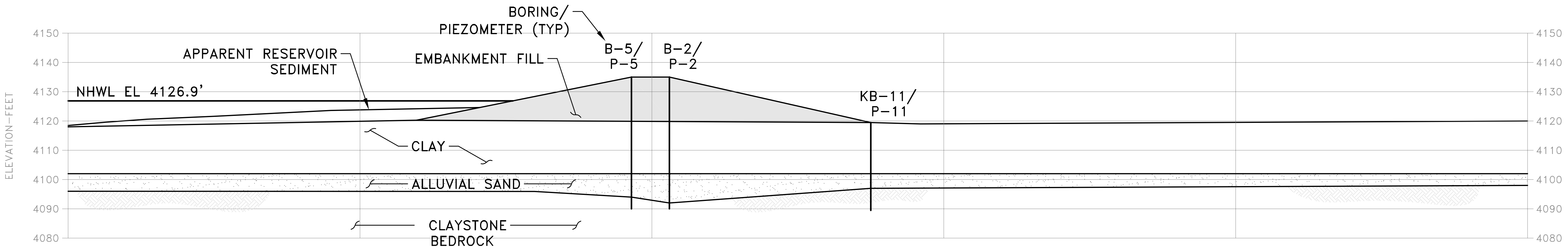
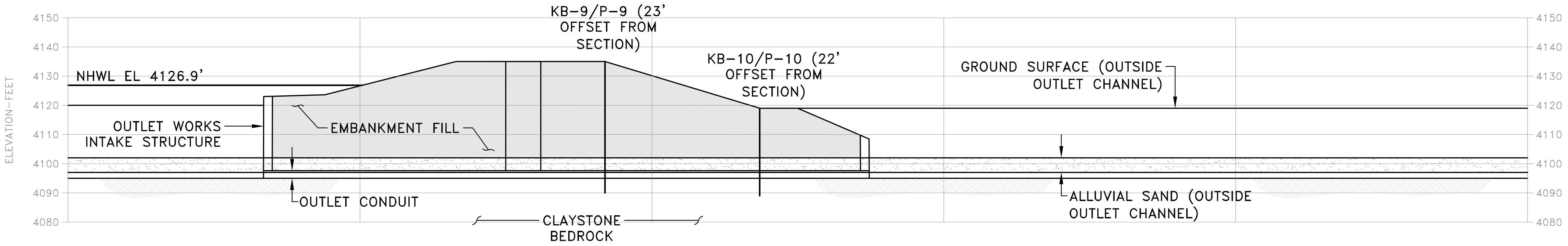
16–1–695	Kumar & Associates	ADOBE CREEK DAM	INTERPRETED GEOLOGIC PROFILES	Fig. 12



SECTION C

20 0 20 40

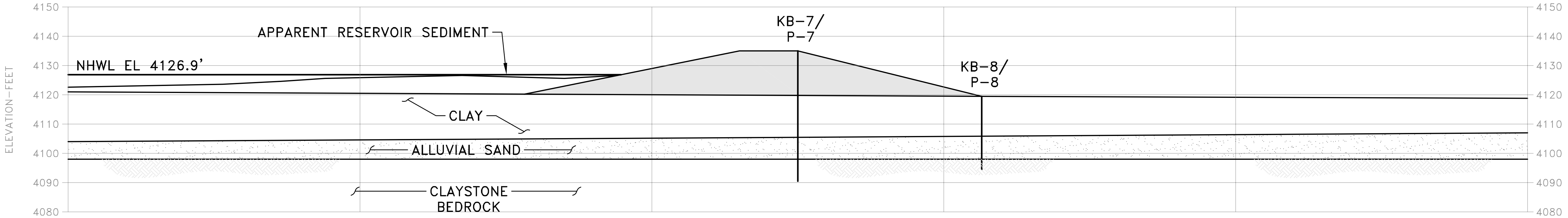
APPROXIMATE SCALE-FEET



OUTLET CONDUIT SECTION D

20 0 20 40

APPROXIMATE SCALE-FEET



SECTION E

20 0 20 40

APPROXIMATE SCALE-FEET

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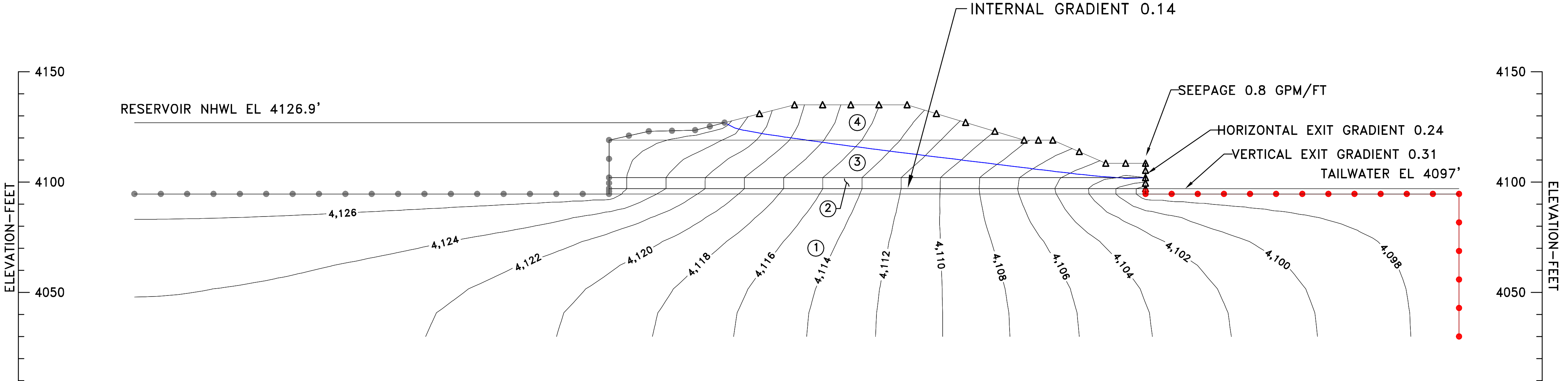
16-1-695	Kumar & Associates	ADOBE CREEK DAM	INTERPRETED GEOLOGIC SECTIONS	Fig. 13

MATERIAL NO.	MATERIAL	Ksat (ft/yr)	Kh (ft/yr)	Kv/kh	Kv (ft/yr)	SATURATED WATER CONTENT	RESIDUAL WATER CONTENT
①	SHALE CLAYSTONE	10	10	0.1	1	0.3	0.1
②	ALLUVIAL SAND	100,000	100,000	0.1	1,000	0.35	0.04
③	CLAY SOIL	100	100	0.1	10	0.5	0.15
④	EXISTING EMBANKMENT FILL	50	50	0.2	10	0.5	0.15
⑤	NEW EMBANKMENT FILL	50	50	0.2	10	0.5	0.15
⑥	FILTER SAND	200,000	200,000	0.5	100,000	0.35	0.02
⑦	SOIL–BENTONITE WALL	0.1	0.1	1	0.1	0.5	0.15
⑧	JET–GROUT COLUMN	1.0	1.0	1	1.0	0.1	0.02



EXISTING DAM CONDITIONS

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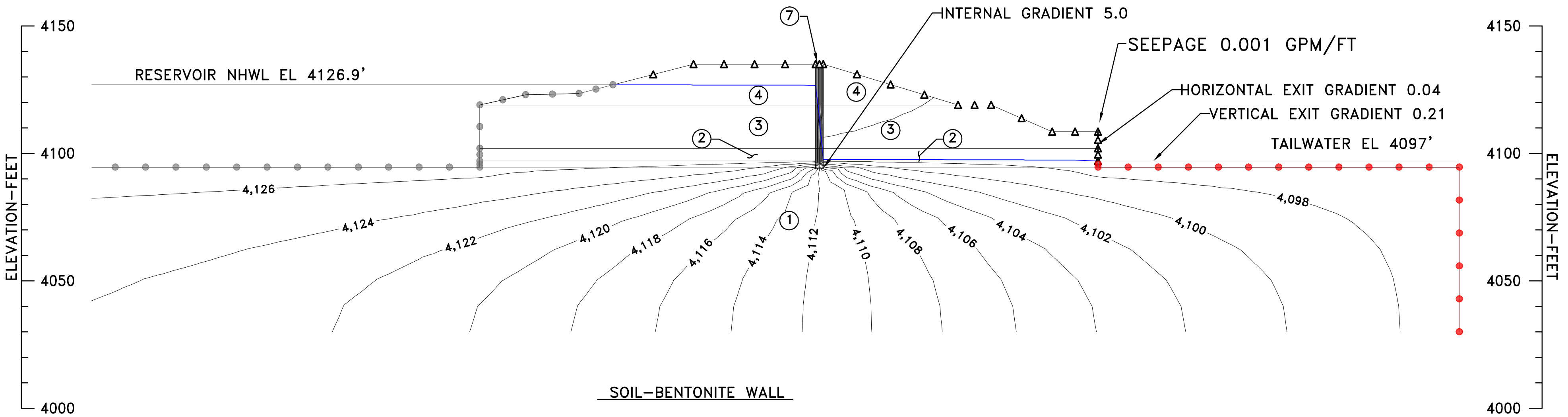
16–1–695

Kumar & Associates

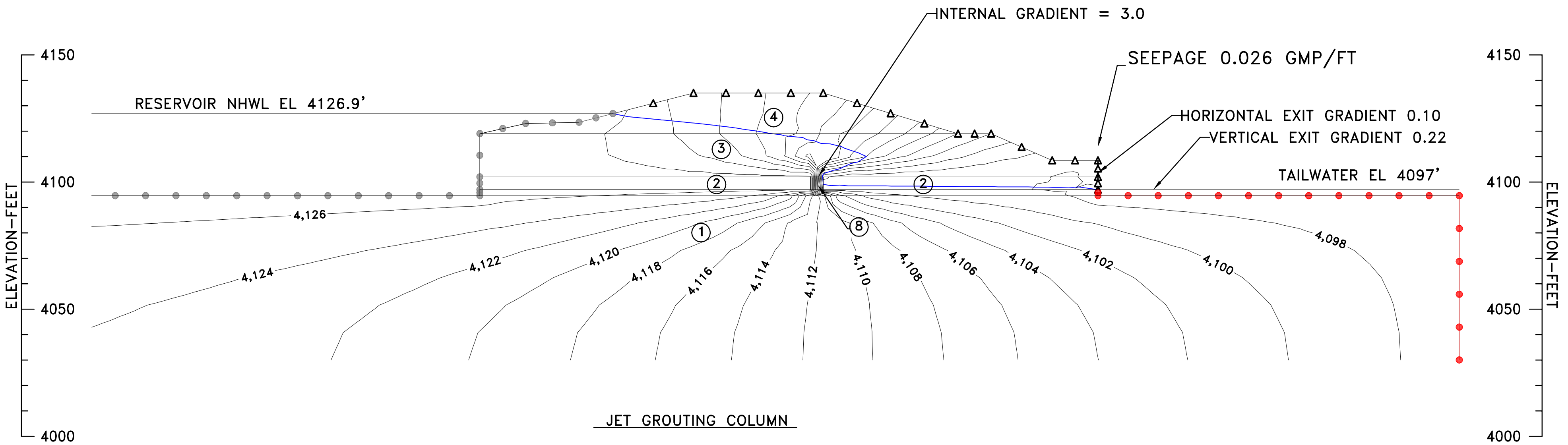
ADOBE CREEK DAM

SEEPAGE ANALYSES OF EXISTING CONDITION

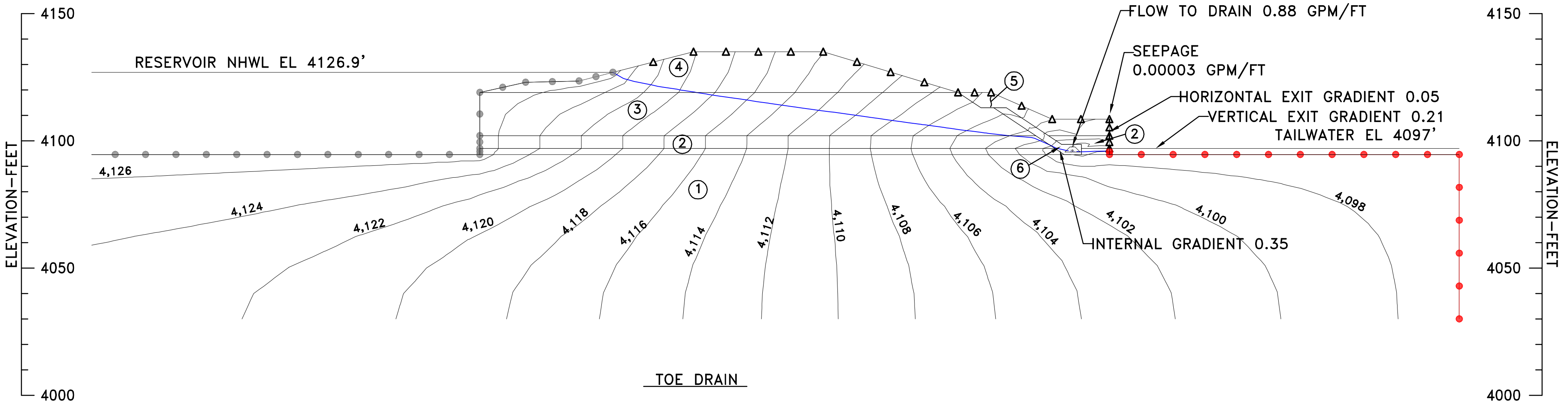
Fig. 14



SOIL–BENTONITE WALL



JET GROUTING COLUMN



TOE DRAIN

MATERIAL NO.	MATERIAL	Ksat (ft/yr)	Kh (ft/yr)	Kv/kh	Kv (ft/yr)	SATURATED WATER CONTENT	RESIDUAL WATER CONTENT
①	SHALE CLAYSTONE	10	10	0.1	1	0.3	0.1
②	ALLUVIAL SAND	100,000	100,000	0.1	1,000	0.35	0.04
③	CLAY SOIL	100	100	0.1	10	0.5	0.15
④	EXISTING EMBANKMENT FILL	50	50	0.2	10	0.5	0.15
⑤	NEW EMBANKMENT FILL	50	50	0.2	10	0.5	0.15
⑥	FILTER SAND	200,000	200,000	0.5	100,000	0.35	0.02
⑦	SOIL–BENTONITE WALL	0.1	0.1	1	0.1	0.5	0.15
⑧	JET–GROUT COLUMN	1.0	1.0	1	1.0	0.1	

16–1–695

Kumar & Associates

ADOBE CREEK DAM

SEEPAGE ANALYSES OF
REHABILITATION ALTERNATIVES

Fig. 15

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

PROJECT NO.:	16-1-695
PROJECT NAME:	Adobe Creek
DATE SAMPLED:	11-14-16 to 11-16-16
DATE RECEIVED:	11-18-16

SAMPLE LOCATION		DATE TESTED	NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (pcf)	GRADATION		PERCENT PASSING NO. 200 SIEVE	ATTERBERG LIMITS		SOIL OR BEDROCK TYPE
BORING	DEPTH (feet)				GRAVEL (%)	SAND (%)		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	
KB-7	4	11-22-16	11.4	113.4			87	38	21	Fill: Lean Clay ((CL)
KB-7	29	11-22-16	15.4	99.7	0	39	61	39	24	Sandy Lean Clay (CL)
KB-7	34	11-22-16	18.1		1	84	15	18	6	Silty to Clayey Sand (SC-SM)
KB-8	14	11-22-16	4.4	101.3	3	88	9	NV	NP	Well-Graded Sand with Silt (SW-SM)
KB-8	19	11-22-16	13.0	114.6	2	93	5	NV	NP	Well-Graded Sand with Silt (SW-SM)
KB-9	9	11-22-16	9.8	110.8			52	35	22	Fill: Sandy Lean Clay (CL)
KB-9	24	11-22-16	19.2	106.7			73	52	31	Fill: Lean Clay with Sand (CL)
KB-9	34	11-22-16	11.2	118.7	2	88	10	NV	NP	Well-Graded Sand with Silt (SW-SM)
KB-9	39	11-22-16	13.7		11	80	9	NV	NP	Well-Graded Sand with Silt (SW-SM)
KB-10	9	11-22-16	22.3	101.4			74	46	29	Fill: Lean Clay with Sand (CL)
KB-10	19	11-22-16	13.4	110.6	4	91	5	NV	NP	Fill: Well-Graded Sand with Silt (SW-SM)
KB-10	24	11-22-16	21.0	100.5	13	17	70	44	17	Claystone (Shale)
KB-11	14	11-22-16	20.7	103.7			70	47	28	Fill: Lean Clay with Sand (CL)
KB-11	24	11-22-16	15.7	110.1	5	88	7	NV	NP	Well-Graded Sand with Silt (SW-SM)
KB-11	29	11-22-16	17.0	102.9	31	29	40	34	16	Clayey Sandstone (Shale)
KB-12	9	11-22-16	13.6	115.9			70	45	27	Fill: Lean Clay with Sand (CL)
KB-12	29	11-22-16	5.8	118.6	1	82	17	36	22	Clayey Sand (SC)
KB-12	34	11-22-16	4.4	93.3	0	92	8	22	11	Well-Graded Sand with Clay (SW-SM)

APPENDIX A

INFORMATION ON EXPLORATIONS COMPLETED BY OTHERS

66

GEOLOGIC LOG OF DRILL HOLE

SHEET [illegible] OF 4

FEATURE Adobe Res Dam PROJECT FT. Lyon Canal Co. STATE Colo

HOLE NO. 1 LOCATION Down stream crest GROUND ELEV. 4138.9 DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 1:30 FINISHED 4:00 6/19/54 DEPTH OF OVERBURDEN TOTAL DEPTH 42 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 19:00 26.08 LOGGED BY R.E.W. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS: DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
							Csg					Clay Dry Clay slightly moist old Dam Top Clay Dry Clay slightly moist moisture content increase slightly never saturated Sand fine-med grained-cl. matrix less permiable Black fissel shale
Shelby Tube Blow count per 6" 9, 16, 25, 29, 34 Shelby Tube Driven in Sand TD	10 10 30 40 50 60 70 80 90							No casing	10 20 30 40 50 60 70 80 90			

not finished as piezo

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole .... D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE .... PROJECT .... STATE .... SHEET .... OF .... HOLE NO. ....

67

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 6

FEATURE Adobe Res Dam PROJECT Ft. Lyon Canal Co. STATE Colo

HOLE NO. 2 LOCATION Downstream Crest GROUND ELEV. 4138.45' DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 9:50 FINISHED 10:50 2/19/78 13:30 DEPTH OF OVERBURDEN TOTAL DEPTH 45' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 23.41 - 2' LOGGED BY R.R.D. LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Ce)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Clay Shelby Tube Blow count pushed Shelby Tube Blow count per 6" 13, 17, 22 Sample in Sand Split Spoon sample Bedrock	10 20 30 40 50 60 70 80 90	☒ ☒ ☒				perfor- ations		c59	10 20 30 40 50 60 70 80 90		☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒	Clay dry Clay slightly moist old Dam Top ~~limestone~~ clay dry ~~piezo level w/ Res full~~, 2/98 clay slightly moist moisture content increases piezo level 6/22/12 - 1/11/13 higher than reservoir Sand, fine to medium grained quartz 70% feldspar 30% TD Black fissile shale

finished as piezo P.2

EXPLANATION

▯ CORE LOSS

▮ CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE PROJECT STATE SHEET OF HOLE NO.

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 6

FEATURE Adobe Res Dam PROJECT FT. Lyon Canal Co STATE Colo

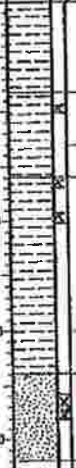
HOLE NO. 3 LOCATION Downstream Crest GROUND ELEV. 4138.7 DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 7:30 FINISHED 9:45 DEPTH OF OVERBURDEN TOTAL DEPTH 43' BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 6/19/84 13:00 24.25 LOGGED BY LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
								CS 9				
Shelby Tube Blow count per 6" 6, 10, 13 15 Split spoon sample Shelby Tube lost core bagged some sand		0%						No casing	TD			Clay dry Old Dam top Clay dry Slightly moist Clay Moist Sand Bed Rock



No piezo

EXPLANATION

CORE LOSS

CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hayeralliza, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE . . . . PROJECT . . . . STATE . . . . SHEET . . . . OF . . . . HOLE NO. . . . .

GEOLOGIC LOG OF DRILL HOLE

SHEET 4 OF 6

FEATURE Adobe Res Dam PROJECT FT Lyon Canal Co STATE Colo

HOLE NO. 4 LOCATION Down Slope GROUND ELEV. 4129.23 DIP (ANGLE FROM HORIZ.)

COORDS. N. E.

BEGUN 4:00 FINISHED 5:30 6/19/84 18-00 DEPTH OF OVERBURDEN TOTAL DEPTH 35 BEARING

DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 19.17' LOGGED BY RE LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
								csg			☒	
											☒	? Top old Dam ?
Shelby Tube Blow count per 6" 11, 17, 22, 27, 36	10	☒							10		☒	
											☒	
Shelby Tube Blow count per 6" 1½, 2, 2, 2, 3	20	☒				perforations			20			Sand
Shelby Tube To clean hole shale at bottom	30								30			
									TD			Bed rock
	40								40			
	50								50			
	60								60			
	70								70			
	80								80			
	90								90			

piezo lost during toe drain work (1984)

EXPLANATION

CORE LOSS

CORE RECOVERY

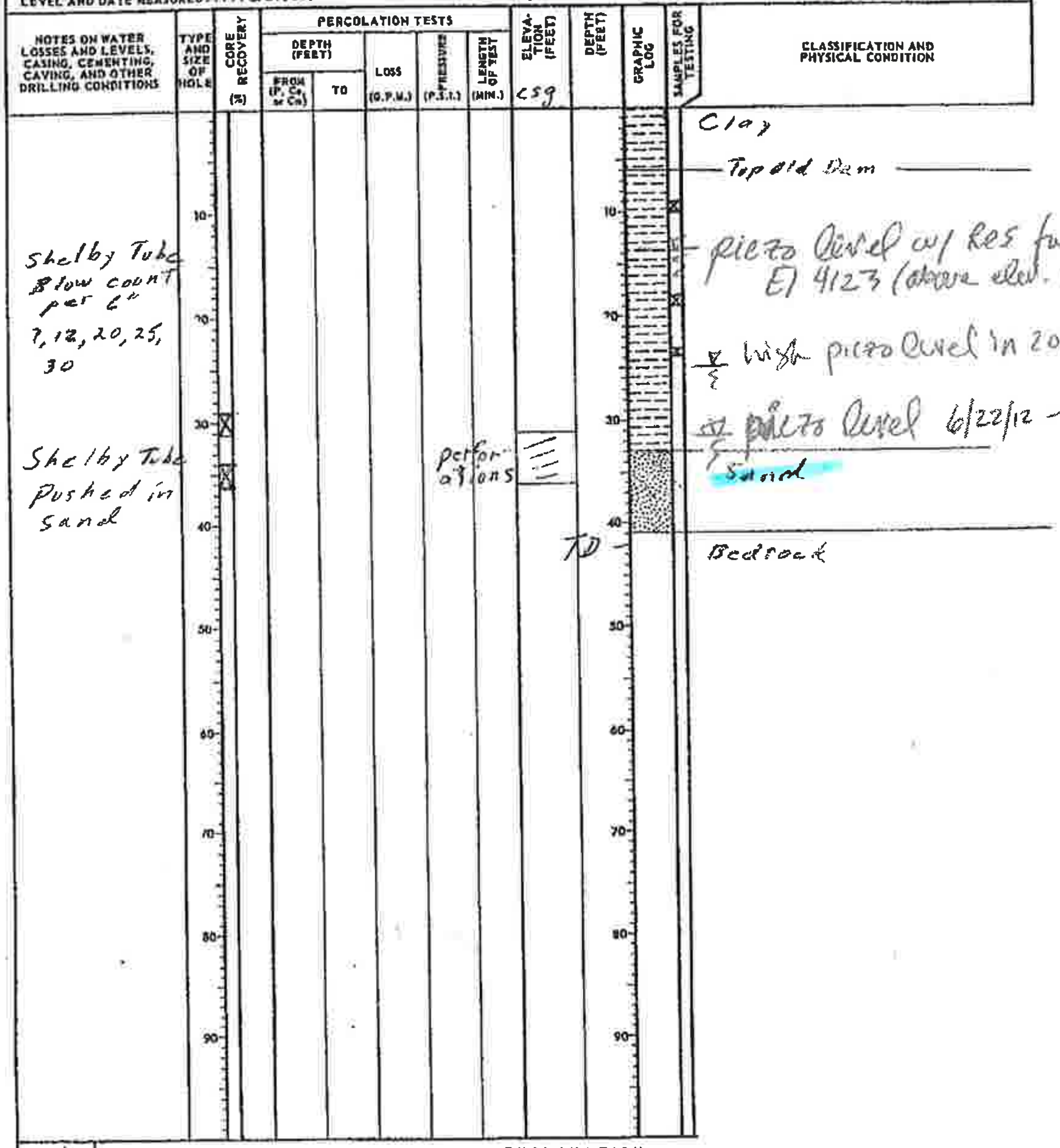
Type of hole . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE PROJECT STATE SHEET OF HOLE NO.

GEOLOGIC LOG OF DRILL HOLE

SHEET 5 OF 6

FEATURE Adobe Res. Dam PROJECT Ft. Lyon Canal Co. STATE Colo
HOLE NO. 5 LOCATION Up Stream Crest GROUND ELEV. 4138.47 DIP (ANGLE FROM HORIZ.)
COORDS. N. E.
BEGUN 4:15 FINISHED 7:00 6/19/84 13:00 DEPTH OF OVERBURDEN TOTAL DEPTH 42 BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 24.2' LOGGED BY R.E.W. LOG REVIEWED BY



Shelby Tube
Blow count
per 6"
7, 12, 20, 25,
30

Shelby Tube
Pushed in
sand

Clay

Top old Dam

piezo level w/ Res full (2/98)
El 4123 (above elev. of toe)

high piezo level in 2012 (relatively low res.)

piezo level 6/22/12 - 1/11/13

Sand

Bedrock

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Hayetollite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Ca = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

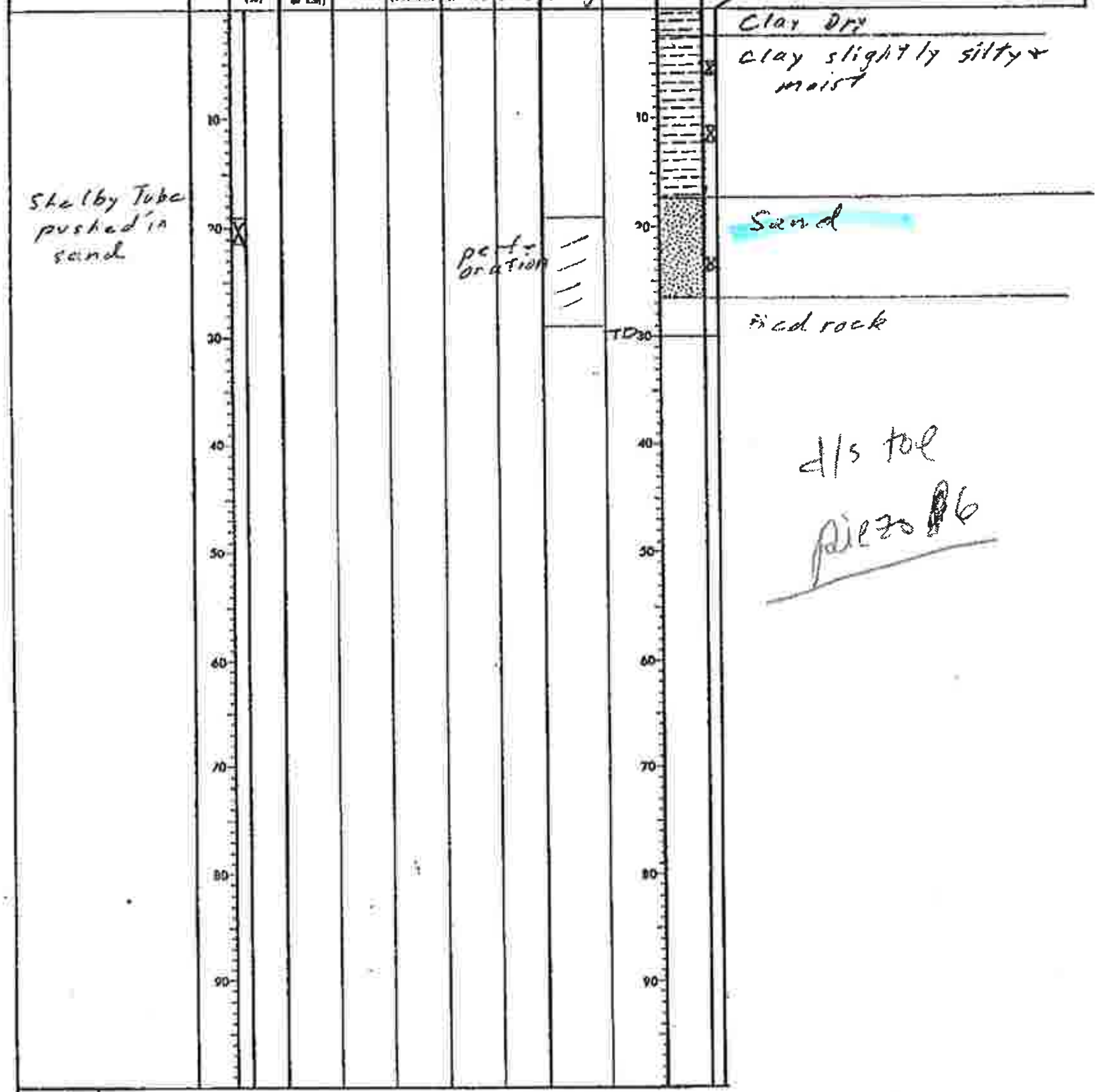
FEATURE .... PROJECT .... STATE .... SHEET .... OF .... HOLE NO. ....

GEOLOGIC LOG OF DRILL HOLE

SHEET 6 OF 6

FEATURE Adobe Res. Dam PROJECT F.T. Lyon Canal Co. STATE Colo.
HOLE NO. 6 LOCATION 1321' S.E. of Cons. Sec. GROUND ELEV. 4122.63 DIP (ANGLE FROM HORIZ.) ....
COORDS. N. .... E. ....
BEGUN 12:15 FINISHED 1:30 DEPTH OF OVERBURDEN .... TOTAL DEPTH 30 BEARING ....
6/19/84 13:00
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED 8.57' LOGGED BY R.E.W. LOG REVIEWED BY ....

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	TYPE AND SIZE OF HOLE	CORE RECOVERY (%)	PERCOLATION TESTS DEPTH (FEET) FROM (P, Cs, or Cm)	TO	LOSS (G.P.M.)	PRESSURE (P.S.I.)	LENGTH OF TEST (MIN.)	ELEVATION (FEET)	DEPTH (FEET)	GRAPHIC LOG	SAMPLES FOR TESTING	CLASSIFICATION AND PHYSICAL CONDITION
Shelby Tube pushed in sand						perforation		csg	TD 30			Clay Dry clay slightly silty + moist Sand Bed rock



d/s toe
piezo 6

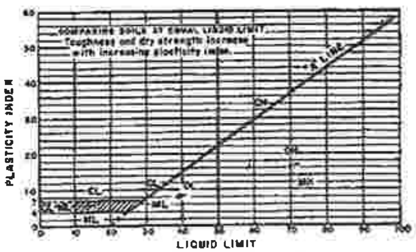
EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE .... PROJECT .... STATE .... SHEET .... OF .... HOLE NO ....

UNIFIED SOIL CLASSIFICATION
INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)						GROUP SYMBOLS [a]	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA			
COARSE GRAINED SOILS More than half of material is larger than No. 200 sieve size [b] (The No. 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size. (For visual classifications, the ¼" size may be used as equivalent to the No. 4 sieve size.)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows:- Less than 5% GW, GP, SW, SP. More than 12% GM, GC, SM, SC. 5% to 12% Borderline cases requiring use of dual symbols.	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing.			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.				Not meeting all gradation requirements for GW	
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			GM	Silty gravels, poorly graded gravel-sand-silt mixtures.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.			Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			Plastic fines (for identification procedures see CL below).			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.				Atterberg limits above "A" line with PI greater than 7	
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size.	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines				$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing.			SP	Poorly graded sands, gravelly sands, little or no fines.	EXAMPLE:- Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine; about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM)			Not meeting all gradation requirements for SW	
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			SM	Silty sands, poorly graded sand-silt mixtures.				Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.
			Plastic fines (for identification procedures see CL below).			SC	Clayey sands, poorly graded sand-clay mixtures.				Atterberg limits above "A" line with PI greater than 7	
FINE GRAINED SOILS More than half of material is smaller than No. 200 sieve size.	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE											
			DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)							
	SILTS AND CLAYS Liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information; and symbol in parentheses.		 PLASTICITY CHART FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS		
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.					
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.				
	SILTS AND CLAYS Liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.					
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays.	EXAMPLE:- Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML)				
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity.					
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other highly organic soils.					

[a] Boundary classifications:- Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder.
[b] All sieve sizes on this chart are U.S. standard.

ADOPTED BY:- CORPS OF ENGINEERS AND BUREAU OF RECLAMATION - JANUARY 1952

Figure 7.—Unified soil classification chart. From drawing 103–D–347.

APPENDIX B

HORIZONTAL EXIT GRADIENT CALCULATIONS

Horizontal Critical Exit Gradient and Calculated Factor of Safety - Adobe Creek Dam Existing Conditions

Project No. 16-1-695
Designer: CAJ
Company: Kumar & Associates, Inc.
Date: 12/7/2016

Design References:

Best Practice in Dam and Levee Safety Risk Analyses.
US Department of the Interior Bureau of Reclamation and US Army Corps of Engineers
Publication No. I-O-20150612, December 2005

Critical Horizontal Seepage Gradients.
Association of State Dam Safety Officials, Journal of Dam Safety: Volume 11, Issue 2, 2013

STEP 1. Establish the geometric and material perameters for the project.

Geometric Parameters:

Angle of Slope at Exit Face Measured from Horizontal: $\beta := 33.6$ degrees

Estimated Horizontal Seepage Gradient from Seep/W Analyses: $ih := 0.24$

Estimated Vertical Seepage Gradient from Seep/W Analyses: $iv := 0.5$

Seepage Flow Angle From Horizontal: $\alpha := \text{atan}\left[\left(\frac{iv}{ih}\right)\text{deg}\right]$ $\alpha := 64.4$ degrees

Soil Parameters:

Saturated Unit Weight of Soil: $\gamma s := 130$ pcf

Unit Weight of Water: $\gamma w := 62.4$ pcf

Bouyant Unit Weight of Soil: $\gamma b := \gamma s - \gamma w = 67.6$ pcf

Estimated Drained Friction Angle of Soil: $\phi := 34$ degrees

STEP 2. Calculate horizontal seepage critical gradient.

Horizontal Critical Gradient:

$$icr := \frac{\gamma b}{\gamma w} \cdot \frac{[\tan[(\phi)\text{deg}] \cdot \cos[[\tan[(\beta)\text{deg}]]\text{deg}]] - \sin[(\beta)\text{deg}]}{[[\tan[(\phi)\text{deg}]] \cdot \sin[(\beta - \alpha)\text{deg}]] + \cos[(\beta - \alpha)\text{deg}]} = 0.26$$

STEP 3. Calculate Factor of Safety for Horizontal Seepage Gradient.

Horizontal Seepage Gradient Factor of Safety):

$$ifos := \frac{icr}{ih} = 1.06$$

Horizontal Critical Exit Gradient and Calculated Factor of Safety - Adobe Creek Dam Soil-Bentonite Wall Alternative

Project No. 16-1-695
Designer: CAJ
Company: Kumar & Associates, Inc.
Date: 12/7/2016

Design References:

Best Practice in Dam and Levee Safety Risk Analyses.
US Department of the Interior Bureau of Reclamation and US Army Corps of Engineers
Publication No. I-O-20150612, December 2005

Critical Horizontal Seepage Gradients.
Association of State Dam Safety Officials, Journal of Dam Safety: Volume 11, Issue 2, 2013

STEP 1. Establish the geometric and material perameters for the project.

Geometric Parameters:

Angle of Slope at Exit Face Measured from Horizontal: $\beta := 33.6$ degrees

Estimated Horizontal Seepage Gradient from Seep/W Analyses: $ih := 0.04$

Estimated Vertical Seepage Gradient from Seep/W Analyses: $iv := 0.17$

Seepage Flow Angle From Horizontal: $\alpha := \text{atan}\left[\left(\frac{iv}{ih}\right)\text{deg}\right]$ $\alpha := 77$ degrees

Soil Parameters:

Saturated Unit Weight of Soil: $\gamma s := 130$ pcf

Unit Weight of Water: $\gamma w := 62.4$ pcf

Bouyant Unit Weight of Soil: $\gamma b := \gamma s - \gamma w = 67.6$ pcf

Estimated Drained Friction Angle of Soil: $\phi := 34$ degrees

STEP 2. Calculate horizontal seepage critical gradient.

Horizontal Critical Gradient:

$$icr := \frac{\gamma b}{\gamma w} \cdot \frac{[\tan[(\phi)\text{deg}] \cdot \cos[[\tan[(\beta)\text{deg}]]\text{deg}]] - \sin[(\beta)\text{deg}]}{[[\tan[(\phi)\text{deg}]] \cdot \sin[(\beta - \alpha)\text{deg}]] + \cos[(\beta - \alpha)\text{deg}]} = 0.5$$

STEP 3. Calculate Factor of Safety for Horizontal Seepage Gradient.

Horizontal Seepage Gradient Factor of Safety):

$$ifos := \frac{icr}{ih} = 12.46$$

Horizontal Critical Exit Gradient and Calculated Factor of Safety - Adobe Creek Dam Jet Grout Column Alternative

Project No. 16-1-695
Designer: CAJ
Company: Kumar & Associates, Inc.
Date: 12/7/2016

Design References:

Best Practice in Dam and Levee Safety Risk Analyses.
US Department of the Interior Bureau of Reclamation and US Army Corps of Engineers
Publication No. I-O-20150612, December 2005

Critical Horizontal Seepage Gradients.
Association of State Dam Safety Officials, Journal of Dam Safety: Volume 11, Issue 2, 2013

STEP 1. Establish the geometric and material perameters for the project.

Geometric Parameters:

Angle of Slope at Exit Face Measured from Horizontal: $\beta := 33.6$ degrees

Estimated Horizontal Seepage Gradient from Seep/W Analyses: $ih := 0.1$

Estimated Vertical Seepage Gradient from Seep/W Analyses: $iv := 0.32$

Seepage Flow Angle From Horizontal: $\alpha := \operatorname{atan}\left[\left(\frac{iv}{ih}\right)deg\right]$ $\alpha := 72$ degrees

Soil Parameters:

Saturated Unit Weight of Soil: $\gamma s := 130$ pcf

Unit Weight of Water: $\gamma w := 62.4$ pcf

Bouyant Unit Weight of Soil: $\gamma b := \gamma s - \gamma w = 67.6$ pcf

Estimated Drained Friction Angle of Soil: $\phi := 34$ degrees

STEP 2. Calculate horizontal seepage critical gradient.

Horizontal Critical Gradient:

$$icr := \frac{\gamma b}{\gamma w} \cdot \frac{[\tan[(\phi)deg] \cdot \cos[[\tan[(\beta)deg]]deg]] - \sin[(\beta)deg]}{[[\tan[(\phi)deg]] \cdot \sin[(\beta - \alpha)deg]] + \cos[(\beta - \alpha)deg]} = 0.36$$

STEP 3. Calculate Factor of Safety for Horizontal Seepage Gradient.

Horizontal Seepage Gradient Factor of Safety):

$$ifos := \frac{icr}{ih} = 3.6$$

Horizontal Critical Exit Gradient and Calculated Factor of Safety - Adobe Creek Dam Toe Drain Alternative

Project No. 16-1-695
Designer: CAJ
Company: Kumar & Associates, Inc.
Date: 12/7/2016

Design References:

Best Practice in Dam and Levee Safety Risk Analyses.
US Department of the Interior Bureau of Reclamation and US Army Corps of Engineers
Publication No. I-O-20150612, December 2005

Critical Horizontal Seepage Gradients.
Association of State Dam Safety Officials, Journal of Dam Safety: Volume 11, Issue 2, 2013

STEP 1. Establish the geometric and material perameters for the project.

Geometric Parameters:

Angle of Slope at Exit Face Measured from Horizontal: $\beta := 33.6$ degrees

Estimated Horizontal Seepage Gradient from Seep/W Analyses: $ih := 0.05$

Estimated Vertical Seepage Gradient from Seep/W Analyses: $iv := 0.1$

Seepage Flow Angle From Horizontal: $\alpha := \mathrm{atan}\left[\left(\frac{iv}{ih}\right)\mathrm{deg}\right]$ $\alpha := 63$ degrees

Soil Parameters:

Saturated Unit Weight of Soil: $\gamma s := 130$ pcf

Unit Weight of Water: $\gamma w := 62.4$ pcf

Bouyant Unit Weight of Soil: $\gamma b := \gamma s - \gamma w = 67.6$ pcf

Estimated Drained Friction Angle of Soil: $\phi := 34$ degrees

STEP 2. Calculate horizontal seepage critical gradient.

Horizontal Critical Gradient:

$$icr := \frac{\gamma b}{\gamma w}\cdot\frac{[\tan[(\phi)\mathrm{deg}]\cdot\cos[[\tan[(\beta)\mathrm{deg}]]\mathrm{deg}]] - \sin[(\beta)\mathrm{deg}]}{[[\tan[(\phi)\mathrm{deg}]]\cdot\sin[(\beta-\alpha)\mathrm{deg}]] + \cos[(\beta-\alpha)\mathrm{deg}]} = 0.24$$

STEP 3. Calculate Factor of Safety for Horizontal Seepage Gradient.

Horizontal Seepage Gradient Factor of Safety):

$$ifos := \frac{icr}{ih} = 4.86$$

Attachment B

Outlet Conduit Inspection Letter

W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers
WWW.WWWHEELER.COM

December 9, 2016

Jerred Hoffman, Superintendent
Fort Lyon Canal Company
750 Bent Avenue,
Las Animas, CO 81054

Subject: **Adobe Creek Dam Outlet Conduit Inspection**
Wheeler Project No. 1830.04

Dear Jerred:

On November 9, 2016, W. W. Wheeler & Associates Inc. (Wheeler) performed an internal inspection of the four outlet works conduits located within Adobe Creek Dam, a storage component of the Fort Lyon Canal, located near Las Animas, Colorado. The inspection consisted of entering each of the four conduits and visually inspecting and video documenting the condition of the conduits. Additional assistance and access to the site was provided by a ditch rider for the Fort Lyon Canal Company (FLCC). The Division 2 Colorado Dam Safety Engineer, Mark Perry, was also present for portions of the outlet inspection. The inspection was performed to satisfy the Task 2 requirements of the Colorado Water Conservation Board Water Supply Reserve Account (WSRA) basin and statewide grant for “Evaluation of the Seepage and Outlet Conduit Issues at Adobe Creek Dam”. A collection of short video recordings of the interior of outlet conduits, photographs, and field notes were utilized to provide this summary of the inspection findings.

BACKGROUND

The section of the outlet conduits inspected was from the control gates, at the center of the dam crest, downstream to the conduit terminal structure. This portion of the outlet conduits is approximately 107 feet long and was comprised of 36-inch-diameter by 3-foot-long sections of vitrified clay pipe, resulting in 34 sections of pipe with 33 pipe joints, as noted in previous inspections. The portion of the conduits upstream of the control gates was not inspected because the upstream conduits were submerged.

The 112-year-old Abode Creek Dam outlet consist of the original vitrified clay pipe encased in non-reinforced concrete. Past inspections of the outlet conduits downstream of the control gates have indicated significant settling and/or movement of the conduit sections has resulted in cracking in the pipes and leakage through the pipe joints. The FLCC performed repairs in all four conduits to seal a total of 50 leaking joints in 1984 and another 27 leaking joints in 2011 using oakum and grout. Grout was also placed in 2011 to patch deterioration and cracks in the crown of conduit pipes. The work in 1984 and 2011 were both considered temporary repairs and the Division 2 Dam Safety Engineer has recommended that the FLCC immediately undertake an outlet works rehabilitation project.

FIELD OBSERVATIONS

On the day of the inspection, the reservoir stage was 19.40 feet, as measured on the outlet intake staff gauge. Seepage water was observed flowing from the four left (as looking downstream) toe drain outfalls as well as the right toe drain outfall, with the highest flows observed coming from the right toe drain. The control gates were closed on the date of inspection, but water from seepage and gate leakage was observed flowing from all four outlet conduits, with the highest flows coming from conduit No. 3 (third from the left as looking downstream). Additional seepage was observed coming through weep holes located on the left and right wing walls on the outlet works terminal structure.

The outlet conduits were inspected starting with Conduit No. 1 (farthest left looking downstream) and finished with Conduit No. 4 (farthest right looking downstream). In general, conduits Nos. 1 and 4 were observed to be in worse condition with higher seepage infiltration rates than conduits Nos. 2 and 3. The condition in all four conduits deteriorated further downstream from the control gates and closer to the outfalls, with the worst conditions observed in the downstream third of the conduits. Extensive cracking was observed in all four conduits with active seepage flowing through many of the cracks on the date of inspection. Observed lateral and circumferential cracks are indicative of pipe failure due to external forces. The worst pipe deterioration was observed where the two types of cracks intercept. At such locations the pipe sidewall has missing sections or the sidewall was protruding towards the center of the pipe. At such locations measurements of the pipe diameter were taken and it was generally found that the pipes were oblong in the vertical direction suggesting squeezing of the pipe from the sides. Mineral buildup without water seepage was also observed on many of the cracks, indicating seepage has occurred at these locations in the past.

Each joint of the four conduits was inspected for gap length between joints, the lateral offset across pipe joints, the condition of previous repairs at each observed crack or joint, and the amount of seepage at each joint. The gaps between joints ranged from one quarter to four inches and were generally close to two inches. Lateral offsets between two pipe sections at joints were observed to be ¼ inch to three inches. The observed non-uniform gap width around the circumference of a joint and lateral offsets at joints are indicative of pipe movement. This was also observed visually when looking at each conduit as a whole. The conduits do not have positive drainage as two to three inches of standing water was observed in each conduit. In addition, photographs and screenshots in the attachments to this letter show the meandering path of each conduit.

Previous conduit repairs were observed during the inspection. In general, the repairs were observed to be in poor condition, with significant cracking of the grout and large portions where grout and oakum were no longer present, leaving large gaps in the joints up to 4 inches deep.

Table No. 1 below summarizes the observed conditions in Conduit No. 1 on the date of the inspection. The observed conditions in Conduit No. 1 are representative of the observed conditions in Conduit No. 4, and to a lesser extent the deteriorated conditions in Conduit Nos. 2 and 3.

Table No. 1: Observed Conditions in Conduit No. 1.

Observed Conditions in Conduit Number 1	
Number of Joints in Conduit	**33**
Quantity of Joints with ½” Gap or Greater	**26**
Quantity of Joints with ½” Lateral Offset or Greater	**25**
Quantity of Circumferential Cracks in Pipe Sections	**12**
Quantity of Lateral Cracks in Pipe Sections	**27**
Number of Active Seepage Points During Inspection	**25**

The control gates were visually inspected from the downstream conduit section and found to be in fair to poor condition. Leakage was observed from gate No. 4 at approximately 10-20 GPM, and significant leakage was observed from gate No. 3 at approximately 50-100 GPM. In both cases the seepage was primarily coming from the top of the gate. Significant scour of the pipe was observed the first one to two feet immediately downstream of the gates in all four conduits. The scour was concentrated on the invert and the lower half of sides of the pipes and was observed to have removed up to 2 inches of pipe wall.

The focus of the inspection was on the interior of the outlet conduits, however, some observations of the intake and terminal structure for outlet works were noted at the time of the inspection. The intake structure concrete has apparently been refaced in the past and this material shows significant deterioration. There was no evidence of a trash rack on the outlet works intake structure, but because of the high water line a trash rack may have been obscured. Discussion with Mark Perry indicated his observations when the reservoir was lower in the past have not shown any evidence of a trash rack. The terminal structure concrete was refaced with shotcrete in 1992. This material is deteriorated and separating along the edges of the downstream face especially around the outlet conduits.

See Attachments A and B for examples of the conditions mentioned above. Attachment A presents photos of the outlet conduits and intake and outlet structures. Attachment B presents screenshots from the video documentation of the outlet conduit inspection. The inspection videos are included with this document in DVD format. The inspections videos have been organized by conduit and labeled by location in each conduit relative to the control gate.

CONCLUSIONS AND RECOMMENDATIONS

Based on Wheeler's November 9, 2016 inspection, as well as previous inspections, it is Wheler's opinion that the outlet works conduits in Adobe Creek Dam are in poor condition with significant seepage, cracking, pipe joint movement, and deterioration. The vitrified clay pipe in Abode Creek Dam is 112 years old and significant cracking was observed throughout all four conduits, with active seepage coming through many of the cracks. In addition, years of settling and movement appears to have caused the three-foot-long outlet pipe sections to move independently resulting in disjointedness of the outlet works conduits and large gaps between pipe sections. Previous repair work to the conduits appears to have provided a temporary fix for gaps and seepage issues, but many of the repairs are considered no longer effective. Do to the poor condition and extensive amount of damage to the pipes, additional repair work to the conduits will likely provide minimal benefit. Wheeler is in agreement with the Division 2 Dam Safety Engineer office that rehabilitation or replacement of the outlet conduits should be considered immediately to address seepage and other dam safety issues associated with the outlet works conduits.

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

Sean Moran

Trevor Mugele, P.E.
Project Engineer

Sean Moran
Engineer

r:\1800\1830\1830.04\documents\outlet inspection 11-9-16\16dec09l_adobe creek dam outlet conduit inspection.docx

Attachment A

Photo Log

Attachment A
Adobe Creek Dam Outlet Conduit Inspection
Photo Log

Photo 1: View of the outlet works intake structure from the left wing wall, looking downstream towards the dam. The reservoir elevation was 19.40 feet on the staff gauge on date of inspection. Note the concrete deterioration. November 9, 2016.

Photo 2: View of the outlet works terminal structure and outlet conduit outfalls from the right wing wall, looking upstream. Note seepage from the weep holes in the left wing wall and gate leakageand seepage flows exiting from the outlet works conduits. November 9, 2016.

Attachment A
Adobe Creek Dam Outlet Conduit Inspection
Photo Log

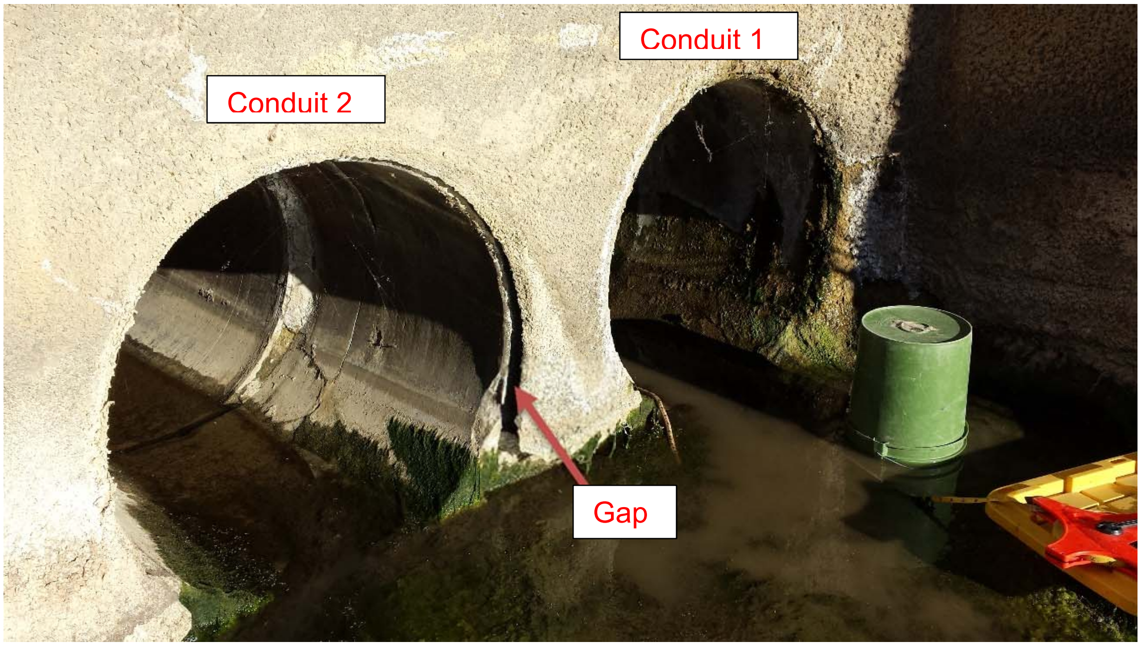


Photo 3: View of discharge from Conduit Nos. 1 & 2, looking upstream. Note gap between facing concrete and terminal structure. November 9, 2016.

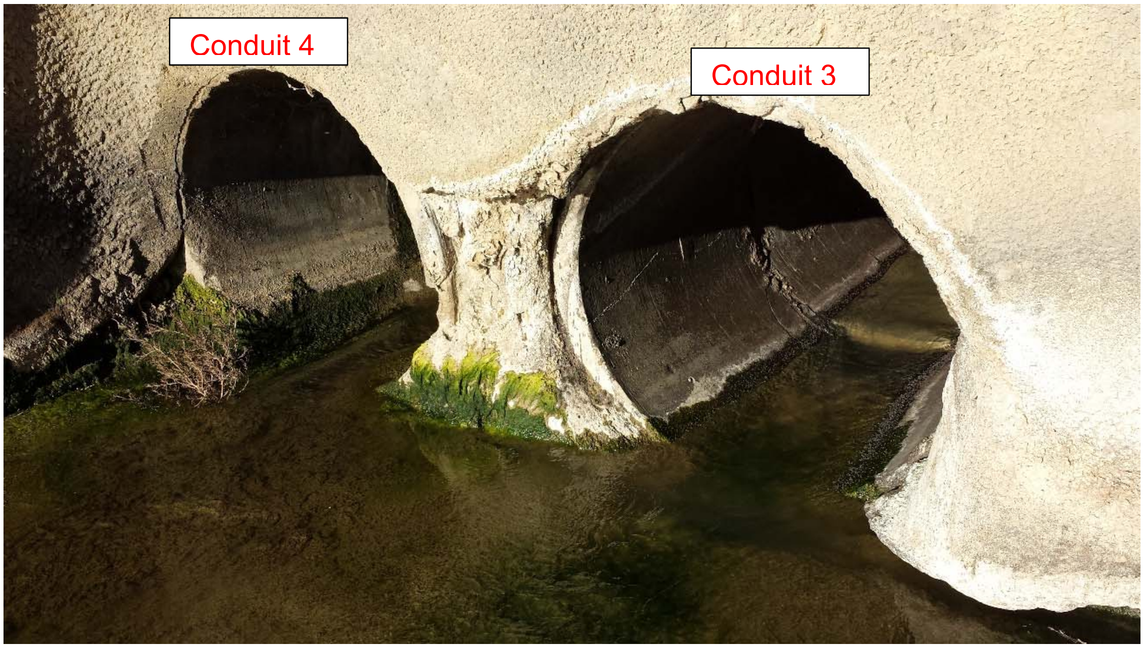


Photo 4: View of discharge from Conduit Nos. 3 & 4, looking upstream. November 9, 2016.

Attachment A
Adobe Creek Dam Outlet Conduit Inspection
Photo Log

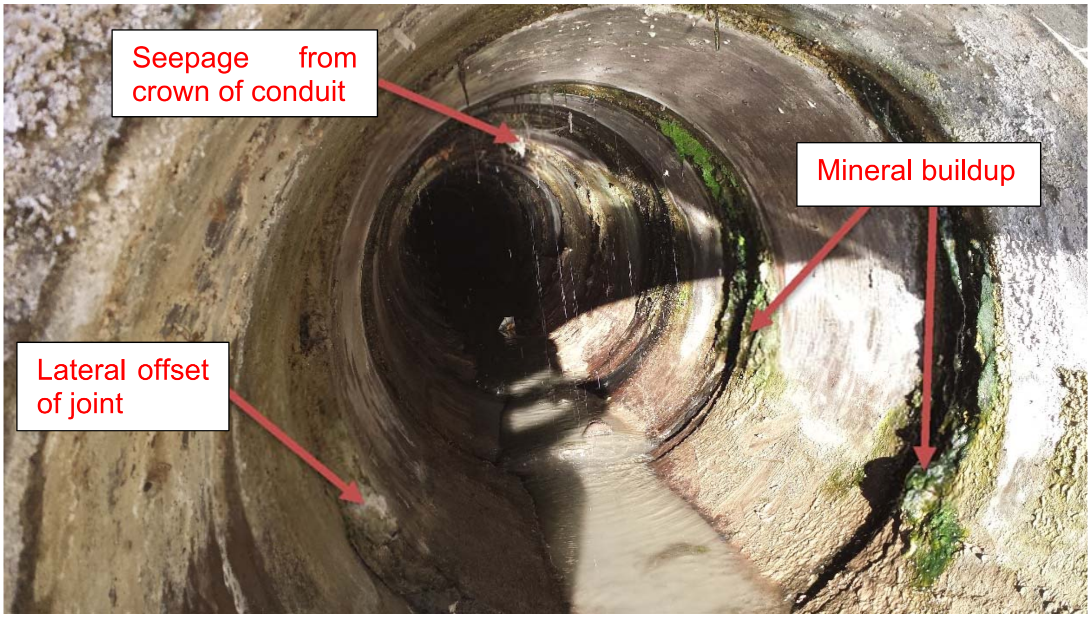


Photo 5: View of Conduit No. 1, taken from the discharge end looking upstream. Note seepage from conduit crest, lateral offset of joints and mineral buildup around joints. November 9, 2016.

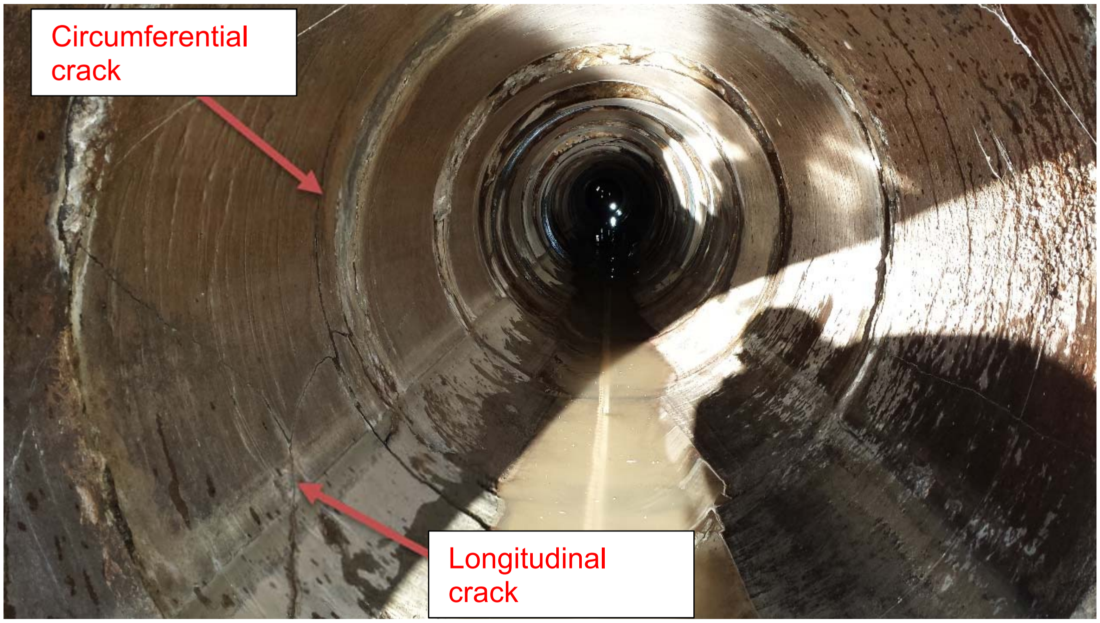


Photo 6: View of Conduit No. 2 taken from the discharge end looking upstream. Note lateral offset of joints and cracking in pipe. November 9, 2016.

Attachment A
Adobe Creek Dam Outlet Conduit Inspection
Photo Log

Photo 7: View of Conduit No. 3 taken from the discharge end looking upstream. Note lateral offset of joints and cracking in pipe. November 9, 2016.

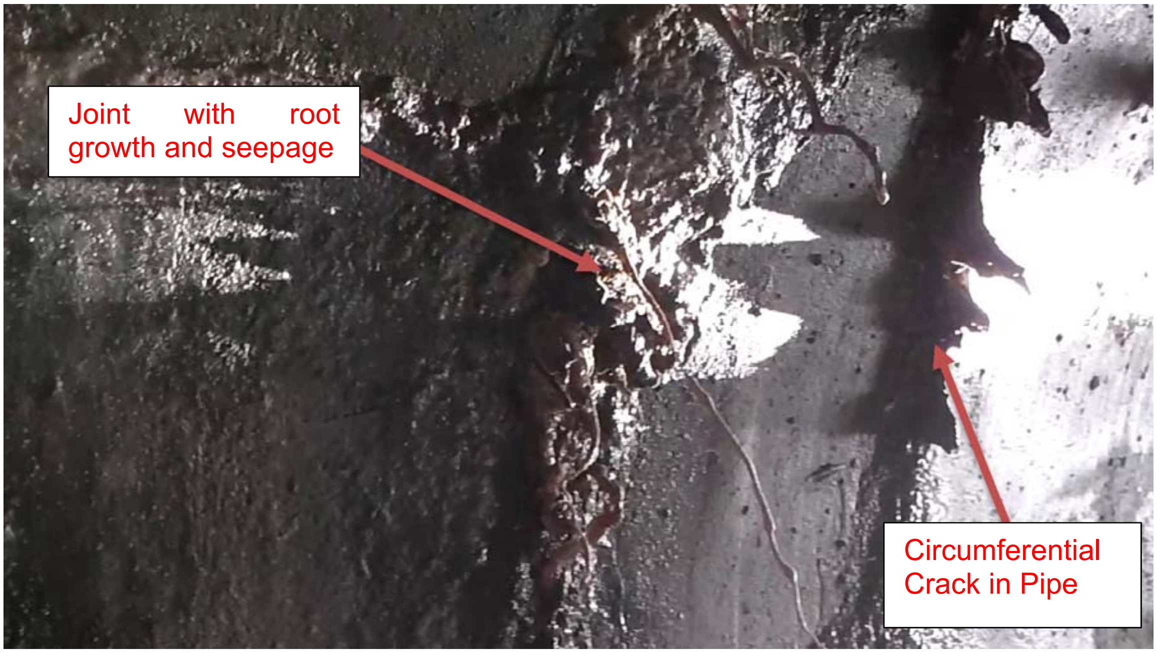
Photo 8: View of Conduit No. 4 taken from the discharge end looking upstream. Note lateral offset of joints and seepage from joints and cracks in pipe. November 9, 2016.

Attachment B

Video Inspection Screenshots

Attachment B
Adobe Creek Dam Outlet Conduit Inspection
Video Inspection

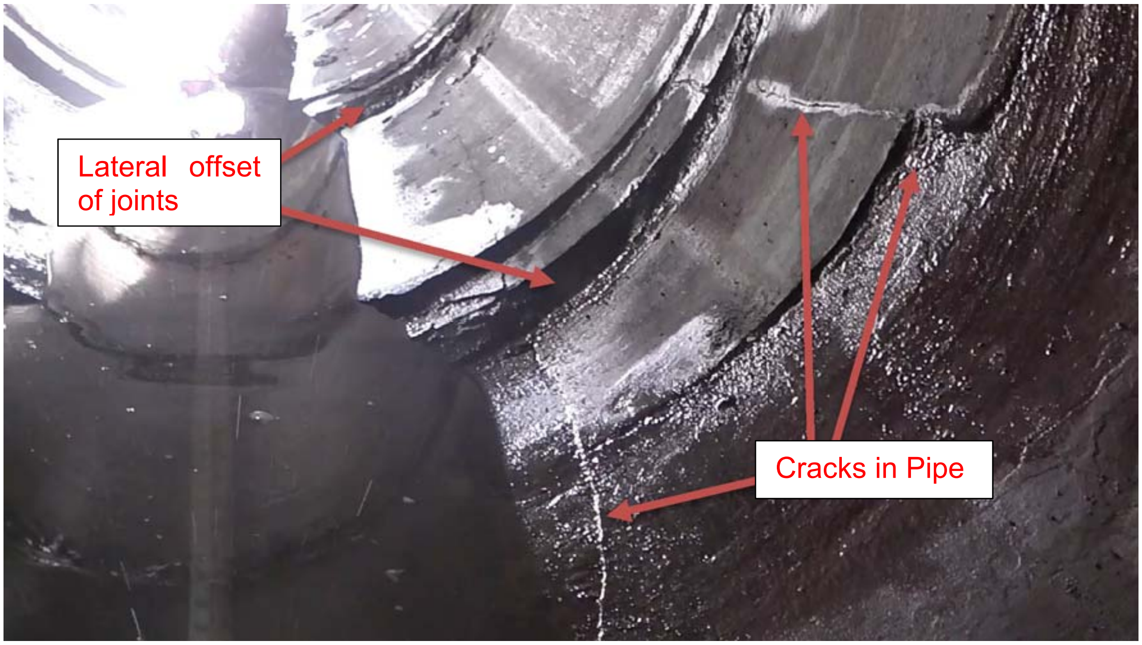
Screenshot 1: View of longitudinal crack running length of pipe section with ¼" lateral displacement, in Conduit No. 1 Station 0+89 feet downstream of gate, looking downstream. November 9, 2016.



Screenshot 2: View of root growth and seepage through joint, with circumferential crack immediately downstream of joint. View is looking left in Conduit No. 1 at Station 0+95 feet downstream of gate. November 9, 2016.

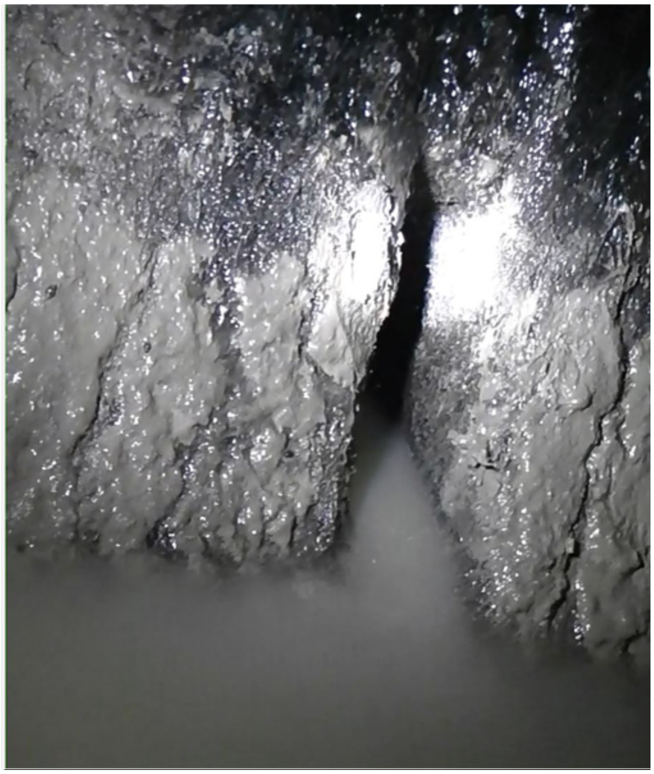
Attachment B
Adobe Creek Dam Outlet Conduit Inspection
Video Inspection

Screenshot 3: View of circumferential crack with seepage and longitudinal crack running length of pipe, in Conduit No. 2 at Station 0+82 feet downstream of gate, looking downstream. Note piece of pipe missing above longitudinal crack. November 9, 2016.



Screenshot 4: View looking downstream in Conduit No. 2 at Station 0+92 feet downstream of gate. Note significant circumferential and longitudinal cracking and lateral offset of joints. November 9, 2016.

Screenshot 5: View looking downstream in Conduit No. 3 at Station 0+81 feet downstream of gate. Note cracking and movement of a piece of the pipe wall. November 9, 2016.



Screenshot 6: Gap in previously repaired pipe joint at bottom.Located in Conduit 4 at Station 0+81 feet downstream of gate. November 9, 2016.

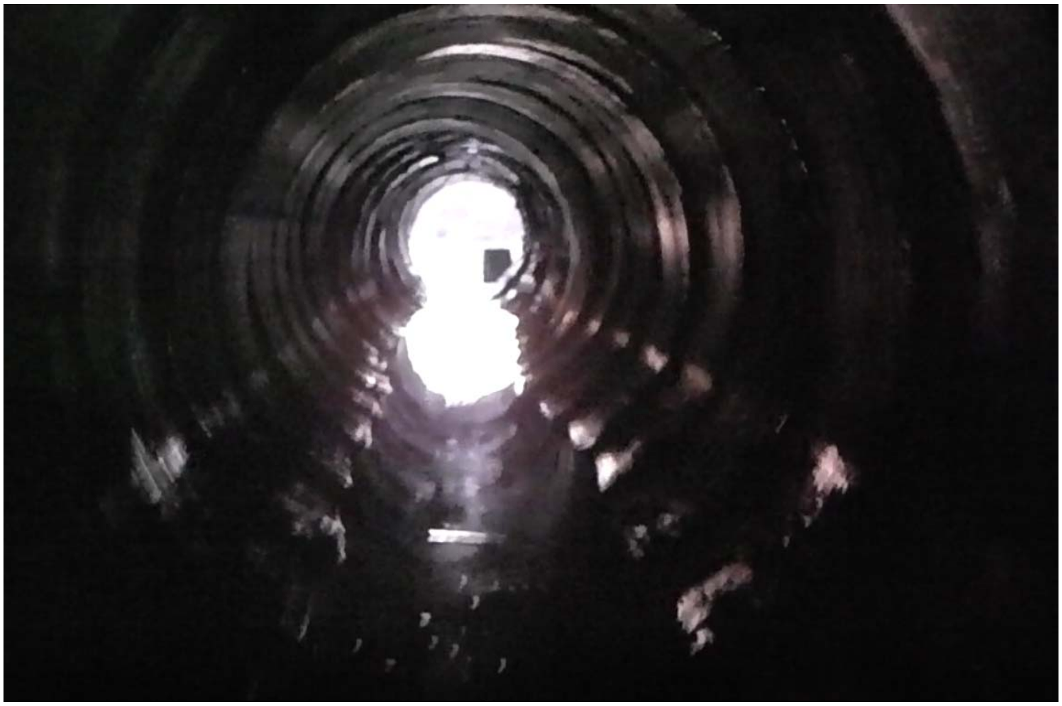
Attachment B
Adobe Creek Dam Outlet Conduit Inspection
Video Inspection

Screenshot 7: View looking downstream in Conduit No. 1 at Station 0+69 feet downstream of gate. Significant seepage, disjointedness and cracking in the pipe was observed from this point to the conduit discharge end. November 9, 2016.

Screenshot 8: View looking downstream in Conduit No. 2 at Station 0+39 feet downstream of gate. View shows cracking in the pipe crown, disjointedness, and movement of pipe sections. November 9, 2016.

Attachment B
Adobe Creek Dam Outlet Conduit Inspection
Video Inspection

Screenshot 9: View looking downstream in Conduit No. 4 at Station 0+23 feet downstream of gate. View shows disjointedness and movement of pipe sections. November 9, 2016.



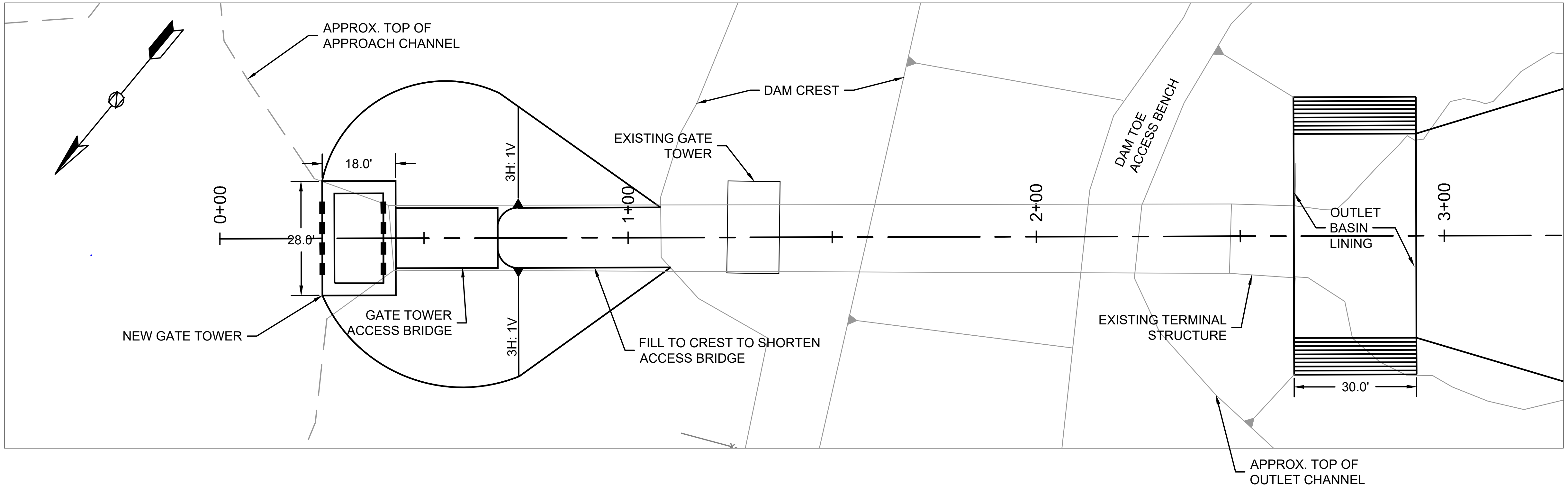
Screenshot 10: View looking downstream in Conduit No. 4 at Station 0+35 downstream of gate. View shows disjointedness and movement of pipe sections. November 9, 2016.

Screenshot 11: View looking upstream at control gate in Conduit No. 3. Note significant leakage around control gate and scour to bottom and sides of pipe. November 9, 2016.

Screenshot 12: View looking upstream at control gate in Conduit No. 2. Note significant scour to pipe imidiately downstream of control gate. November 9, 2016.

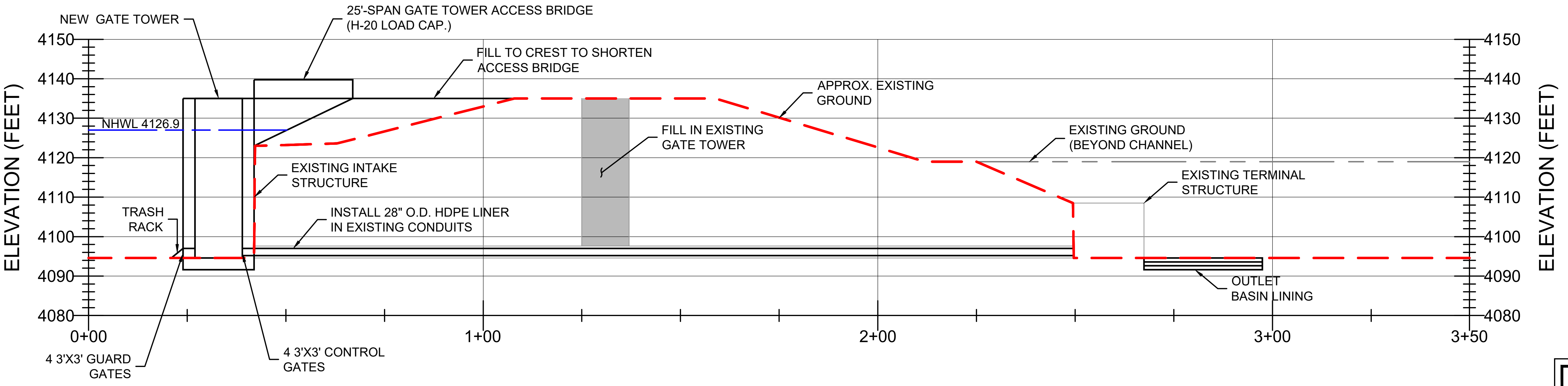
Attachment C

Alternative Conceptual Design Drawings



① LINE EXISTING OUTLET CONDUITS
PLAN VIEW

0 10 30 60
Scale in Feet



② LINE EXISTING OUTLET CONDUITS
SECTION VIEW

0 10 30 60
Scale in Feet

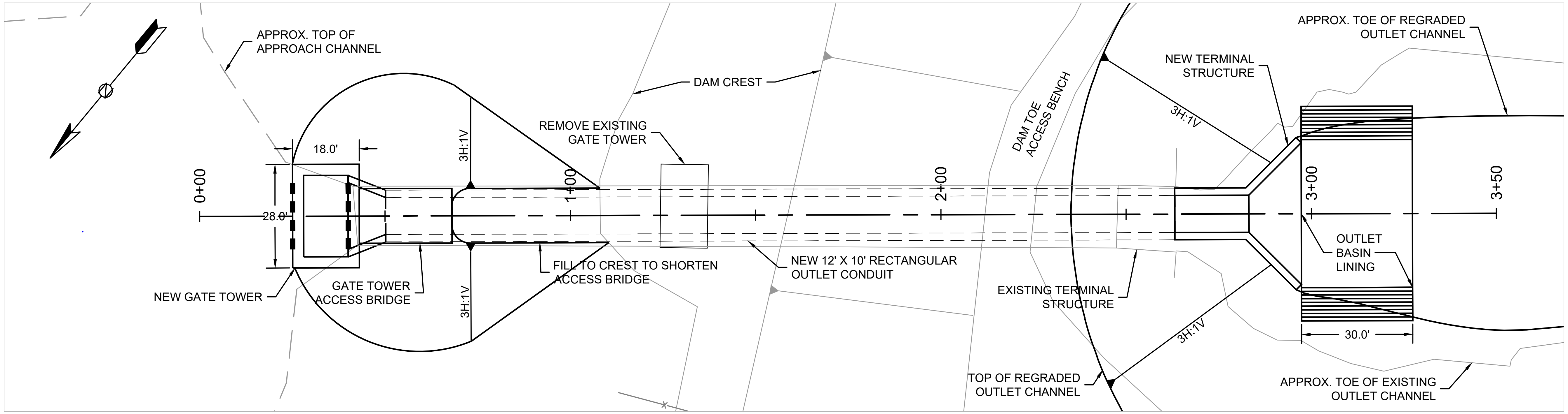
W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

January 2017

Adobe Creek Dam
Conceptual Design
Outlet Lining Alternative

Job Number 1830.04	Figure 1

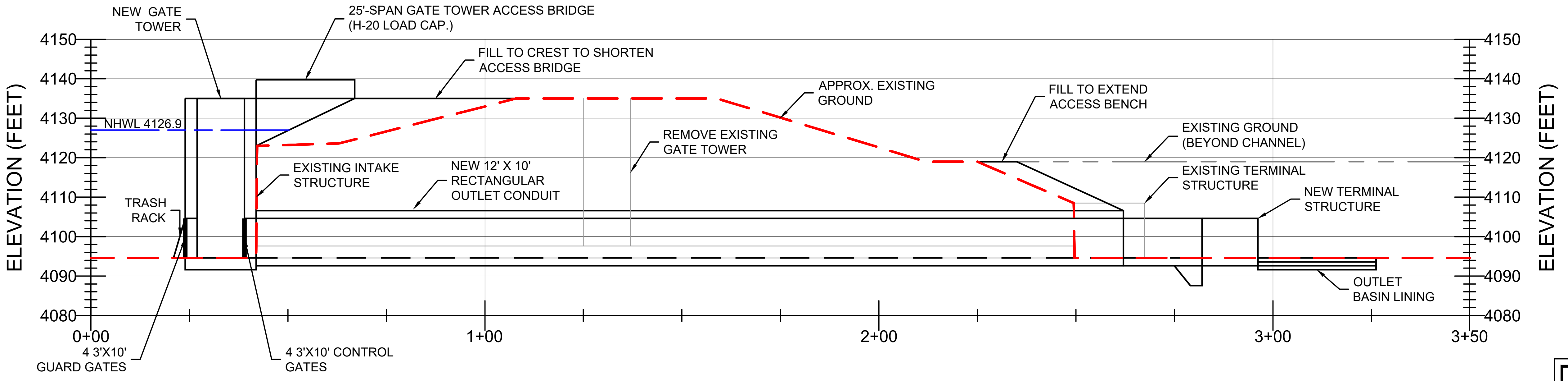
R:\1800\1830\1830.04\DRAWINGS\Boring Plan 1-26-17 11:59am trevor XREFS: AdobeCreekPlaces; Climax_4C; Wheeler Logo;



1 OUTLET CONDUIT REPLACEMENT

PLAN VIEW

0 10 30 60
Scale in Feet



2 OUTLET CONDUIT REPLACEMENT

SECTION VIEW

0 10 30 60
Scale in Feet

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

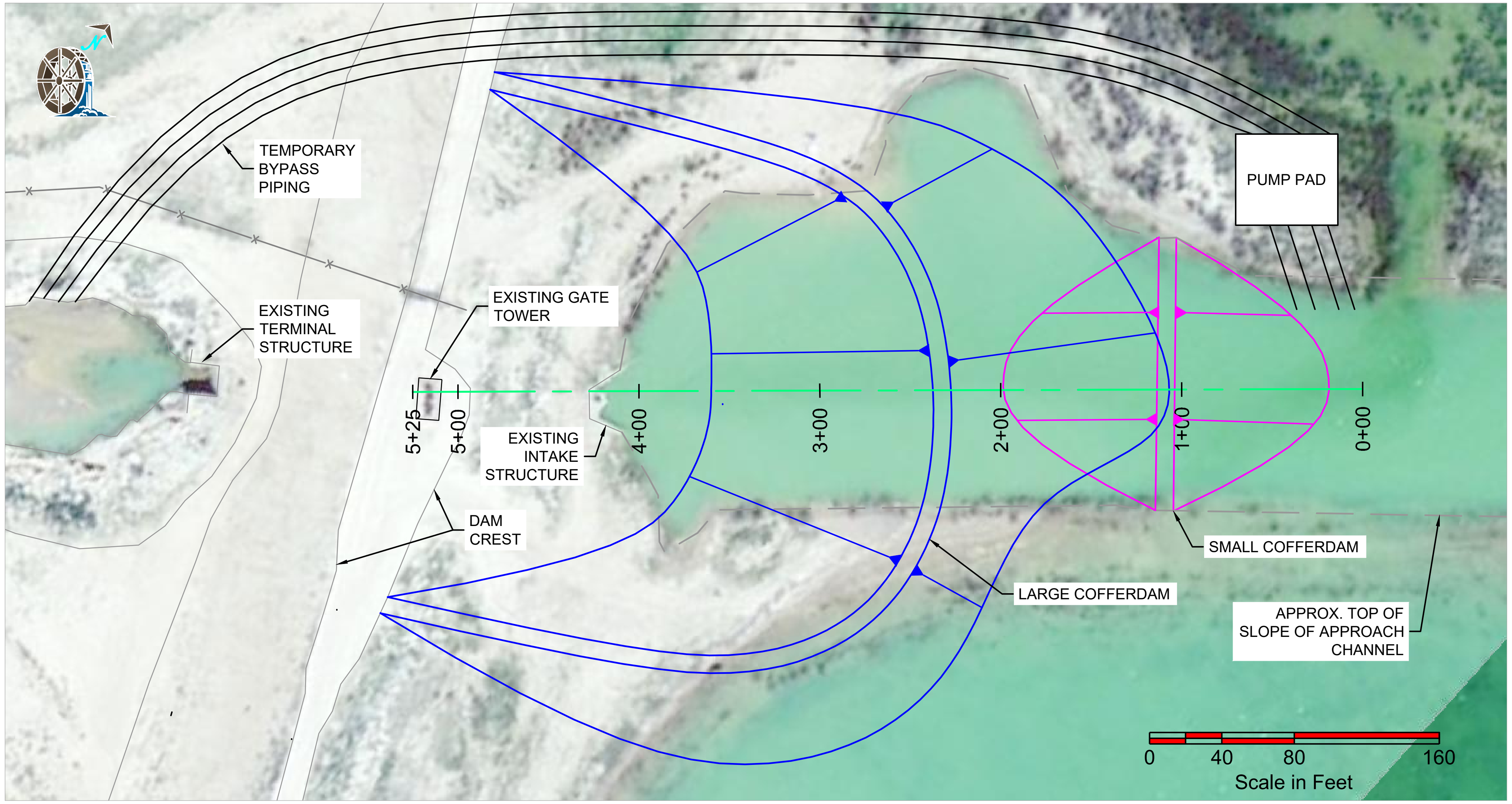
January 2017

Adobe Creek Dam
Conceptual Design
Outlet Replacement Alternative

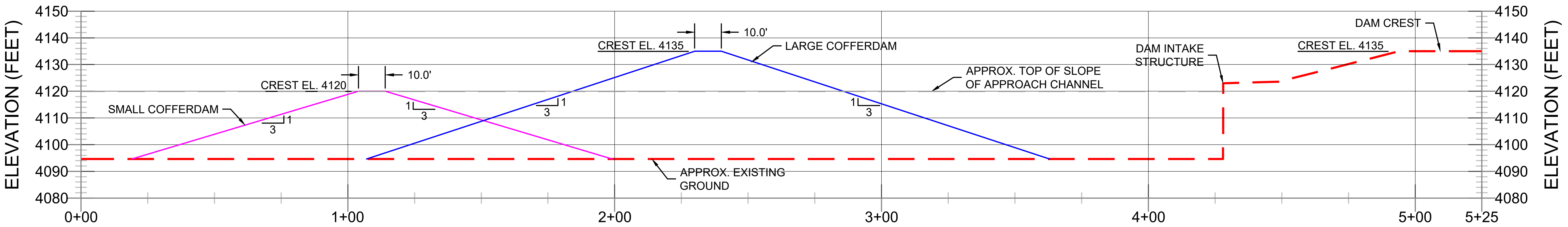
Job Number
1830.04

Figure 2

R:\1800\1830\1830.04\DRAWINGS\Boring Plan 1-26-17 12:21pm trevor XREFS: AdobeCreekPlaces; Climax_4C; Wheeler Logo:



① COFFERDAM DAM OPTIONS
PLAN VIEW



② COFFERDAM DAM OPTIONS
PROFILE VIEW

0 20 40 80
Scale in Feet

January 2017

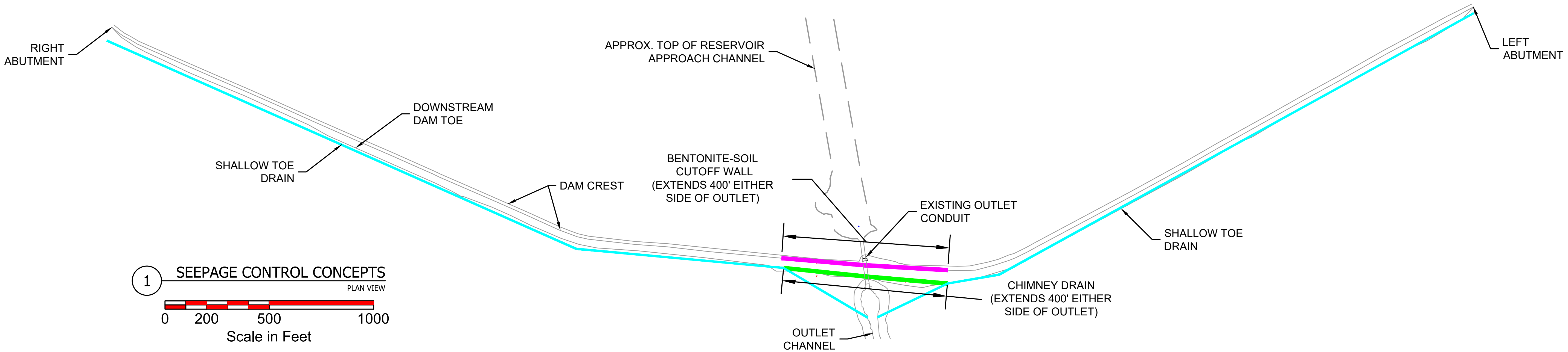
W. W. WHEELER
& ASSOCIATES, INC.
Water Resources Engineers

Adobe Creek Dam
Conceptual Design Options
Temporary Reservoir Control

Job Number
1830.04

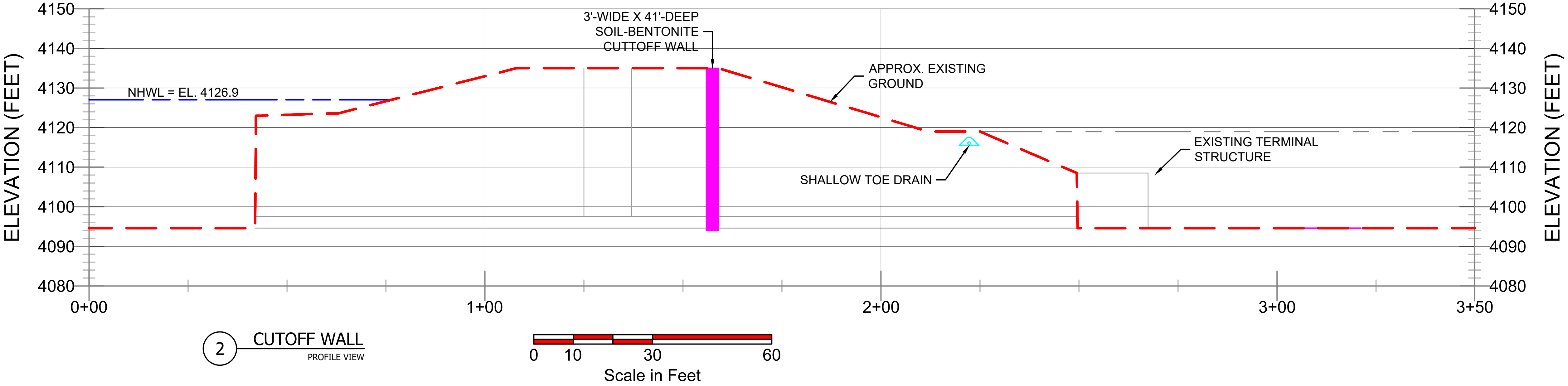
Figure 3

R:\1800\1830\1830.04\DRAWINGS\Boring Plan 1-26-17 01:12pm trevor XREFS: AdobeCreekPlaces; Climax_4C; Wheeler Logo:



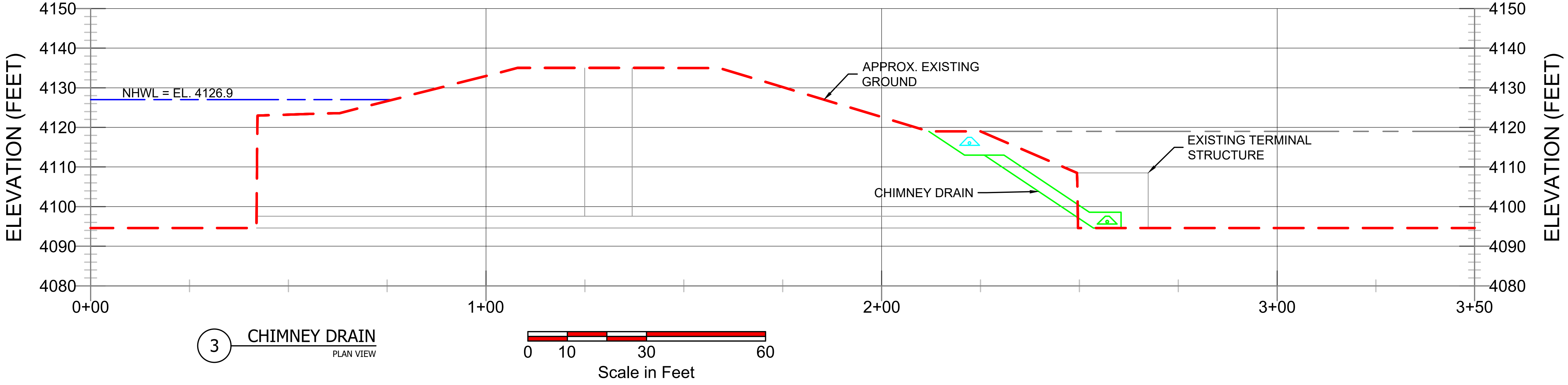
1 SEEPAGE CONTROL CONCEPTS

PLAN VIEW



2 CUTOFF WALL

PROFILE VIEW



3 CHIMNEY DRAIN

PLAN VIEW

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

Adobe Creek Dam
Conceptual Design
Seepage Control Alternatives

January 2017

Job Number
1830.04

Figure 4

R:\1800\1830\1830.04\DRAWINGS\Boring Plan 1-26-17 01:51pm trevor XREFS: AdobeCreekPlaces; Climax_4C; Wheeler Logo;

Attachment D

Alternatives Analysis Cost Opinion

TABLE D.1
ADOBE CREEK DAM
OUTLET WORKS AND SEEPAGE CONTROL REHABILITATION CONCEPTS
COMPONENT COST OPINION LIST

FORT LYON CANAL COMPANY

Item No.	Description	Quantity	Unit	Unit Price	Amount	Markup %	Contingency Markup Total
Preparatory Work - Small Reservoir Control							
1a	Storm Water Management - Erosion and Sediment Control	1	LS	$10,000.00	$10,000	0	$10,000
1b.	Cofferdam Construction and Removal	1	LS	$350,000.00	$350,000	0.1	$385,000
1c.	Temporary Reservoir Control	1	LS	$220,000.00	$220,000	0	$220,000
	Subtotal				**$580,000**		**$615,000**
Preparatory Work - Large Reservoir Control							
2a.	Storm Water Management - Erosion and Sediment Control	1	LS	$10,000.00	$10,000	0	$10,000
2b.	Cofferdam Construction and Removal	1	LS	$1,851,500.00	$1,851,500	0.1	$2,037,000
2c.	Temporary Reservoir Control	1	LS	$220,000.00	$220,000	0	$220,000
	Subtotal				**$2,081,500**		**$2,267,000**
Earthwork- Slurry Wall and Toe Drain Installation							
3a.	Furnish and Install Slurry Cutoff Wall	800	LF	$320.00	$256,000	0.1	$282,000
3b.	Furnish and Install Toe Drain (Main Embankment)	800	LF	$75.00	$60,000	0.1	$66,000
	Subtotal				**$316,000**		**$348,000**
Earthwork- Chimney Drain Installation							
4a.	Furnish and Place Type A Filter Sand	3,150	CY	$60.00	$189,000	0.1	$208,000
4b.	Furnishing and Installing Toe Drain Pipe	800	LF	$75.00	$60,000	0.1	$66,000
	Subtotal				**$249,000**		**$274,000**
Outlet Works - Existing Outlet Modifications and Lining							
5a.	Intake Structure Demolition	1	LS	$9,600.00	$10,000	0	$10,000
5b.	Furnish and Install New Intake Tower with Access Bridge	1	LS	$589,700.00	$590,000	0.05	$620,000
5c.	Outlet Works Conduit Lining and Grouting	1	LS	$672,000.00	$672,000	0.05	$706,000
5d.	Furnish and Install New Outlet Gates	1	LS	$178,200.00	$178,000	0.05	$187,000
5e.	Furnish and Install Outlet Filter Diaphragm	50	CY	$60.00	$3,000	0.1	$3,000
5f.	Furnish and Install Soil Cement lining	260	CY	$180.00	$47,000	0.1	$52,000
5g.	Furnish and Install Intake Trashrack	1	LS	$20,000.00	$20,000	0.05	$21,000
	Subtotal				**$1,520,000**		**$1,599,000**
Outlet Works - Outlet Works Replacement							
6a.	Outlet Excavation	27,000	CY	$8.00	$216,000	0.1	$238,000
6b.	Existing Outlet Demolition	1	LS	$48,800.00	$49,000	0	$49,000
6c.	Furnish and Install New Intake Tower and Access Bridge	1	LS	$589,700.00	$590,000	0.05	$620,000
6d.	Furnish and Install New Outlet Conduit	800	CY	$1,500.00	$1,200,000	0.05	$1,260,000
6e.	Furnish and Install New Intake Tower Slide Gates and Operators	1	LS	$481,000.00	$481,000	0.05	$505,000
6f.	Furnish and Install Outlet Filter Diaphragm	100	CY	$60.00	$6,000	0.1	$7,000
6g.	Furnish and Install New Type II Outlet Basin Soil Cement Lininc	1	LS	$166,800.00	$167,000	0.05	$175,000
6h.	Furnish and Install Intake Trashrack	1	LS	$20,000.00	$20,000	0.05	$21,000
6i.	Canal Overflow Spillway Improvements	1	LS	$521,000.00	$521,000	0.1	$573,000
	Subtotal				**$3,250,000**		**$3,448,000**

TABLE D.1 PROVIDES INDEPENDENT OPINIONS OF PROBABLE DIRECT CONSTRUCTION COSTS FOR EACH COMPONENT
SEE TABLE D.2 AND TABLE D.3 FOR COMPLETE COST OPINIONS FOR EACH REHABILITATION ALTERNATIVE CONSIDERED

TABLE D.2
ADOBE CREEK DAM
OUTLET WORKS AND SEEPAGE CONTROL REHABILITATION CONCEPTS
OUTLET WORKS LINING ALTERNATIVE - OPINION OF PROBABLE COSTS

FORT LYON CANAL COMPANY

Item No.	Description	Quantity	Unit	Unit Price	Amount	Markup %	Contingency Markup Total
Preparatory Work - Small Reservoir Control							
1a	Storm Water Management - Erosion and Sediment Control	1	LS	$10,000.00	$10,000	0	$10,000
1b.	Cofferdam Construction and Removal	1	LS	$350,000.00	$350,000	0.1	$385,000
1c.	Temporary Reservoir Control	1	LS	$220,000.00	$220,000	0	$220,000
	Subtotal				**$580,000**		**$615,000**
Preparatory Work - Large Reservoir Control							
2a.	Storm Water Management - Erosion and Sediment Control	0	LS	$10,000.00	$0	0	$0
2b.	Cofferdam Construction and Removal		LS	$1,851,500.00	$0	0.1	$0
2c.	Temporary Reservoir Control		LS	$220,000.00	$0	0	$0
	Subtotal				**$0**		**$0**
Earthwork- Slurry Wall and Toe Drain Installation							
3a.	Furnish and Install Slurry Cutoff Wall		LF	$320.00	$0	0.1	$0
3b.	Furnish and Install Toe Drain (Main Embankment)		LF	$75.00	$0	0.1	$0
	Subtotal				**$0**		**$0**
Earthwork- Chimney Drain Installation							
4a.	Furnish and Place Type A Filter Sand	3,150	CY	$60.00	$189,000	0.1	$208,000
4b.	Furnishing and Installing Toe Drain Pipe	800	LF	$75.00	$60,000	0.1	$66,000
	Subtotal				**$249,000**		**$274,000**
Outlet Works - Existing Outlet Modifications and Lining							
5a.	Intake Structure Demolition	1	LS	$9,600.00	$10,000	0	$10,000
5b.	Furnish and Install New Intake Tower with Access Bridge	1	LS	$589,700.00	$590,000	0.05	$620,000
5c.	Outlet Works Conduit Lining and Grouting	1	LS	$672,000.00	$672,000	0.05	$706,000
5d.	Furnish and Install New Outlet Gates	1	LS	$178,200.00	$178,000	0.05	$187,000
5e.	Furnish and Install Outlet Filter Diaphragm	50	CY	$60.00	$3,000	0.1	$3,000
5f.	Furnish and Install Soil Cement lining	260	CY	$180.00	$47,000	0.1	$52,000
5g.	Furnish and Install Intake Trashrack	1	LS	$20,000.00	$20,000	0.05	$21,000
	Subtotal				**$1,520,000**		**$1,599,000**
Outlet Works - Outlet Works Replacement							
6a.	Outlet Excavation	0	CY	$8.00	$0	0.1	$0
6b.	Existing Outlet Demolition	0	LS	$48,800.00	$0	0	$0
6c.	Furnish and Install New Intake Tower and Access Bridge	0	LS	$589,700.00	$0	0.05	$0
6d.	Furnish and Install New Outlet Conduit	0	CY	$1,500.00	$0	0.05	$0
6e.	Furnish and Install New Intake Tower Slide Gates and Operators	0	LS	$481,000.00	$0	0.05	$0
6f.	Furnish and Install Outlet Filter Diaphragm	0	CY	$60.00	$0	0.1	$0
6g.	Furnish and Install New Type II Outlet Basin Soil Cement Lining	0	LS	$166,800.00	$0	0.05	$0
6h.	Furnish and Install Intake Trashrack	0	LS	$20,000.00	$0	0.05	$0
6i.	Canal Overflow Spillway Improvements	0	LS	$521,000.00	$0	0.1	$0
	Subtotal				**$0**		**$0**
Miscellaneous Items							
7	Site Reclamation	1	LS	$20,000.00	$20,000	0	$20,000
8	Additional Embankment Toe Drain Installation	6,300	LF	$75.00	$473,000	0.1	$520,000
	Subtotal				**$493,000**		**$540,000**
Total Construction Costs							$3,028,000
9	Mobilization (10% of DCS)	10	%				$302,800.00
10	Unscheduled Items (10% of DCS)	10	%				$302,800.00
DIRECT CONSTRUCTION COSTS							**$3,633,600.00**
INDIRECT COSTS							
11	Construction Contingency (20% of DCS)	15	%				$454,200.00
12	Surveying	1	LS	$20,000.00	$20,000		$20,000
13	Final Design Investigations	1	LS	$50,000.00	$50,000		$50,000
14	Final Design Engineering (8% of DCS)	8	%				$290,688.00
15	Permitting and Administrative Costs (2% of DCS)	2	%				$72,672.00
16	Construction Administration and Engineering (10% of DCS)		%				$363,360.00
TOTAL INDIRECT COSTS							**$1,250,920.00**
TOTAL ALTERNATIVE COSTS (DCS +IC)							**$4,884,520.00**

TABLE D.3
ADOBE CREEK DAM
OUTLET WORKS AND SEEPAGE CONTROL REHABILITATION CONCEPTS
OUTLET WORKS REPLACEMENT ALTERNATIVE - OPINION OF PROBABLE COSTS

FORT LYON CANAL COMPANY

Item No.	Description	Quantity	Unit	Unit Price	Amount	Markup %	Contingency Markup Total
Preparatory Work - Small Reservoir Control							
1a	Storm Water Management - Erosion and Sediment Control	1	LS	$10,000.00	$10,000	0	$10,000
1b.	Cofferdam Construction and Removal	1	LS	$350,000.00	$350,000	0.1	$385,000
1c.	Temporary Reservoir Control	1	LS	$220,000.00	$220,000	0	$220,000
	Subtotal				**$580,000**		**$615,000**
Preparatory Work - Large Reservoir Control							
2a.	Storm Water Management - Erosion and Sediment Control	0	LS	$10,000.00	$0	0	$0
2b.	Cofferdam Construction and Removal		LS	$1,851,500.00	$0	0.1	$0
2c.	Temporary Reservoir Control		LS	$220,000.00	$0	0	$0
	Subtotal				**$0**		**$0**
Earthwork- Slurry Wall and Toe Drain Installation							
3a.	Furnish and Install Slurry Cutoff Wall		LF	$320.00	$0	0.1	$0
3b.	Furnish and Install Toe Drain (Main Embankment)		LF	$75.00	$0	0.1	$0
	Subtotal				**$0**		**$0**
Earthwork- Chimney Drain Installation							
4a.	Furnish and Place Type A Filter Sand	3,150	CY	$60.00	$189,000	0.1	$208,000
4b.	Furnishing and Installing Toe Drain Pipe	800	LF	$75.00	$60,000	0.1	$66,000
	Subtotal				**$249,000**		**$274,000**
Outlet Works - Existing Outlet Modifications and Lining							
5a.	Intake Structure Demolition	0	LS	$9,600.00	$0	0	$0
5b.	Furnish and Install New Intake Tower with Access Bridge	0	LS	$589,700.00	$0	0.05	$0
5c.	Outlet Works Conduit Lining and Grouting	0	LS	$672,000.00	$0	0.05	$0
5d.	Furnish and Install New Outlet Gates	0	LS	$178,200.00	$0	0.05	$0
5e.	Furnish and Install Outlet Filter Diaphragm	0	CY	$60.00	$0	0.1	$0
5f.	Furnish and Install Soil Cement lining	0	CY	$180.00	$0	0.1	$0
5g.	Furnish and Install Intake Trashrack	0	LS	$20,000.00	$0	0.05	$0
	Subtotal				**$0**		**$0**
Outlet Works - Outlet Works Replacement							
6a.	Outlet Excavation	27,000	CY	$8.00	$216,000	0.1	$238,000
6b.	Existing Outlet Demolition	1	LS	$48,800.00	$49,000	0	$49,000
6c.	Furnish and Install New Intake Tower and Access Bridge	1	LS	$589,700.00	$590,000	0.05	$620,000
6d.	Furnish and Install New Outlet Conduit	800	CY	$1,500.00	$1,200,000	0.05	$1,260,000
6e.	Furnish and Install New Intake Tower Slide Gates and Operators	1	LS	$481,000.00	$481,000	0.05	$505,000
6f.	Furnish and Install Outlet Filter Diaphragm	100	CY	$60.00	$6,000	0.1	$7,000
6g.	Furnish and Install New Type II Outlet Basin Soil Cement Lining	1	LS	$166,800.00	$167,000	0.05	$175,000
6h.	Furnish and Install Intake Trashrack	1	LS	$20,000.00	$20,000	0.05	$21,000
6i.	Canal Overflow Spillway Improvements	1	LS	$521,000.00	$521,000	0.1	$573,000
	Subtotal				**$3,250,000**		**$3,448,000**
Miscellaneous Items							
7	Site Reclamation	1	LS	$20,000.00	$20,000	0	$20,000
8	Additional Embankment Toe Drain Installation	6,300	LF	$75.00	$473,000	0.1	$520,000
	Subtotal				**$493,000**		**$540,000**
Total Construction Costs							$4,877,000
9	Mobilization (10% of DCS)	10	%				$487,700.00
10	Unscheduled Items (10% of DCS)	10	%				$487,700.00
DIRECT CONSTRUCTION COSTS							**$5,852,400.00**
INDIRECT COSTS							
11	Construction Contingency (15% of DCS)	15	%				$731,550.00
12	Surveying	1	LS	$20,000.00	$20,000		$20,000
13	Final Design Investigations	1	LS	$50,000.00	$50,000		$50,000
14	Final Design Engineering (8% of DCS)	8	%				$468,192.00
15	Permitting and Administrative Costs (2% of DCS)	2	%				$117,048.00
16	Construction Administration and Engineering (10% of DCS)	10	%				$585,240.00
TOTAL INDIRECT COSTS							**$1,972,030.00**
TOTAL ALTERNATIVE COSTS (DCS +IC)							**$7,824,430.00**