Prepared for:
Wisconsin Division of Facilities Development
Madison, Wisconsin

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Middleton, Wisconsin
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May 2014

WDNR Dam Repair Studies

Yellowstone Dam

WDNR FF No. 33.06

Wisconsin Division of Facilities Development DFD Project No. 13H3H

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1.0 Introduction

The Yellowstone Dam is an integral part of Yellowstone Lake State Park and is an asset to those who enjoy local outdoor recreation. The purpose of this project was to assess the deficiencies at the dam and develop alternatives and probable cost estimates for dam repair work. The project involved field observations, file reviews, topographic survey, data collection, deficiency identification, alternatives development, cost estimating, meetings, and report submittals.

In 1947 a widespread survey of southern Wisconsin was completed to obtain possible locations for artificial lakes. Yellowstone valley was determined to be a possibility. Between then and 1954 most of the planning and engineering design of the dam was completed, and the lake began filling on June 14, 1954. In 1968 the dam was drawdown for a period of 4 weeks to complete maintenance and repair work on the dam slopes, shore, beach, and boat launch areas, as well as a chemical rehabilitation of the fishery. In 1992 the vertical gate's gear reduction system was repaired and the gate was removed and serviced.

The Wisconsin Department of Natural Resources (WDNR) owns and maintains Yellowstone Dam and the park it is located in. Inspections of the dam in 1980, 1989, 2007, and 2011, along with multiple site visits by AECOM staff in 2013 and 2014, have identified a number of issues to be addressed. In addition, a Dam Failure Analysis and Assessment (DFA) was conducted in 2013 by General Engineering Company. According to the results of the DFA, the spillway can pass a 1,000-year storm event if the gate is open. However, one of the main issues covered in this report is that the vertical slide gate is currently not being operated due to difficulty in operation of the gate by park staff during previous attempts.

The Wisconsin Department of Facility Development (DFD) engaged AECOM to evaluate the current condition of Yellowstone Dam and to prepare conceptual alternatives to address the issues identified. The alternatives presented were developed to meet current WDNR dam safety requirements and considering public safety. Opinions of probable costs were also developed. AECOM contracted with Badger State Drilling and JF Brennan Co. to assist in portions of the field evaluations.

The repair and replacement alternatives presented in this report are conceptual. Final design calculations, drawings, and specifications will be required to implement the selected alternatives. The embankment alternatives presented have been evaluated for stability and meet the required factors of safety. The conceptual recommendations for the primary spillway were developed to restore the gate to working condition and meet the required spillway capacity for the dam. Tree removal and rip rap recommendations have limited flexibility for adjusting the locations and quantities as these items should meet current Wisconsin DNR standards. Embankment repair recommendations have flexibility for adjusting the locations and quantities as the existing embankment is currently stable; however, future embankment alterations may be needed if seepage conditions worsen or if embankment soils are mobilized by seepage flows.

<u>Dam Description</u>

The Yellowstone Dam consists of from left to right, looking downstream (Appendix A, Sheet 1):

- A left earthen embankment approximately 1,250 feet long,
- Two fixed crest ogee spillway bays (20'W & 19'W), a vertical slide gate (20'W x 7.6' H), and two fixed crest ogee spillway bays (19'W & 20'W),
- A right earthen embankment approximately 60 feet long, and
- A low level lake drain located approximately 50 feet left of the spillway structure.

Table 1-1 provides a summary of the pertinent information about Yellowstone Dam.

Table 1-1 **Yellowstone Dam Data Summary**	
Drainage Area	41.70 square miles[2]
River Name	Yellowstone River
Dam	
Type	Earthen Embankment
Crest Elevation	841-842 feet[1]
Structural Height	32 feet[2]
Hydraulic Height	21 feet [2]
Upstream Slope	Varies 3H:1V to 4H:1V[3]
Downstream Slope	2H:1V[3]
Length of Embankment	1370 feet[2], 1320 feet[1]
Width of Crest	16 feet[3], 15 to 25 feet[1]
Principal Spillway	
Type & Size	From Left to Right: 20' W fixed ogee, 19' W fixed ogee, 20' W x 7'6" H vertical slide gate, 19' W fixed ogee, 20' W fixed ogee.[3]
Maximum Discharge Capacity	8400 cfs[2]
Spillway Crest Elevation	Ogee: 834.45 feet[1.3] Gate Sill: 826.45 feet[1.3]
Downstream Apron Invert	807.45 feet[1,3]
Auxiliary Spillway	
Type and size	Low Level Lake Drain: 60" diameter CMP, gate structure for 54" x 54" vertical sluice gate.[3]
Upstream/Downstream Invert	808.95 feet[1,3]
Maximum Discharge Capacity	300 cfs[4]
Impoundment	
Impoundment Name	Yellowstone Lake[2]
Normal Pool Surface Area	455 acres[2]
Normal Pool Elevation	834.45 feet[1]
Maximum Pool Storage	6400 acre-feet[2]
Hazard Classification	High[2]

1. AECOM Survey (11/20/2013)
2. WDNR Dams Database
3. Original Design Plans, 1953
4. National Dam Safety Inspection Report, 1981

Note: Elevations are referenced to North American Vertical Datum 1988 (NAVD88)

Basis of Evaluation

AECOM performed the following activities to develop this deficiency and preliminary alternatives evaluation.

- AECOM reviewed the available information relevant to the project including design reports, previous studies, inspection reports, and project drawings provided by the WDNR.
- Visual observations of the embankment, spillway, and surrounding area were completed on two separate site visits (October 15, 2013 and November 25, 2013).
    - The October 15, 2013 site visit was performed by Justin Warner of AECOM, Jeff Klamik of the WDOA and Brent Binder of the WDNR for the purpose of scoping the alternatives study.
    - The November 25, 2013 site visit was performed by Jerry Krueger and Justin Warner of AECOM to further evaluate the site conditions.
- A topographic survey of the dam site was conducted by AECOM (Appendix A, Sheet 1).
- Four soil borings were performed (photo 13) at locations selected by AECOM (See the Site Plan in Appendix A for the boring locations). Four wells were installed in the boreholes to monitor the water elevation and perform hydraulic conductivity tests.
- The soil samples from the borings were returned to the AECOM laboratory for classification and testing. Attachment C contains the boring logs, well diagrams, and soil laboratory test results for representative soil samples.
- Hydraulic conductivity tests were performed on February 13, 2014 by Justin Warner and Damien Hesse of AECOM (photo 14).
- A site visit was conducted on April 14, 2014 by AECOM and J.F. Brennan Co. A remotely operated vehicle (ROV) was used to observe the low level lake drain conduits and gate structure.
- Seepage and stability models for existing conditions and each embankment alternative have been developed using GeoStudio2012 software based on the topographic survey, soil borings, laboratory test results, and well testing data.
- AECOM developed conceptual alternatives and recommendations to address each deficiency.
- AECOM developed opinions of probable costs for each alternative and recommendation using cost information from similar projects, engineering judgment, contractor input, and/or published cost data.

2.0 Existing Condition Evaluation

2.1 Site Visits and Topographic Survey

Jerry Krueger, P.E. and Justin Warner, P.E. of AECOM conducted site visits on October 15, 2013 and November 25, 2013. Observations of the key areas of concern previously identified were conducted, with additional notes taken of other potential issues not identified by park employees or previous inspections. Photographs were taken during the visits. Photographs taken during the site visits are included with descriptive captions in Appendix B. Copies of the field notes are included in Appendix B. All following references to left and right are with respect to looking in a downstream direction.

A topographic surveying was completed for the Yellowstone Dam on November 20, 2013 by AECOM (Appendix A, Sheet 1). The survey data was referenced to benchmarks BM 1012-A and BM 1012-B. BM 1012-A is a bronze disk marked Public Service Commission of Wisconsin (PSC) on top of the west end of the north spillway wing wall. BM 11012-A had an initial recorded elevation of 75.99 feet, PSC Datum on November 21, 1955. It now is referenced to elevation 842.44 feet based on Global Positioning System (GPS) observations referenced to horizontal datum, North American Datum (NAD 83, 2011) and North American Vertical Datum (NAVD 88, which was adjusted in 2007). BM 1012-B is a bronze disk marked Public Service Commission of Wisconsin on top of the west end of the south dam abutment. It had an initial recorded elevation of 76.00 feet, PSC datum on November 21, 1955. The elevation has been adjusted to 842.47 feet based on GPS observations referenced to NAD 83 (2011) and NAVD 88 (2007).

2.2 Field Observations and Identified Deficiencies

<u>Embankment Seepage</u>

Apparent seepage has been observed along the length of the downstream toe of the dam for a significant period of time. The Dam Safety Inspection Report from December 2011, Ref: 33.06, states that from the 2007 inspection to the 2011 inspection the toe seepage has increased although no boils or other visible signs of piping were noticed. However, it was noted that the dense vegetation prevented a complete assessment and extent of the seepage. The water level measurements in the monitoring wells installed near the toe of the dam indict the phreatic water surface is at or slightly above the ground surface at the toe of the dam. The original design drawings indicate a gravel keyway was incorporated into the foundation of the downstream portion of the embankment. The gravel keyway could be allowing seepage water to exit the embankment at the toe as designed. The gravel keyway could also be assisting in minimizing piping of embankment soils.

Seepage through earthen embankments is not unusual and can be controlled through filter materials similar to the gravel keyway at Yellowstone Dam. However, seepage water and surface water runoff at Yellowstone Dam can't be drained from the embankment's toe area because the adjacent parking access road exists at a higher elevation. The access road is essentially blocking drainage of the embankment toe area causing the soils to be saturated and ponding water. The excess water could create excess pressure on the soil which could potentially become unstable as the dam was not designed to have ponding surfacing water at that location. The excess water also prevents park staff from adequately controlling the vegetation as the area is often too wet to use mowing equipment. Unwanted vegetation provides areas for piping along the root system and could compromise the dam's function of restricting water movement.

Vertical Slide Gate

The vertical slide gate located in the center bay of the spillway was last operated in 2012 (photos 4 & 5). The gate is operated with a motor, gear reduction boxes connected by a horizontal shaft, and vertical screws attached to each end of the gate. The system is mounted on structural steel framework that makes up part of the access platform. Park staff attempted to operate the vertical slide gate in the early 1990's and found the gate inoperable. It was discovered that a gear in the gear reduction case was severely damaged. In addition, portions of the framework supporting the hoist system were damaged. The gate and framework were repaired by Terra Engineering and Construction. However, the vertical slide gate is currently not operated due to several issues with the hoist system that arose from a 2012 operation of the gate. More recently, Mr. John Arthur of the WDNR reported several problems during the 2012 operation including electrical, motor disengagement, and chain issues. Mr. Arthur also noted the system seemed to be experiencing excessive loading during operation. In order to avoid loss of lake levels, Mr. Arthur is reluctant to operate the gate until necessary repairs are completed. Based on a review of the original design plans it appears the existing vertical screws have a capacity of 35 tons; however, the overall system is sized to handle 10,000 pounds. The overall capacity of the system is only slightly higher than the weight of the vertical gate not including additional loads caused by water against the gate. We suspect the hoist system may be undersized, causing recurring operational issues.

The operation of this gate is required to meet the minimum spillway capacity requirement equal to a 1,000-year flow. According to park staff, the water surface of the lake has risen to within 2 feet of the embankment crest during high flow periods within the last several years. The gate may have been open approximately 3 inches during these events. Based on past events, former park staff have expressed concerns regarding the possibility of water overtopping the embankment if the gate is inoperable.

Since the additional flow capacity provided by the gate is required to meet the minimum spillway capacity requirement, the gate should be operable at all times and tested regularly to ensure it can be used properly in an emergency. In the event of a significant flood, the current state of the gate and hoist mechanism may not allow enough flow to pass, and the risk of overtopping the embankment could pose an immediate hazard to life and property downstream.

Low Level Lake Drain

The sluice gate access shaft and mechanism is located on the crest of the dam near the left spillway wall. According to the original design drawings, the intake and outlet conduits are 60-inch diameter corrugated metal pipe (CMP) installed in the 1950's. According to Mr. John Arthur of the WDNR, the sluice gate was last operated in the early 1990's. Although Mr. Arthur wasn't present during this event, he was informed by other park staff that a large amount of sediment was expelled from the outlet pipe during the operation.

The sluice gate was operated during a site visit by AECOM on March 17, 2014. The hoist system was greased and the gate was raised approximately 2 inches for approximately 10 minutes. The gate and hoist system appeared to be in good condition and operated smoothly. It was noted that sediment was moving from the outfall into the spillway apron while the gate was open. When the gate was closed it was lowered back to its initial position and sediment flow from the outfall did not continue, indicating that sediment or debris buildup was not present beneath the gate and that the gate is likely sealed properly.

AECOM contracted with JF Brennan Co. to perform underwater observations of the sluiceway pipes and access structure on April 14, 2014. The observations were completed using a remotely operated vehicle (ROV). Visibility was poor during the investigation; however, the ROV was equipped with a sonar scanner that assisted in the assessment of the pipes condition. Overall the pipes appeared to be in fair condition with minimal corrosion. Buckling or deformation of the pipes was not observed visually or with the sonar scan results. The upstream CMP pipe appeared to be in better condition than the

downstream pipe. This can likely be attributed to the variability in water level at the outfall resulting in cyclic air and water exposure. This combination of air and water exposure typically increases corrosion.

The upstream intake is fitted with a trash rack. Based on the sonar scan, it appears that a circular vertical structure may be present at the intake. The downstream half of this vertical structure appeared to be a constructed of a stone headwall consistent with the design drawings. The upstream half of this vertical structure had a weaker sonar return. This may suggest sediment may have filled in portions of the intake channel and a type of sinkhole formed in the sediment during previous gate operations. However, it is unknown if the upstream half of this circular shape is constructed of more substantial materials. It appears that approximately 1 to 2 feet of sediment is present in the upstream conduit. After underwater observations were performed in the upstream conduit and gate structure, the gate was opened approximately one foot. Discharge at the outfall contained significant amounts of sediment. The lack of routine operation of the low level lake drain allows sediment build up within the conduits and gate structure. In addition, routine maintenance and operation of the gate extend the life of the system and confirm operability.

The sonar scan recording of the low level lake drain components will be provided on an electronic data storage device.

Rip Rap

AECOM observed that the rip rap extending from the current water's edge to approximately 15 feet upslope is sparse in most areas. Rip rap prevents wave and ice action from eroding embankment soils and prevents slope instabilities.

Trees and Woody Vegetation

Woody vegetation and trees are overgrown on the right embankment and left groin of the dam. Large roots, particularly when decayed, are pathways for water migration through the dam and increases the potential for internal soil erosion. The trees and woody vegetation in these areas should be removed so that park staff can adequately maintain appropriate erosion-resistant vegetation.

Other Noted Deficiencies

Two benchmarks exist for the Yellowstone Dam and are located on the upstream spillway wing walls. Three benchmarks are required for the dam. Two additional benchmarks are needed remote from the dam and should be referenced to North American Vertical Datum 1988 (NAVD 88).

An Emergency Action Plan (EAP) and Inspection, Operation, and Maintenance (IOM) Plan are required for this dam. These document deficiencies have been noted during previous inspections and to our knowledge have not been completed.

3.0 Subsurface Investigation and Site Characterization

3.1 Field Investigation

Boring Layout

The AECOM subsurface investigation consisted of drilling four (4) borings. Two (2) of the borings were located on the dam crest (borings B-1 and B-3) and two (2) near the downstream toe of the dam (borings B-2 and B-4). The boring locations were selected by AECOM to obtain two representative cross sections through the dam for stability and seepage analysis.

The ground/water surface elevation at each of the as-drilled boring locations was determined by an AECOM survey crew and referenced to the North American Vertical Datum of 1988 (NAVD). The approximate boring and benchmark locations and corresponding ground surface elevations are shown on the Plan and Profile Map (Appendix A, Sheet 1).

Drilling and Sampling Procedures

The borings were completed by a two-person Badger State Drilling, Inc. (BSD) drill crew using a CME-850 drill rig. The borings were advanced using solid stem flight for the first 5 to 7 feet. Temporary steel casing was then installed to maintain the stability of the borehole and the borings were further advanced using rotary wash boring methods. The termination depths of borings B-2 and B-4, located along the downstream toe of the embankment, were 23 and 22 feet, respectively. The termination depths of borings B-1 and B-3, located on the crest of the embankment, were 55 and 51 feet, respectively.

Continuous soil sampling was performed for the entire depth of the borings. Soil samples were obtained using split-barrel sampling techniques in general accordance with ASTM Standard D1586.

A log of the soil samples obtained from the borings was maintained by the drill crew. Soil samples were sealed in the field and returned to our Madison, Wisconsin laboratory for further testing. After completion, all four soil borings were converted into piezometers for the purpose of obtaining long term groundwater measurements and performing hydraulic conductivity tests. Water level observations were obtained on February 13 and April 14 2014,from piezometers B-1 through B-4, and hydraulic conductivity tests were performed in piezometers B-1 and B-3 on February 13, 2014. Copies of the piezometer construction diagrams are contained in Appendix C.

Laboratory Procedures

The soil samples were visually examined and classified by an AECOM Geotechnical Engineer on the basis of texture, grain size distribution, and plasticity. The estimated group symbol included in parentheses following the soil descriptions on the boring logs is in general conformance with the Unified Soil Classification System.

Index tests consisting of moisture content, organic content, Atterberg limits, and grain-size distribution were performed on representative soil samples in general accordance with applicable ASTM standards. Calibrated penetrometer tests were performed on representative portions of selected cohesive soil samples to estimate the unconfined compressive strength. Where granular soils were encountered, the Standard Penetration Test (SPT) resistance values were determined in-situ. Results of the field and laboratory tests were then plotted on boring logs which are contained in Appendix C. The individual laboratory test results completed to date are also contained in Appendix C. Soil samples recovered

from the borings will be retained in our laboratory for a period of two years after which they will be discarded unless specific instructions as to their disposition are received.

3.2 Subsurface Characterization

Subsurface Profile

Based on the soil borings, the subsurface profile generally consisted of embankment fill underlain by alternating layers of native granular, cohesive and limited organic deposits and then weathered bedrock. The subsurface profile is described in greater detail in the following paragraphs.

Embankment Fill

Borings B-1 and B-3 were located at the downstream edge of the embankment crest and were used to characterize the embankment fill properties. From the crest surface to a depth of about 9 to 11.5 feet (elev. 831.7 to 829.3 feet), the embankment fill consisted of cohesive and semi-cohesive deposits of silt (ML) and silty clay (CL) with minor amounts of sand, gravel and organic matter. The relative density of the silt fill was in the loose to medium dense range based on the Standard Penetration Test (SPT) N-values obtained in-situ. The consistency of the silty clay fill was in the stiff to very stiff range based on the unconfined compressive strength estimated from calibrated penetrometer test results. The moisture content of representative silty clay fill samples ranged from approximately 18 to 24 percent.

The cohesive and semi-cohesive fill deposits were underlain by granular fill deposits to depths ranging from 23 to 24 feet (elev. 817.7 to 816.8 feet). The upper 7.5 to 10 feet of granular fill consisted of silty fine to medium sand (SM) with some clay and traces of gravel. The relative density of the silty sand was in the loose to medium dense range based on the SPT results. The lower 4 to 5 feet of granular fill consisted of poorly graded fine to medium sand (SP, SP-SM) with traces of silt and gravel. The relative density of the poorly graded sand was in the loose to dense range based on SPT results. Based on a review of the available design drawings for the Yellowstone Dam, we anticipate that the poorly graded sand layer may be a remnant of the granular drainage layer that was constructed beneath the downstream slope and toe of the embankment. The total depth of fill encountered in borings B-1 and B-3 was approximately 23 to 24 feet.

Borings B-2 and B-4 were located along the downstream toe of the embankment. Boring B-2 did not encounter fill soils. Boring B-4 encountered a 6-inch veneer of topsoil at the surface and then a layer of possible fill to a depth of 1.5 feet (elev. 821.7 feet). The possible fill consisted of silty fine to medium sand (SM) with traces of organic matter. The relative density of the silty sand was in the loose range based on SPT results.

Native Granular and Cohesive Deposits

Native soils were encountered below the embankment fill in borings B-1, B-3 and B-4 and at the surface in boring B-2. The elevation at which native soils were encountered ranged from approximately 823.9 to 816.8 feet. The native soils extended to elevations ranging from about 805.8 to 803.7 feet in borings B-1, B-3 and B-4 and to the termination elevation of 800.9 feet in boring B-2. The native soils generally consisted of a layer of silty clay (CL) underlain by layers of granular material (SM, SP, GP). Limited deposits of organic material were also encountered at several boring locations (described below). The native silty clay was typically in the soft to very stiff range and contained varying amounts of sand, gravel and organic matter. The moisture content of representative silty clay samples ranged from approximately 7 to 40 percent, indicating that the native silty clay may be slightly to moderately compressible. The underlying native granular deposits generally consisted of silty sand (SM), poorly graded sand (SP) and poorly graded gravel (GP) with minor amounts of silt and clay. The relative density of the native granular deposits was in the very loose to medium dense range based on SPT results.

Organic Silty Clay

Native moderately organic deposits were encountered at the ground surface in boring B-2 at the downstream toe to a depth of 3 feet (elev. 820.9 feet), and also from a depth of 7 to 15 feet (elev. 816.9 to 808.9 feet). Organic deposits were also encountered in boring B-1 from a depth of 27 to 33 feet (elev. 813.7 to 807.7 feet). The organic deposits generally consisted of moderately organic silty clay (OL, OH) with trace amounts of sand, peat and wood. The consistency of the organic silty clay was very soft to stiff based on the unconfined compressive strength estimated from calibrated penetrometer test results. Moisture contents of representative organic samples ranged from approximately 64 to 90 percent, indicating that the organic silty clay is at least moderately compressible. The moisture content of the organic silty clay was typically at or near the plastic limit estimated from Atterberg limits tests.

Weathered Bedrock

Bedrock that had weathered to a soil texture was encountered beneath the native granular deposits in borings B-1, B-3 and B-4. The weathered bedrock was encountered at an approximate elevation range of 805.8 to 803.7 feet. Weathered bedrock was not encountered in boring B-2 prior to terminating the soil boring at elevation 800.9 feet. The weathered bedrock was classified as fine to coarse gravel (GP) with some fine to coarse sand based on the recovered split spoon samples. The relative density of the weathered bedrock generally ranged from dense to very dense based on SPT results.

Additional variations to the above general profile were noted. Refer to the individual boring logs in Appendix C for specific information. It should be noted that the stratification lines indicated on the boring logs and the soil profiles were selected on the basis of laboratory tests, field logs, and visual observations of the recovered samples. The stratification lines that occur on the boring logs and soil profiles are in some cases estimated; in-situ, the transition between soil types in both the horizontal and vertical directions may be gradual.

Laboratory Results

Grain size analysis, organic content, and Atterberg limits tests were performed on representative samples obtained from the borings. The results of the grain size analysis, organic content, and Atterberg limits test are summarized in Table 3-1 below.

Table 3-1
Laboratory Index Test Results Summary

Boring No.	Sample No.	Depth Range (ft)	Organic Content (%)	Atterberg Limits			Grain Size				USCS Symbol
				Liquid Limit	Plastic Limit	Plasticity Index	% Gravel	% Sand	% Silt	% Clay	
B-1	6	11.0-13.0	-	-	-	-	0.0	35.0	46.1	18.9	CL
	15	29.0-31.0	12.0	46	105	59	-	-	-	-	OH
B-2	5	9.0-11.0	10.3	31	79	48	-	-	-	-	OH
B-3	10	19.0-21.0	-	-	-	-	0.0	90.2	9.8		SP-SM
B-4	4	6.0-8.0	2.9	22	48	26	-	-	-	-	CL

Groundwater Conditions

The soil borings were converted into piezometers at the completion of drilling operations. Monthly water level measurements were obtained by AECOM field staff in February, March and April of 2014. The groundwater level measurements are summarized in Table 3-2.

Table 3-2
Groundwater Level Measurement Summary

Piezometer No.	Top of PVC Elev. (ft, NAVD 88)	Measurement Date					
		02/13/14		03/17/14		04/14/14	
		Depth (ft)	Elevation (ft)	Depth (ft)	Elevation (ft)	Depth (ft)	Elevation (ft)
B-1	840.43	15.91	824.52	15.84	824.59	15.68	811.31
B-2	826.99	3.23 (ice)	823.76	2.60 (ice)	821.16	2.52	837.88
B-3	840.45	17.07	823.38	16.85	823.60	16.51	823.94
B-4	826.11	3.10 (ice)	823.01	3.30 (ice)	822.81	2.70	823.41
Lake Level	-	-		-	833.4	-	834.9

In-situ rising head hydraulic conductivity tests were completed in piezometers B-1 and B-3 in general accordance with ASTM D 4044 on February 13, 2014. Piezometers B-2 and B-4 were not tested due to the presence of ice within the piezometer riser pipe. The results of the in-situ hydraulic conductivity tests are summarized in Table 3-3 below. The individual test results are contained in Appendix C.

Table 3-3
In-Situ Rising Head Hydraulic Conductivity Test Results

Piezometer No.	Screen Length (ft)	Screen Interval		Screened Soil Type	Hydraulic Conductivity	
		Depth (ft bgs)	Elevation (ft, NAVD 88)		(ft/sec)	(cm/sec)
B-1	10	28.0-38.0	812.7-802.7	OL, GP	9.9E-3	2.66E-1
B-2	10	7.0-17.0	816.9-806.9	CL, OL, SM	Not Tested	
B-3	10	30.2-40.2	810.6-800.6	CL, SM, GP	3.01E-3	9.16E-2
B-4	10	7.0-17.0	816.2-806.2	CL, SM, SP	Not Tested	

As noted in Table 3-3, the wells were generally screened at or above the weathered bedrock layer. The results of the hydraulic conductivity tests are in general agreement with published values for materials of this type (Holtz and Kovacs, 1981).

4.0 Geotechnical, Hydraulic, and Structural Analysis

4.1 Introduction

The global stability of the existing Yellowstone Dam embankment and proposed repair alternatives was evaluated under the following generalized loading conditions:

1. Maximum Storage Pool under Long-Term Steady State Seepage – herein referred to as "normal pool conditions",
2. Maximum Surcharge Pool under Steady State Seepage – herein referred to as "flood pool conditions", and
3. Sudden Drawdown from Maximum Surcharge Pool – herein referred to as "sudden drawdown conditions".

The factor of safety (FOS) against global failure for the above conditions was modeled based on the results of the soil borings, the groundwater measurements and computer-estimated phreatic surfaces (i.e., seepage analysis). The stability models were developed in accordance with the United States Army Corps of Engineers (USACE) Engineering Manual (EM) 1110-2-92 (rev. October 2003). The embankment was not evaluated for stability under earthquake conditions because this area of the United States (Wisconsin Rapids, Wisconsin) is generally not considered seismically active (ref. USACE Engineering Regulation 1110-2-1806). The following subsections outline the methods used to develop the stability models and present the results of the evaluation.

4.2 Embankment Sections and Subsurface Profile

Existing Conditions

Two representative cross sections were developed for the existing Yellowstone Dam earth embankment. The cross section locations were selected based on site observations, survey results and the results of the 2014 AECOM subsurface investigation. The cross sections were generally located in areas of the embankment that were observed to have the steepest downstream slope and/or visual signs of seepage. Cross section A-A' was located toward the left side of the embankment at approximate station 3+48.9. Cross section C-C' was located at approximate station 8+24.3, which is toward the right side of the embankment. The locations of the cross sections are shown on the Plan and Profile Diagram (Appendix A, Sheet 1). The existing embankment geometry at each cross section was developed from the results of the topographic survey completed by AECOM in November 2013 and a review of historical design drawings for areas that were not surveyed (e.g., upstream slope below the water line)

The subsurface profiles at sections A-A' and C-C' were based on the results of the borings completed by AECOM as part of this study. From top to bottom, the embankment subsurface profile generally consisted of sand, silt, and clay fill soils to depths of approximately 23 to 24 feet, then native granular, cohesive and limited organic deposits, and then weathered bedrock. Please refer to the boring logs in Appendix C for more detail regarding the subsurface profile of the Yellowstone Dam embankment.

Proposed Embankment Alternatives

Two repair alternatives and one monitoring/observation alternative are being considered for the Yellowstone Dam embankment. The alternatives are summarized below. A detailed discussion of each embankment alternative is contained in Section 5.0.

Alternative 1: Monitoring/Observation with Weir, Basin, and Drain

This alternative includes regular monitoring and observation of the embankment seepage with the installation of a weir basin and drain near the parking lot. This feature allows park staff to monitor the seepage flow and sediment mobilization. The stability and seepage models presented herein for the existing embankment geometry should be reevaluated if significant changes in the embankment seepage, upstream water level and/or downstream water level are observed.

Alternative 2: Embankment Fill and Toe Drain

This alternative involves raising the grades in the low area between the road and the toe of the dam to allow for adequate vegetation control while maintaining embankment stability. A toe drain system would be installed to direct seepage water to the spillway outlet. The toe drain would run along the toe of the dam for approximately 1,100 feet. The drain would then be trenched under the parking lot for approximately 150 feet. The outlet of the drainage system could be located downstream of the left spillway training wall so that the seepage water is drained directly into the downstream channel without cutting a hole in the current spillway wall. An end apron would be installed where the pipe outfalls to prevent erosion.

Alternative 3: Toe Drain Only

This alternative involves only the installation of a toe drain along the downstream toe of the embankment. The toe drain would be nearly identical to the drain described in Alternative 2. The only major difference would be the installation requirements. Due to the wet soil and dense vegetation along the downstream toe, it is likely that a gravel working pad would be needed along the toe drain alignment to provide temporary support for the equipment used to install the drain.

In order to evaluate the seepage characteristics and global stability of the proposed embankment alternatives, the geometry and subsurface profile at cross section A-A' and C-C' were modified in accordance with the proposed new embankment geometry as described above. The embankment geometry and subsurface profile at section A-A' was assumed to be representative of the general embankment geometry and subsurface profile in the left portion of the embankment. The embankment geometry and subsurface profile at section C-C' was assumed to be representative of the general embankment geometry and subsurface conditions in the right portion of the embankment. A summary of the embankment sections evaluated for seepage and stability is presented in Table 4-1.

Table 4-1
Embankment Sections Evaluated for Seepage and Stability

Geometry	Cross Section	
	A-A'	C-C'
Existing Geometry	Evaluated	Evaluated
Alternative 2	Evaluated	Evaluated
Alternative 3	Evaluated	Evaluated

4.3 Model Development

Embankment Phreatic Surface

The phreatic surface is the position of the water table within an earth embankment. Pore water pressure is positive below the phreatic surface (saturated conditions) and negative above the phreatic surface (unsaturated conditions). The position of the phreatic surface is dependent on several factors including

the hydraulic properties of the embankment materials, the water level at the upstream and downstream sides of the embankment, etc. The position of the phreatic surface is a critical factor in determining the global stability of earth embankments. In accordance with USACE EM 1110-2-92, the global stability of an earth embankment must be evaluated for the unique phreatic surfaces that result from a variety of operating conditions (normal pool, flood pool, sudden drawdown, etc.).

Typically, the position of the phreatic surface is estimated from on-site measurements (piezometers, staff gauges, etc.) or predicted using modeling software. For this evaluation, AECOM used the computer program SEEP/W (Geo-Slope International, Ltd., GeoStudio 2012, Version 8.0.10) to model the flow of groundwater and estimate the position of the phreatic surface within the existing embankment geometry and the proposed repair alternatives. The SEEP/W model was calibrated by comparing the estimated phreatic surface under normal pool conditions for the existing embankment with the limited water level measurements obtained in the piezometers.

The SEEP/W program uses a finite-element approach as applied to fluid flow to simulate the flow of groundwater through porous media. In SEEP/W, the position of the phreatic surface within an earth embankment is estimated by evaluating a finite-element model based on boundary conditions and material hydraulic conductivities input by the user. The methods used to select the appropriate boundary conditions and material hydraulic conductivities for the Yellowstone Dam earth embankment are outlined in Sections 4.3.2 and 4.5.1, respectively.

For normal and flood pool conditions, groundwater seepage through the existing embankment geometry and the embankment repair alternatives was evaluated using a steady state analysis. In a steady state analysis, the boundary conditions are held constant with time. Therefore, a steady state analysis does not predict the timing for which steady state seepage conditions will occur, but rather the long term groundwater conditions that will result from a given set of boundary conditions.

For rapid drawdown conditions, groundwater seepage through the embankment for the alternatives and existing profiles was evaluated using a transient seepage analysis. In a transient analysis, the boundary conditions are typically varied with time. Thus, a transient analysis can predict the magnitude and timing of changes in the embankment phreatic surface under a time-dependent set of boundary conditions.

Seepage Evaluation Boundary Conditions

Groundwater flow through an earth embankment is generally caused by a difference in head between the upstream and downstream boundary of the embankment. Groundwater will generally flow from an area of higher head to lower head. Depending on the surface water conditions, the area of higher head may be located at the upstream (normal or flood pool) or downstream (rapid drawdown) boundary. In SEEP/W, the head difference across an embankment is defined using constant (for steady state analyses) or time-dependent (for transient analyses) head boundary conditions input by the user. Seepage through the existing embankment geometry and proposed repair alternatives was evaluated for three (3) operating conditions: 1) Normal Pool, 2) Flood Pool, and 3) Rapid Drawdown. The head boundaries used to define these operating conditions in SEEP/W are described in detail below.

- **Normal Pool Condition**– Upstream Reservoir (Headwater Boundary Condition) = 835.2 feet NAVD. The upstream reservoir normal pool elevation is based on estimates provided in the Dam Failure Analysis (DFA).
- **Flood Pool Condition** – Upstream Reservoir (Headwater Boundary Condition) = 840.2 feet NAVD. The upstream reservoir flood pool elevation is based on estimates provided in the Dam Failure Analysis (DFA).
- **Sudden Drawdown Condition** – Upstream Reservoir is drawn down from the Flood Pool Condition (840.2 feet NAVD) to an elevation of 812.2 feet NAVD over the course of an hour.

WDNR typically limits standard drawdown rates (for maintenance, etc.) to 6 inches per day or less; therefore, a total drawdown of the reservoir over a period of 1 hour is considered extremely rare and unlikely.

A constant tailwater is generally not maintained on the downstream side of the embankment. Based on visual observations along the downstream toe, the groundwater elevation is likely at or near the surface due to the wetlands area and flat topographic profile downstream of the embankment. In addition, seepage is occurring on the downstream slope above the embankment toe in some areas. To account for this variability in groundwater elevation, the downstream toe and slope face of the embankment were defined as "potential seepage faces" in SEEP/W. A seepage face is an area where water reaches the ground surface and exits the embankment, but cannot pond (pore water pressure equals 0 but constant head is not maintained) because of the typically sloped nature of the face. Seepage faces along the toe and downstream slope face of embankments can be detrimental to slope stability.

Stability Evaluation

The computer program SLOPE/W (Geo-Slope International, Ltd., GeoStudio 2012, Version 8.0.10) was used to evaluate the stability of the existing embankment geometry and the proposed repair alternatives. The SLOPE/W program uses a limit equilibrium approach as applied to the method of slices to determine slope stability. Factors of Safety (FS) for normal and flood pool conditions were computed using the Morgenstern-Price method which satisfies both force and moment equilibrium. For normal and flood pool conditions, the steady state phreatic surface predicted by the SEEP/W program was directly imported into SLOPE/W to determine the slope stability FS.

FS for the sudden drawdown condition were computed using the Morganstern-Price method in conjunction with the Duncan, Wright, and Wong Staged Method of analysis for drawdown conditions (ref. USACE Engineering Manual 1110-2-1902 Section 2-5). The Staged Method requires the input of two embankment phreatic surfaces in order to determine the FS. These consist of: 1) an initial phreatic surface representing the pore water pressure conditions prior to drawdown, i.e., flood pool condition, and 2) a final phreatic surface representing the pore water pressure conditions after drawdown has occurred, i.e. sudden drawdown condition. The "initial" phreatic surface was developed from the results of the steady state SEEP/W analysis for the flood pool condition. The "final" phreatic surface was developed from the results of the transient SEEP/W analysis for the sudden drawdown condition.

4.4 Critical Failure Surface Definition

Slope failures in embankments with seepage are typically characterized as 'rotational', i.e. the failure mass appears to have rotated around an imaginary axis point. Thus, a circular failure, defined by user specified 'entry', 'exit', and radius ranges, was used to estimate potential failure surfaces and corresponding factors of safety in the SLOPE/W model. The entry and exit ranges were each defined by 20 possible entry/exit increments over the range. Additionally, the radius range was defined by 20 possible radius increments over the range. This means that each SLOPE/W model was evaluated for roughly 8000 possible failure surfaces.

For the normal pool and flood pool conditions, the failure surface entry range was located on the crest and upstream reservoir side of the embankment and the failure surface exit range was located on the downstream face of the embankment. The failure mass was assumed to move from left to right (upstream to downstream). For the sudden drawdown condition, the failure surface entry range was located on the crest and downstream face of the embankment and the failure surface exit range was located on the upstream face of the embankment. The failure mass was assumed to move from right to left (downstream to upstream).

The critical failure surface and corresponding FS for each loading conditions was selected using engineering judgment. In order to be considered "critical", a failure surface was required to satisfy at least one (but not necessarily all) of the following criteria:

1. The predicted failure surface intersected the phreatic surface within the embankment (which could lead to progressive failures at an exposed seepage face), or

2. The predicted failure surface intersected the embankment crest above the phreatic surface in such a way that a loss of freeboard would occur (which could lead to overtopping of the embankment), or

3. The predicted failure surface was deep-seated, i.e., the failure surface extended to a minimum depth of 5 feet below the ground surface at its deepest point. Failure surfaces shallower than about 5 feet (i.e., shallow sloughing, surface erosion) are typically considered overly conservative and/or controllable with adequate slope vegetation.

The failure surface with the lowest FS that satisfied at least one of the above conditions was chosen as the critical failure surface. The critical failure surface and corresponding FS for each loading condition is shown on the stability outputs provided in Appendix D.1.

4.5 Material Properties

Hydraulic Conductivity

The material hydraulic conductivities used in the seepage evaluation were estimated, where possible, from the results of in-situ testing completed in the on-site monitoring wells. Where test data was not available, the material hydraulic conductivity was estimated based on accepted engineering correlations with grain size and material type. The material hydraulic conductivities utilized in the seepage analysis are summarized in Table 4-2 below.

Material Strength Parameters

For normal pool and flood pool conditions, the soil profile was modeled using the Mohr-Coulomb failure criterion under drained conditions (i.e., effective stress analysis (ESA)) where excess pore water pressure has fully dissipated. For sudden drawdown conditions, the global stability was evaluated using the Duncan, Wright and Wong Staged Method of analysis which requires both drained and undrained (i.e., total stress analysis (TSA)) material strength parameters for lower permeability soils (silt, clay, etc.), if present.

The material unit weights and strength properties were estimated based on published engineering correlations with material type, Standard Penetration Test (SPT) N-values obtained in-situ, and calibrated penetrometer test results. The material properties used in the SLOPE/W stability models are presented in Table 4-2.

Table 4-2
Material Properties - Seepage and Stability Analysis

Material Description	Unit Weight (lb/ft^3)	Drained Strength Properties		Undrained Strength Properties		Hydraulic Properties	Ref.
		Effective Cohesion, c' (lb/ft^2)	Internal Angle of Friction, ϕ' (deg.)	Undrained Shear Strength, s_u (psf)	Internal Angle of Friction, ϕ (deg.)	Saturated Hydraulic Conductivity, K_{sat} (ft/sec)	
Fill: Silty Clay	130	250	29	2500	0	3.28E-8	[1][3][4][6]
Fill: Silty F-M Sand	120	0	31	0	31	3.28E-4	[1][3][5]
Fill: Pervious Toe Drain (F-M Sand)	120	0	31	0	31	3.28E-3	[1][3][5]
Fill: Rip Rap	135	0	40	0	38	3.28E-1	[1][3][5]
Native Silty Clay	125	150	28	1500	0	3.28E-9	[1][3][4][6]
Silty F-M Sand	120	0	31	0	31	3.28E-4	[1][3][5]
Organic Silty Clay	90	100	20	0	0	3.28E-8	[1][3][6]
Weathered Bedrock	135	0	40	0	38	5.00E-3	[2][3][5]
Toe Grade Fill	120	0	31	0	31	3.28E-3	[1][3][5]

References:
[1] Holtz, R.D. and Kovacs, W.D. *An Introduction to Geotechnical Engineering*. (1981) - Figure 7.6
[2] In-situ rising head hydraulic conductivity test results (B-1 and B-3)
[3] NAVFAC DM 7.1 Table 6
[4] Effective cohesion of silty clay assumed to approximately 10% of undrained shear strength
[5] NAVFAC DM 7.1 Figure 7
[6] FHWA Soils Manual, Vol. 1, Figure 5.21

4.6 Results and Conclusions

The individual seepage and stability outputs for the existing embankment geometry are presented in Appendix D.1. The embankment phreatic surface predicted by the SEEP/W model for the existing embankment under normal pool conditions is in general agreement with the groundwater level measurements obtained from the piezometers.

The stability analysis results for the existing embankment are summarized in Table 4-3.

Table 4-3
Seepage and Stability Analysis Results - Existing Embankment

Section	Factor of Safety(1)		
	Normal Pool Minimum Required FS = 1.5	Flood Pool Minimum Required FS = 1.4	Rapid Drawdown Minimum Required FS = 1.1
A-A'	1.5	1.4	1.2
C-C'	1.6	1.6	1.3

Note: (1) USACE EM 1110-2-1902 requirements for stability.

According to Table 3-1 of USACE EM 1110-2-1902, the following factors of safety are required for earth and rock-fill dams:

- Long-term conditions (normal pool/steady state seepage) = 1.5
- Maximum surcharge pool (flood pool) = 1.4
- Rapid drawdown (drawn down from maximum surcharge pool) = 1.1

Based on these requirements, the embankment is considered stable under all three of the analyzed loading conditions.

As outlined in Section 4.2.2, two embankment alternatives have been proposed to address seepage issues along the downstream slope and toe of the embankment. The individual seepage and stability outputs for the embankment alternatives are presented in Appendix D.2 and D.3. The results of the stability analysis for the alternatives are summarized in Table 4-4.

Table 4-4

Seepage and Stability Analysis Results – Proposed Embankment Alternatives

Alternative No.	Embankment Section	Factor of Safety		
		Normal Pool	Flood Pool	Rapid Drawdown
1	A-A’	Same as Existing Condition		
	C-C’			
2	A-A’	1.8	1.8	1.2
	C-C’	1.9	1.9	1.2
3	A-A’	1.6	1.5	1.2
	C-C’	1.9	1.9	1.2

Note: (1) Left embankment section is represented in the stability evaluation by the cross section A-A’. Right embankment section is represented in the stability evaluation by the cross section C-C’.

Based on the results of the seepage and stability evaluation, the proposed embankment alternatives are considered stable under normal, flood, and rapid drawdown conditions according to the requirements outlined in USACE EM 1110-2-92 Table 3-1. In addition, alternatives 2 and 3 provide a slight increase in overall FS as compared to the existing embankment geometry. This is likely due to the presence of the toe drain which results in a lowering of the phreatic surface along the downstream slope and toe.

5.0 Repair Alternatives and Recommendations

5.1 Embankment Repair Alternatives

Ponding water and seepage through the embankment continues to occur between the downstream toe and the parking lot access road (photos 1 & 2). Continuous seepage creates excess pressure on the embankment soil and could eventually lead to piping, loss of fines and potentially compromising slope stability. Upon exiting the embankment, the excess seepage water is unable to drain because the road downstream from the toe is at a higher elevation. This causes ponding which prevents the park staff from adequately controlling vegetation along the downstream toe during the spring, summer, and fall months. According to the Dam Safety Inspection Report (December 2011, Ref: 33.06), toe seepage increased between the 2007 and 2011 inspections; however, no boils or other visible signs of piping have been observed. However, it was noted that the dense vegetation prevented a complete assessment of the extent and effect of the seepage. If seepage continues and embankment soils begin to be mobilized, the stability of the embankment could worsen.

<u>Alternative 1: Monitoring \ Observation Plan with Weir, Basin, and Drain</u>

This alternative includes the implementation of a monitoring \ observation plan without taking immediate action for repair. The observation and monitoring plan would need to be conducted periodically throughout the course of a year to monitor the seepage conditions as the seasons change. We recommended that a qualified engineer or inspector be hired to conduct a detailed site walk through at least four (4) times per year. Park staff could conduct additional site walks more often. The monitoring \ observation plan would include a visual assessment of seepage through the embankment and measurements of the water levels in the four (4) on-site wells. The dense vegetation in the area is an issue for the monitoring \ observation. We recommended the vegetation be trimmed as often as necessary to allow for ease of observation \ monitoring. A controlled burn could be an option to trimming; however, the wet conditions may reduce the effectiveness of this method. An individual wetland disturbance permit may be required because the area from the upstream embankment crest to beyond the parking lot access road is currently classified as wetlands (Appendix A, Sheet 6).

The WDNR recommends a stilling basin and v-notch weir be installed near the northwest corner of the access road and parking lot intersection to assist in quantifying seepage flows and to monitor for the presence of mobilized embankment soils. A 12-inch solid drain pipe should be installed at the bottom of the basin and extend downstream of the left spillway wing wall. A trench would be excavated through the parking lot and asphalt repair conducted after compacted backfill soils are replaced. The invert of the drain pipe should be placed at a depth of at least 5.5 feet in the stilling basin and sloped toward the outfall. This would allow for a future toe drain connection which would eliminate disturbing the parking lot area again. An end apron should be installed at the outlet.

<u>Alternative 2: Embankment Fill and Toe Drain</u>

This alternative involves raising the grades in the low area between the road and the toe of the dam to allow for adequate vegetation control while maintaining embankment stability (Appendix A, Figure 2 & Sheet 2). This alternative also includes installation of a toe drain to direct seepage water away from the embankment. The fill for this area would likely be placed before the toe drain, since this area is saturated nearly year round. The new fill should be placed from the road toward the toe to allow the equipment to work on the dry, compacted fill. An individual wetland disturbance permit may be required because the area to be filled is classified as wetlands (Appendix A, Sheet 6).

Once the fill is placed, installation of the toe drain could begin. The toe drain system would direct seepage water to the tailwater area. Conceptual components of the toe drain are shown in Appendix A, Sheet 3 for reference. We recommend the toe drain piping consist of slotted 12 inch diameter PVC pipe along the toe of the embankment for approximately 1,100 feet. The drain would then be trenched under the parking lot as solid 12 inch PVC pipe for approximately 150 feet (Appendix A, Figure 2 & Sheet 2). The size of the toe drain pipe is determined based on the amount of flow anticipated. The anticipated flow was calculated based on the material properties of the soil characterized from the two (2) borings at the toe of the embankment. The outlet of the drainage system should be located downstream of the left spillway training wall so that the seepage water is drained directly into the downstream channel without cutting a hole in the existing spillway wall. An end apron should be installed where the pipe outfalls to prevent soil undercutting. The outlet would have to be directed to the tailwater area because the existing grades downstream of the toe and access road are relatively level and would not allow for adequate drainage of the affected area.

Alternative 3: Toe Drain Only

This alternative involves the installation of a toe drain along the downstream toe of the embankment. The toe drain would be identical in type, size, filter material, and location, to the drain described in Alternative 2. A major difference from Alternative 2 would be the access to the toe drain area. Due to the wet soil and dense vegetation in the area it is likely that a gravel surface would be needed along the toe drain footprint to support heavy equipment. Upon completion of the installation the gravel layer could remain as long as a wetland disturbance permit has been obtained. The asphalt in the parking lot that will be removed during drain installation will be replaced.

Embankment Alternatives 2 and 3 present construction issues due to the soft soil and wet area between the toe and the access road. Alternative 2 would likely require filling to proceed from the paved access road towards the embankment toe. Alternative 3 would likely require gravel bedding to be placed along the toe drain footprint to provide heavy equipment a stable working platform. This gravel bedding could be left in place after construction is completed. The area between the embankment crest and paved access road is currently mapped wetlands (Appendix A, Sheet 6). Both Alternatives 2 and 3 will most likely require wetland disturbance permits.

5.2 Vertical Slide Gate

As previously mentioned, park staff are reluctant to operate the vertical slide gate on the spillway due to past failures of the hoist system. The motor and gear reduction boxes appear to be undersized to reliably lift the gate. During the most recent attempt to open the gate in 2012, the motor kicked the breakers off periodically and the electric motor seemed to be straining to lift the gate.

We recommend the motor and gear reduction boxes be upgraded to handle the forces present at the gate (Appendix A, Sheet 4). In addition, the steel framing supporting the hoist pedestals appear to be undersized due to previous damage and subsequent attempts to repair the structural integrity. We recommended that the steel supporting the hoist system be upgraded to handle the anticipated loads (Appendix A, Sheet 5 & photo 16). This would require new steel beams and cross bracing underneath the hoist pedestals. The removable grating that is currently in place between the two hoist stands is difficult to remove in the event that gate repairs are needed. We recommended that while the structural steel in this area is being replaced the removable grates also be redesigned for improved access to the gate components.

We do not anticipate that the vertical gate will require removal during the hoist system upgrades; however, we anticipate a crane capable of reaching and lifting the hoist components and structural steel elements will be needed.

5.3 Low Level Lake Drain

The low level lake drain consists of the gate and hoist access structure, the intake CMP pipe that extends approximately 90 feet from the bottom of the structure, and the outfall CMP that extends approximately 85 feet downstream and exits through the left spillway wing wall (Appendix A, Sheet 1). As mentioned previously, the sluice gate was operated on March 17, 2014 and was functioning as designed (photo 15).

The CMPs of the low level lake drain appeared to be in fair condition with minimal corrosion and no signs of buckling or deformation. The sonar scan results indicate that the upstream pipe is in better condition than the downstream pipe; however, it appears that both pipes are in good working order and do not need repairs at this time. We recommended that the pipes, access structure, and gate condition be assessed at least every 10 years by an ROV or dive team. We also recommended that the low level lake drain operation be tested once per year and that a log be kept of such operations with details about the conditions such as (date, weather, hoist condition, ease operation, sediment discharge characteristics, etc.).

We anticipate Yellowstone Dam's embankment and concrete spillway will remain functional longer than the CMP conduits of the low level lake drain. We estimate the existing CMP conduits will require replacement in approximately 20 years. As such, we are providing a repair alternative and associated costs for a future repair to the low level lake drain conduits.

A potential future repair alternative for the CMPs would include slip lining using rigid HDPE pipe. We anticipate the HDPE pipe installation would occur underwater from the upstream intake using a cable and winch system to pull the new pipe into position. Rigid pipe access is not possible from the downstream outfall because the CMP intersects the outfall structure at an angle. As such, the new pipe installation would be performed in two stages and utilize a pipe plug on the upstream intake to isolate flow from the system while the sluice gate is open. A possible construction sequence is provided below:

- Open the sluice gate to remove the sediments within the gate structure and CMPs,
- Remove the upstream inlet grating,
- Heat fuse the HDPE pipe on the embankment,
- With the sluice gate closed, use a winch and cable system to pull the downstream pipe segment through the intake from the lake side to the gate structure,
- Plug the upstream intake and open the gate to continuing pulling the downstream pipe segment using a winch and cable system at the outfall,
- Continue pulling the downstream pipe just past the sluice gate,
- Close the sluice gate and remove the plug at the intake,
- Install the upstream pipe segment using a cable and winch system to pull the pipe through the intake from the lake side to the gate structure,
- Install a cofferdam around the outfall area and a plug at the upstream intake, and
- Open the sluice gate and dewater both pipes for annulus grouting.

5.4 Rip Rap

Rip rap along the majority of the upstream embankment slope is sparse (photo 8). Rip rap prevents wave erosion and ice damage to the embankment soils. We recommend that additional medium and heavy rip rap be placed to protect the embankment against wave and ice action (Appendix A, Figure 3). A variety of rip rap sizes is preferred to minimize large voids that can expose the embankment soils. The rip rap should be concentrated around and above the normal pool elevation. We recommended that the rip rap extend 5 feet below the normal pool elevation and 7 feet up slope of the normal pool elevation to

protect against periods of high water and ice action. The length of the embankment that is in need of rip rap is approximately 1250 feet. Access to the upstream slope would be from the crest of the dam and the roadway to the left of the embankment. Restoration of the embankment crest soils will likely be needed after placement of rip rap.

5.5 Tree and Woody Vegetation Removal

Trees and woody vegetation are present on the right embankment (photos 9 & 10). The area between the toe of the dam and the roadway also needs to be cleared regularly of woody vegetation (photos 1 & 2). The left downstream groin of the embankment also contains unwanted vegetation (photo 11). The trees and woody vegetation should be removed to an appropriate clearance distance of 20 ft (Appendix A, Figure 3). The root systems of trees and woody vegetation allow for water to more easily migrate through the embankment. Piping along root pathways can reduce the stability of the embankment. Trees and woody vegetation should be removed according to the recommended clearance distance of 20 feet (Dam Safety Inspection December 2011). Stumps and roots should be removed and the resulting voids backfilled with compacted fill. The surface should be restored with topsoil and erosion-resistant plantings to prevent future erosion.

The right embankment has limited access other than by foot. This area would need to be cleared by hand. The cleared woody vegetation and trees could be burned on-site or kept away from the dam embankment and toe. The cut materials should be kept off the embankment because it would provide habit for burrowing animals.

5.6 Other Noted Deficiencies

Benchmarks

Three benchmarks are required by the WDNR for the dam. Two benchmarks are present on the spillway structure and were used for reference during the November 20, 2013 survey. Two additional benchmarks should be established remote from the dam. New benchmark elevations should be referenced to the NAVD 88 and documented with the WDNR Dam Safety Engineer. It was determined in the March 12, 2014 meeting between the DFD, WDNR, and AECOM that benchmarks could be completed by a contractor while conducting other work at the site and should be included in their scope of work at that time.

Emergency Action Plan (EAP)

An EAP is required by NR 333.07. This document is necessary to ensure proper actions of the dam owner and local, state, or federal organizations in the case of an emergency. It was determined in the March 12, 2014 meeting between the DFD, WDNR, and AECOM that WDNR staff develop the EAP.

Inspection, Operation, and Maintenance (IOM) Plan

An IOM is required by NR 333.07. This document is to insure that all activities related to inspection, operation, and maintenance of the dam are specified clearly and list who is responsible for oversight of each action. It was determined in the March 12, 2014 meeting between the DFD, WDNR, and AECOM that WDNR staff will develop the IOM.

6.0 Opinion of Probable Costs

AECOM has developed opinions of probable costs for the alternatives and recommendations to repair the Yellowstone Dam presented in this evaluation. Our cost estimates include provisions for, mobilization, contingency, remote access, final engineering design, DFD management fee, and construction resident engineering. Land acquisition costs, if necessary, are not included. Table 6-1 summarizes our opinions of probable costs for the repair recommendations. Detailed worksheets of our opinions are included in Appendix E.

Table 6-1
Summary of Probable Costs
Yellowstone Dam

Deficiency	Alternative	Alternative Description	Opinion of Probable Cost (2016 Dollars)
Embankment Seepage	Alternative 1: Monitoring with Weir, Basin, and Drain	Implement an observation \ monitoring plan without taking immediate action to correct the seepage. Vegetation clearing is recommended to increase the visibility of the slope. Install a stilling basin with v-notch weir at the corner of the parking lot and access road. Install a 12-inch drain pipe under the parking lot and an end apron downstream of the spillway wing wall.	$4,400 (Annually) $35,100 (Weir, Basin, and Drain)
	Alternative 2: Toe Drain and Grade Fill	Install a toe drain along the downstream toe of the slope to allow for excess seepage water to be drained away from the slope. Place fill in between the embankment and the road to raise the grades to a 1% slope for adequate surface water drainage away from the embankment.	$415,500
	Alternative 3: Toe Drain Only	Install a toe drain along the downstream toe of the slope to allow for excess seepage water to be drained away from the slope.	$120,900
Vertical Slide Gate	Not Applicable	The hoist system, in particular the motor and gear boxes appear to be undersized. We recommended that new gear boxes and motor be installed to adequately handle the forces present at the vertical gate.	$183,000
Low Level Lake Drain - Observation	Not Applicable	Hire an ROV or dive team to assess the pipes, gate, and access structure at least every 10 years. Park staff should operate and test the gate at least every year and this item should be included in the IOM.	$14,700

Table 6-1 (cont.)
Summary of Probable Costs
Yellowstone Dam

Deficiency	Alternative	Alternative Description	Opinion of Probable Cost (2016 Dollars)
Low Level Lake Drain – Future Slip Lining	Not Applicable	We anticipated that the low level lake drain conduits will need to be slip lined in the future.	$432,700
Rip Rap	Not Applicable	A layer of rip rap is needed along the entire slope length. Restoration of the embankment crest will likely be needed after placement of rip rap.	$143,700
Tree and Woody Vegetation Removal	Not Applicable	The right embankment and left groin of the dam have significant tree and woody vegetation. These areas should have a 20 foot clearing zone from the dam embankment. Stumps should be removed and the voids backfilled with compacted soil and seeded with erosion resistant vegetation.	$27,700
Benchmarks	Not Applicable	Two (2) new benchmarks should be established off the dam. New benchmark elevations should be referenced to the NAVD 88 and documented with the WDNR Dam Safety Engineer.	$9,700

These opinions are based on 2014 unit prices for similar projects, engineering judgment, and/or published cost data. The costs have been escalated at 5% per year for a period to 2 years to arrive at the costs anticipated to be incurred in 2016. Costs include mobilization, contingency, remote access, final engineering design, DFD management fee, and construction resident engineering. Actual bids and project costs may vary based on contractor's perceived risk, site access, season, market conditions, and prevailing wage and unit prices at the time of bidding. No warranty concerning the accuracy of costs presented herein are expressed or implied.

7.0 Conclusion and Recommendations

Table 7-1 summarizes the embankment alternatives and repair recommendations for Yellowstone Dam. We have also included construction issues, advantages, disadvantages and probable costs for each activity in Table 7-1. Table 7-2 provides a summary of the preferred repair alternatives, associated costs, and a suggested timeline for implementation.

7.1 Embankment

The embankment seepage has been a previously noted deficiency for this dam (Inspection Reports: 2007 & 2011). As of the 2011 inspection report and upon AECOM site visits no boils or sediment movement have been observed. However, the continuing seepage could present an issue if soil is mobilized or the seepage increases. We recommend an observation \ monitoring plan for the immediate future. The observation and monitoring should be conducted by a qualified individual and we recommended that this be completed quarterly. It may be beneficial to increase the rate of visual observations done by park staff between the formal inspections to ensure that seepage and ponding is being monitored more regularly. A stilling basin and v-notch weir should be installed at the corner of the parking lot and access road with a pipe drain underneath the parking lot. This feature would allow for monitoring and recording of the flow and sediment movement from the ponding area. We recommend that action be taken in the future to remedy this issue if significant changes in seepage occur or if soil piping is observed. This report outlines two alternatives that could address the seepage and ponding water. The current wetland classification for this toe area would most likely require a wetland disturbance permit before construction in this area can begin (Appendix A, Sheet 6). We recommended that vegetation is this area be routinely trimmed to provide improved monitoring of the seepage at the toe of the dam.

7.2 Vertical Slide Gate

The spillway capacity gained by opening the vertical slide gate is required to meet the 1,000 year flow requirement for a high hazard dam. The current gate hoist system appears to be undersized and has had difficulty lifting the gate in past attempts. We recommended that the hoist system be upgraded to an appropriate capacity to routinely and reliably operate the vertical gate. The structural steel supporting the hoist pedestals has been damaged during hoist operations in the past. We recommended that the steel beams that support the hoist system be replaced. The current system of removable grates is difficult to access and remove by park staff. Since the structural steel will be replaced we recommended that the grate system be updated at the same time.

7.3 Low Level Lake Drain

The low level lake drain gate and hoist system appear to be operable and functioning as designed. The hoist system was tested on March 17, 2014 by AECOM and the pipes were observed on April 14, 2014 by JF Brennan Co. and AECOM. The low level lake drain pipes appear to be in acceptable condition based upon the sonar scan results and the limited visibility video that we observed on-site. Based on this assessment we recommend that the pipe be viewed by an ROV or dive team at least every 10 years to determine the on-going condition of the pipes. We also recommend that the sluice gate be tested every year. A testing schedule should be included in the Inspection, Operation, and Maintenance (IOM) plan and a log of the important details of each test should be kept (e.g. date, weather, hoist condition, ease of gear turning, is there sediment discharge, etc.).

We are not recommending repairs be performed to the low level lake drain conduits at this time; however, we anticipate repairs to the conduits will be necessary in approximately 20 years. As such, we recommend slip lining the conduits with rigid HDPE pipe in the future.

7.4 Rip Rap

Rip rap on the upstream slope is needed to prevent ice and wave damage. We recommend that supplemental medium to large riprap be placed along the entire length of the slope. The rip rap should be placed 5 feet below the normal water elevation and 7 feet upslope. Restoration of the embankment crest soils will likely be needed after placement of rip rap due to heavy equipment operations.

7.5 Tree and Woody Vegetation Removal

Tree and woody vegetation removal is needed on the right embankment and left groin. Tree roots provide pathways for water and provide shelter for burrowing animals. The right embankment clearing would need to be conducted by hand because of limited access, while the left groin could be completed with the assistance of tree clearing equipment.

7.6 Other Noted Deficiencies

Two benchmarks are required remote from the dam and should be referenced to NAVD 88 datum. An EAP and IOM are required for this dam as soon as possible. WDNR staff will develop the EAP and IOM.

Table 7-1
Summary of Alternatives

Deficiency	Alternative	Description	Construction Issues	Advantages	Disadvantages	Opinion of Probable Cost (2016 dollars)
Embankment Seepage	Alternative 1: Monitoring with Weir, Basin, and Drain	Implement an observation \ monitoring plan without taking immediate action to correct the seepage. Vegetation clearing is recommended to increase the visibility of the slope. Install a stilling basin with a V-notch weir at the corner of the parking lot and access road. Install a 12-inch drain pipe under the parking lot and an end apron downstream of the spillway wing wall.	Difficult to assess seepage with the current vegetation. Controlled burn may be difficult due to the dense, wet vegetation. An individual wetland disturbance permit may be required.	Least expensive embankment alternative. V-notch weir provides simple flow estimates for toe seepage.	Park staff would continue to have difficulty managing the vegetation in this area. Ongoing observation requirements. Future repair may be required. An individual wetland disturbance permit may be required.	$4,400 (Annually) $35,100 (Weir, Basin, and Drain)
	Alternative 2: Toe Drain and Grade Fill	Install a toe drain along the downstream toe of the slope to allow for excess seepage water to be drained away from the slope. Place fill in between the embankment and the road to raise the grades to a 1% slope for adequate surface water drainage away from the embankment.	An individual wetland disturbance permit may be required.	Solution for toe seepage and water ponding. Easier for park staff to control vegetation. Preserves embankment stability.	Most expensive embankment alternative. An individual wetland disturbance permit may be required.	$415,500
	Alternative 3: Toe Drain Only	Install a toe drain along the downstream toe of the slope to allow for excess seepage water to be drained away from the slope. This should reduce the ponding water and may allow park staff to control vegetation in this area.	This is a wet area year round. May need gravel fill to access trench. An individual wetland disturbance permit may be required.	Less expensive than toe drain and grade fill. Easier for park staff to perform routine vegetation control. Preserves embankment stability.	An individual wetland disturbance permit may be required. Wet embankment toe condition may remain.	$120,900
Vertical Slide Gate	Not Applicable	The hoist system, in particular the motor and gear boxes appear to be undersized. It is recommended that new gear boxes and motor be installed to adequately handle the forces present at the vertical gate. Upgraded steel supports are also recommended.	A large crane, near the spillway, will be needed for installation of vertical gate components and structural steel sections.	This repair remedies the spillway deficiency and allows park staff to control the lake level during high flow seasons.	Large crane will be needed to reach the middle of the spillway walkway.	$183,000
Low Level Lake Drain - Observation	Not Applicable	Hire an ROV or dive team to assess the pipes, gate, and access structure at least every 10 years. Park staff should operate and test the gate every year. This item should be included in the IOM.	None anticipated	Small time commitment and low expense to investigate every 10 years and test sluice gate every year.	If issues are uncovered in the future more expensive repairs will be required to restore the hydraulic and structural capacity of the CMPs.	$14,700
Low Level Lake Drain - Future Slip Lining	Not Applicable	It is anticipated that the low level lake drain conduits will need to be slip lined in the future.	The outlet of the conduit structure complicates installation as the pipes would be inserted from the upstream intake.	Repair would allow continued use of the low level lake drain for future reservoir control and prevents potential embankment failure should CMPs fail.	High cost. Underwater construction.	$432,700
Rip Rap	Not Applicable	A layer of rip rap is needed along the entire upstream slope length. Restoration of the embankment crest soils will likely be needed after placement of rip rap.	Restoration of the crest soils may be needed after rip rap placement.	Protects the embankment from wave and ice erosion.	Restoration of the embankment crest soils will likely be needed after placement of rip rap.	$143,700
Tree and Woody Vegetation Removal	Not Applicable	The right embankment and left groin of the dam have significant tree and woody vegetation. These areas should have a 20 foot clearing zone from the dam embankment. Stumps and roots should be removed and the voids backfilled with compacted soil and erosion resistant vegetation.	Access to right embankment is limited and work would likely be performed by hand.	Removes unwanted vegetation and restores embankment integrity. Reduces seepage potential and animal burrows.	The right embankment is only accessible by foot which increases the cost of tree and woody vegetation clearing.	$27,700
Benchmarks	Not Applicable	Two (2) benchmarks should be established remote from the dam. New benchmark elevations should be referenced to the NAVD 88 and documented with the WDNR Dam Safety Engineer.	None anticipated	Benchmarks allow reference elevations to monitor the dams operations and performance.	None anticipated	$9,700

Table 7-2
Preferred Repairs Summary and Suggested Timeline

Deficiency	Alternative	Within 1 year	1-3 Years	3+ Years	On-Going Monitoring
Embankment Seepage	Alternative 1: Monitoring with Weir, Basin, and Drain		$35,100 (Weir, Basin, and Drain)		$4,400 (Annually)
	Alternative 2: Toe Drain and Grade Fill			$415,500	
	Alternative 3: Toe Drain Only			$120,900 (preferred)	
Vertical Slide Gate	Not Applicable	$183,000			
Low Level Lake Drain - Observation	Not Applicable				$14,700 (Every 10 yrs.)
Low Level Lake Drain - Future Slip Lining	Not Applicable			$432,700	
Rip Rap	Not Applicable		$143,700		
Tree and Woody Vegetation Removal	Not Applicable		$27,700		
Benchmarks	Not Applicable		$9,700		
Preferred Repairs Total[1]		$183,000	$181,200	$553,600	Not Applicable[2]
Cumulative Project Total (Preferred)		$917,800[2]			

Notes:
1. The Preferred Repair Total is the sum of the probable costs including the preferred alternative for deficiencies that have more than one repair alternative. The recommended alternative is identified by (Preferred) in the Table.
2. On-going monitoring cost are not included in the Preferred Repairs Total or Cumulative Project Total

8.0 References

General Engineering Company, 2013, Dam Failure Analysis and Assessment for Yellowstone Dam, September 2013.

Geo-Slope International, Ltd., 2012, SEEP/W – GeoStudio 2012, Version 8.0.10.

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Holtz, R., and Kovacs, W., 1981, Introduction to Geotechnical Engineering. Prentice-Hall, Englewood Cliffs, New Jersey.

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WDNR Dams Database, Yellowstone Dam Detailed Information. Field File No. 33.06. Dam Key Sequence No. 72

WDNR Parks, Yellowstone Lake State Park History, Last Revised: Tuesday May 1, 2012 http://dnr.wi.gov/topic/parks/name/yellowstone/history.html.

Appendix A – Figures and Plans

Figure 1 – Site Location Diagram

Sheet 1 – Plan and Profile

Figure 2 – Toe Drain and Grade Fill Location Diagram

Sheet 2 – Toe Drain and Grade Fill Plan and Profile

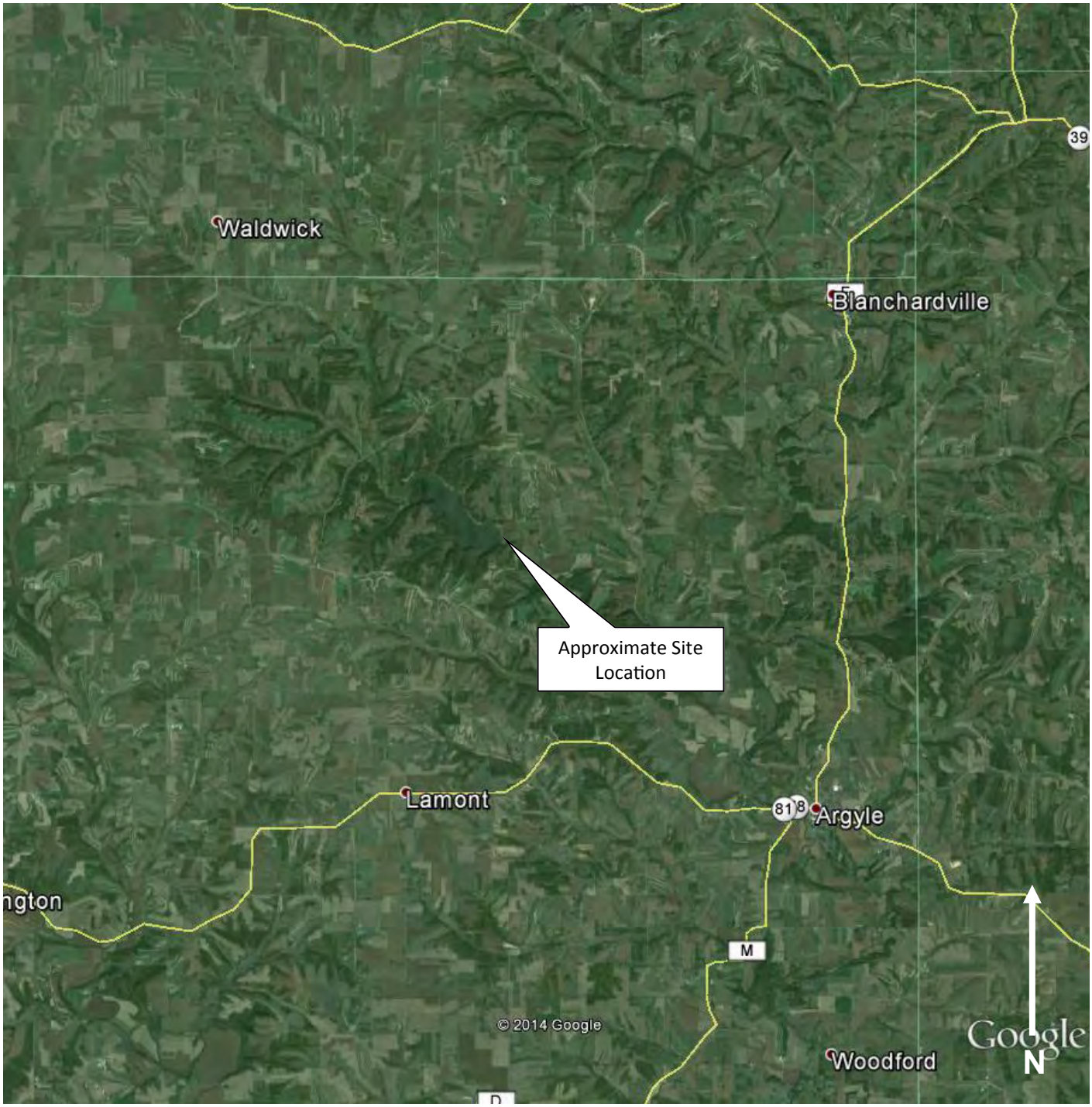
Sheet 3 – Toe Drain Conceptual Drawing

Sheet 4 – Vertical Slide Gate Gear Box and Motor Repair

Sheet 5 – Vertical Slide Gate Structural Steel Upgrade

Figure 3 – Rip Rap and Tree Removal Location Diagram

Sheet 6 – Wetland Areas



Note: Map created with Google Earth Pro
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Miles
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SITE LOCATION DIAGRAM

YELLOWSTONE DAM

YELLOWSTONE LAKE STATE PARK

BLANCHARDVILLE, WI

Drawn: DEH 04/01/14

Checked: GAK 4/30/14

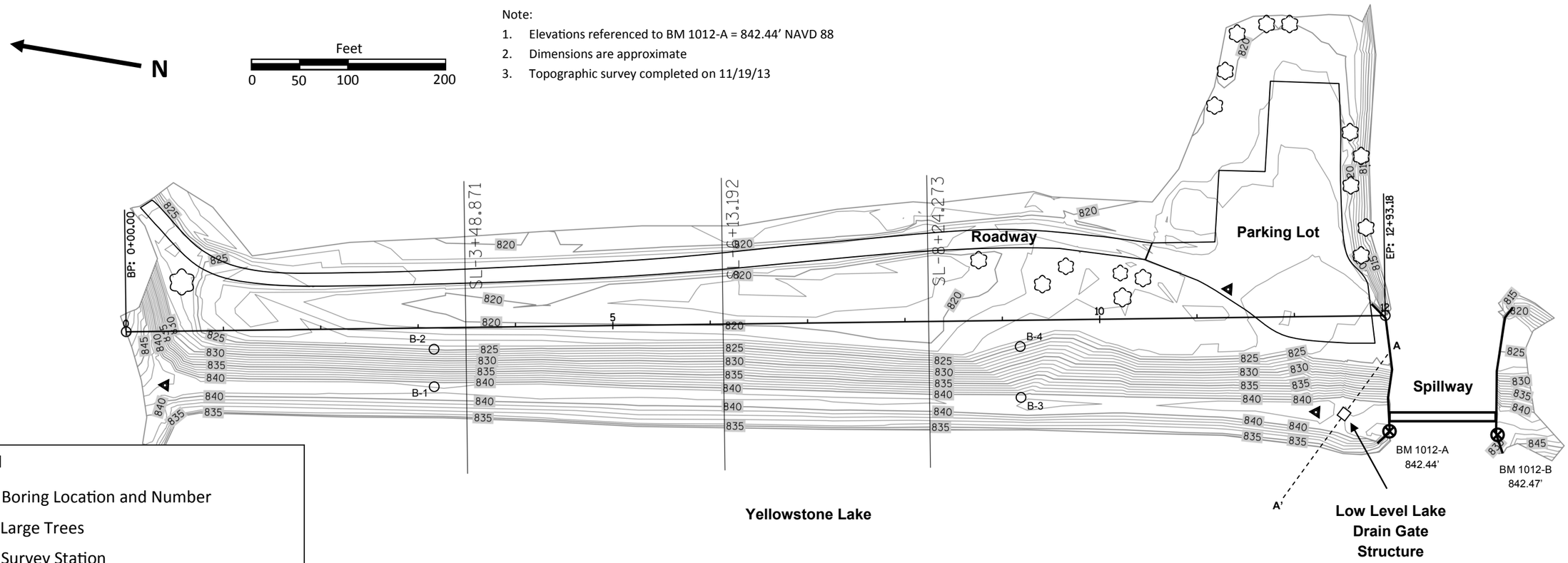
Approved: GAK 4/30/14

Project No. 60311420

Figure No. 1

Note:

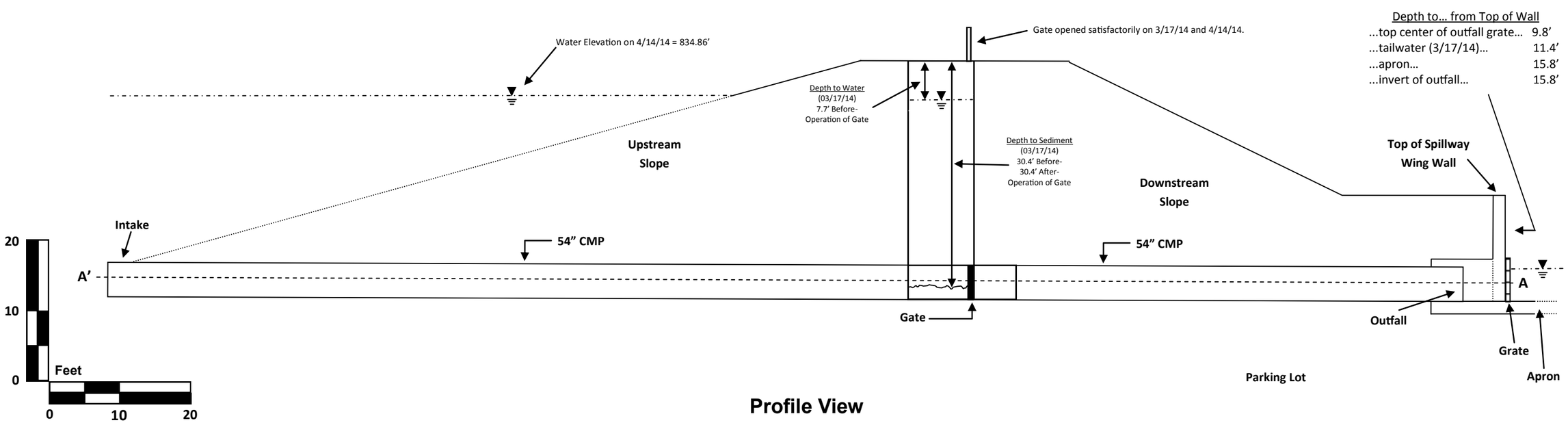
1. Elevations referenced to BM 1012-A = 842.44' NAVD 88
2. Dimensions are approximate
3. Topographic survey completed on 11/19/13



Legend

- B-1 Boring Location and Number
- Large Trees
- Survey Station
- Benchmark Location

Plan View



Depth to... from Top of Wall

...top center of outfall grate...	9.8'
...tailwater (3/17/14)...	11.4'
...apron...	15.8'
...invert of outfall...	15.8'

Profile View

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State of Wisconsin
Department of Administration
Division of Facilities Development

Yellowstone Dam
Yellowstone Lake State Park
Plan and Profile

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Graphic Scale	As Shown
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TOE DRAIN and GRADE FILL

YELLOWSTONE DAM

YELLOWSTONE LAKE STATE PARK

BLANCHARDVILLE, WI

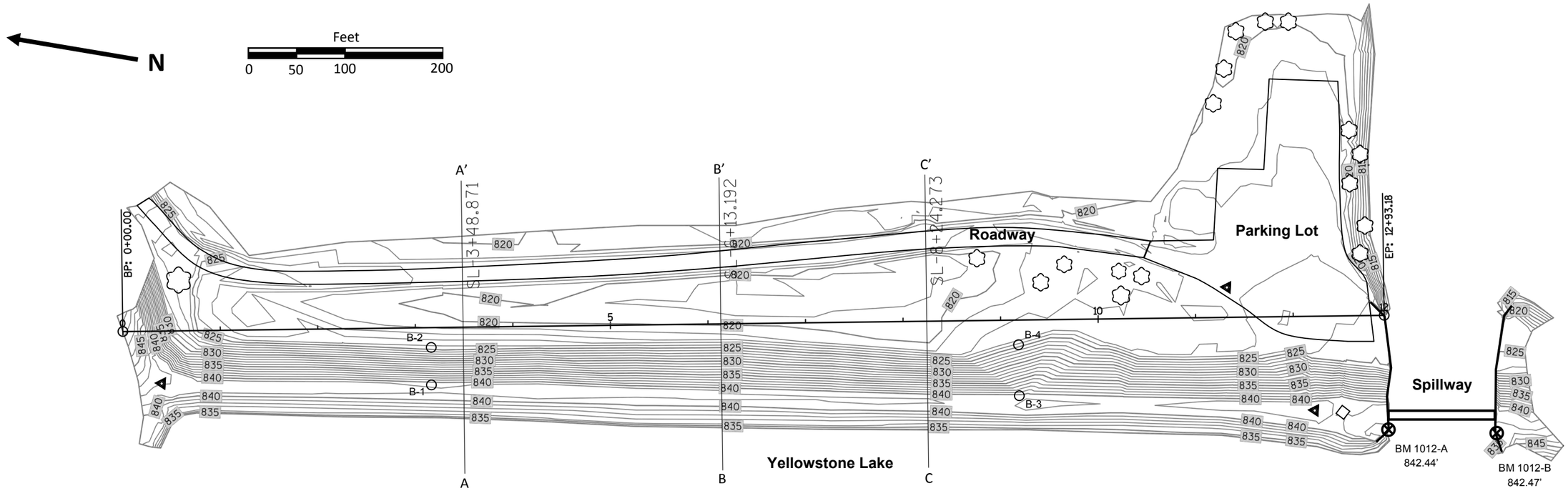
Drawn: DEH 04/02/14

Checked: GAK 4/30/14

Approved: GAK 4/30/14

Project No. 60311420

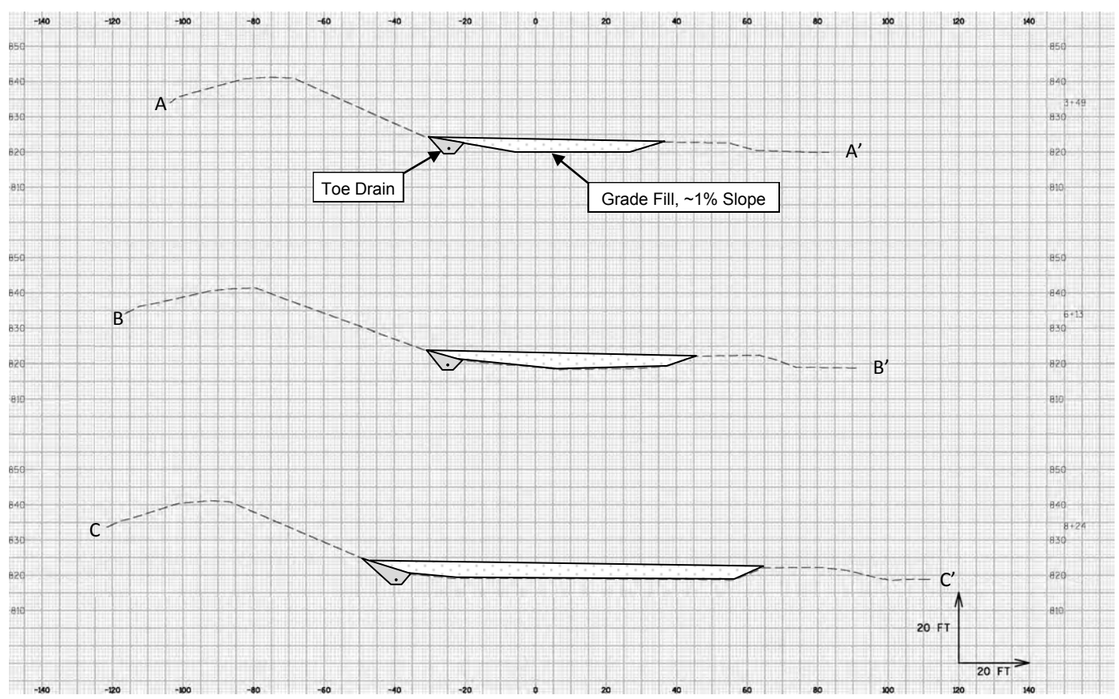
Figure No. 2



Plan View

Note:

1. Elevations referenced to BM 1012-A = 842.44' NAVD 88
2. Dimensions are approximate



Profile View

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Yellowstone Dam
Yellowstone Lake State Park
Toe Drain and Grade Fill Plan and Profile

Revisions:

No.	Date	Description

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DSF Number	13H3H
Set Type	PR
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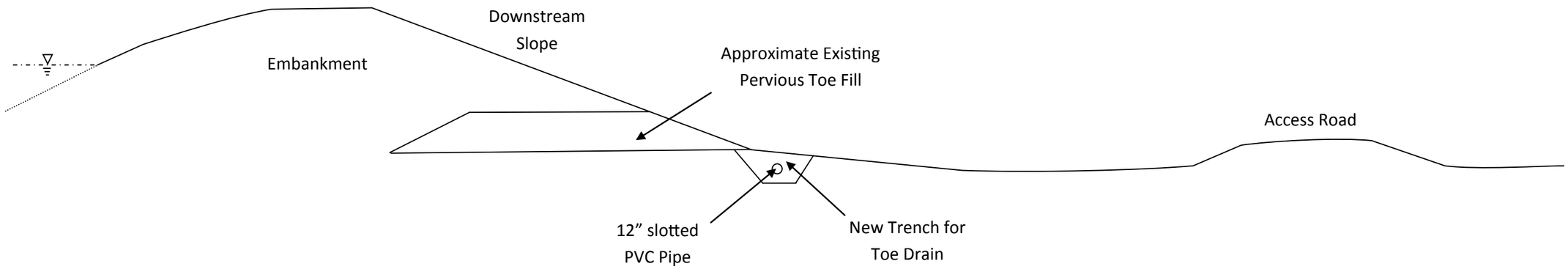
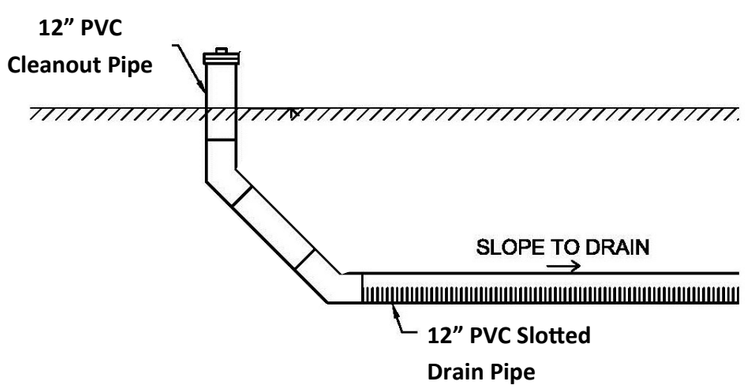
Sheet Number	2

Note: These are conceptual drawings and are not to scale. They are intended for general reference only.

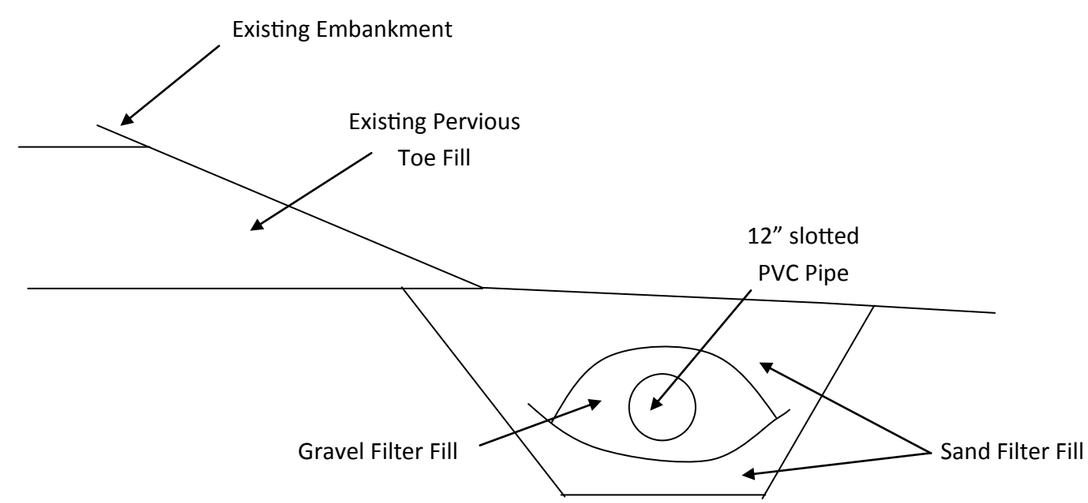


Profile View



CLEANOUT DETAIL

SCALE: N.T.S.



Toe Drain Profile View

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Yellowstone Dam
Yellowstone Lake State Park
Toe Drain Conceptual Drawing

Revisions:

No.	Date	Description

Graphic Scale	NTS
DSF Number	13H3H
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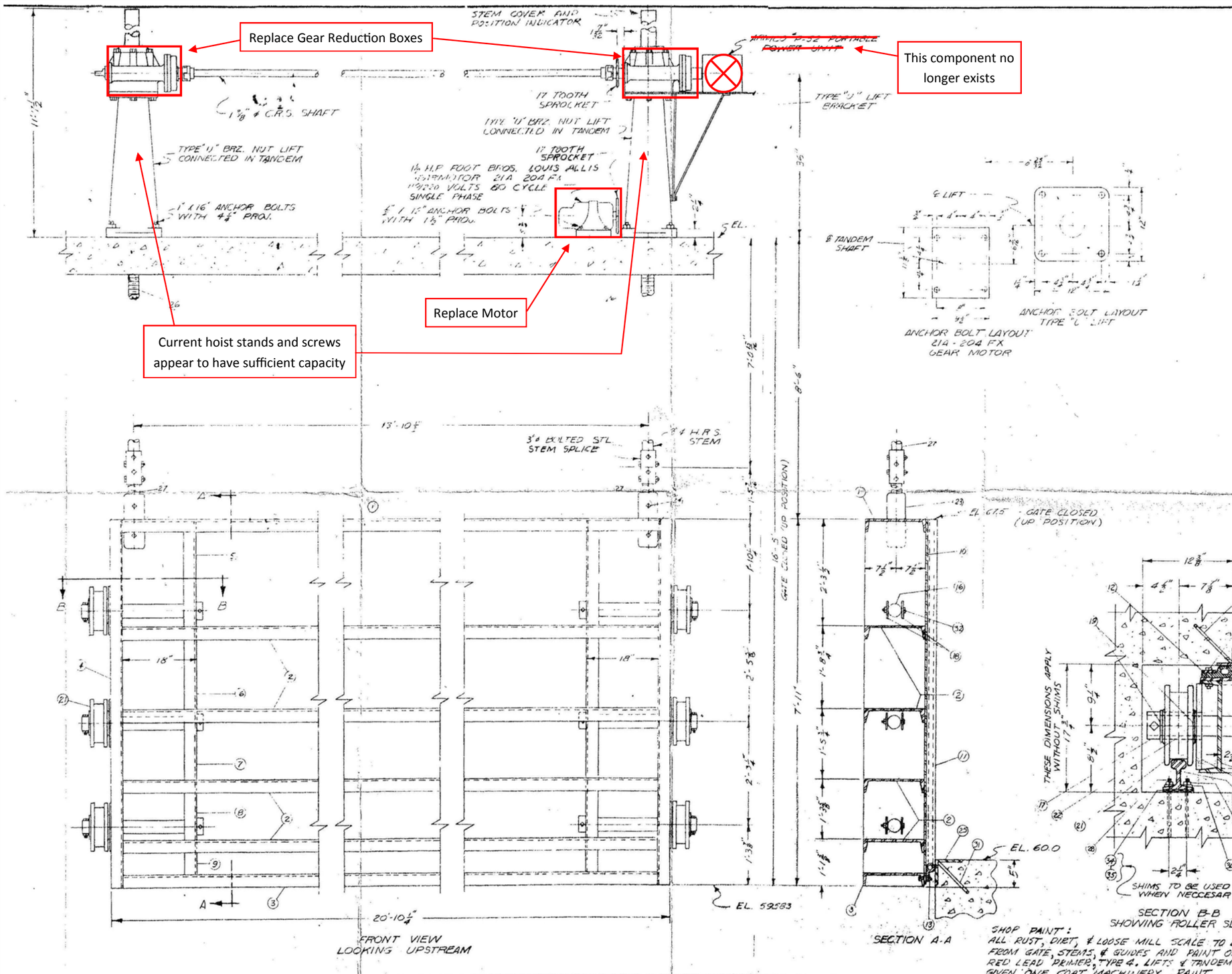
Sheet Number	3



BILL OF MATERIALS

PART NO.	NO. REQ'D.	DESCRIPTION
1	1	15" [@ 33.9# X 20'-3 1/2" LG.
2	4	" X "
3	1	" X "
4	2	" X 7'-11" LG.
5	2	" X 2'-3" LG.
6	2	" X 1'-8 1/4" LG.
7	2	" X 1'-5 1/4" LG.
8	2	" X 1'-3 1/8" LG.
9	2	" X 9 3/8" LG.
10	1	1/4" FACE PLATE X 20'-9 3/4" X 7'-10 1/2"
11	1	4" VULCANIZED LAMBCHOP SEAL X 36'-6 3/4" LG.
12	2	1/4" X 2" SEAL FLATS X 7'-10 3/8" LG. SIDE
13	1	1/4" X 2" SEAL FLATS X 20'-5 1/2" LG. BOTTOM
14	2	3" X 3" X 1/4" SEAL ANGLES X 15'-0" LG.
15	2	40# A.S.C.E. GUIDE RAILS X 16'-0" LG.
16	6	3" ϕ C.R.S. ROLLER SHAFTS X 29 11/16" LG.
17	6	3" I.D. X 4 1/2" O.D. SHAFT COLLARS X 1 1/2" LG.
18	12	3/8" X 1 1/2" SHAFT FLATS X 3 1/2" LG.
19	24	3" I.D. X 6" O.D. PLATE WASHERS
20	6	1/2" X 14 1/2" X 15" BEARING PLATES
21	6	10" ϕ C.I. ROLLERS, PATT. NO. 4507-D
22	6	3" I.D. X 4" O.D. LUBRITE BUSHING X 4 3/8" L
23	4	STEM BLOCK C.I., PATT. NO. 2232-D
24	4	3/4" ϕ X 1 1/2" CAP SCREWS
25	1	3" X 3" X 1/4" L BOTTOM SEAL ANGLE X 20'-6"
26	2	3" ϕ H.R.S. STEM X 18'-6" LG., THD. 9'-3"
27	2	3" ϕ H.R.S. STEM X 2'-0" LG.
28	34	1/2" ϕ X 12" ANCHOR BOLTS
29	34	1/2" ϕ NUTS
30	34	1/2" ϕ BEVEL WASHERS
31	51	1/2" ϕ X 10" ANCHOR RODS
32	12	1/2" ϕ X 5" MACH. BOLTS
33	74	3/8" ϕ X 2" " "
34	2	1/16" X 3 1/2" GUIDE RAIL SHIMS X 16'-0" LG.
35	4	1/16" X 3 1/2" " " " " " "
36		
38		
39		
40		
41		

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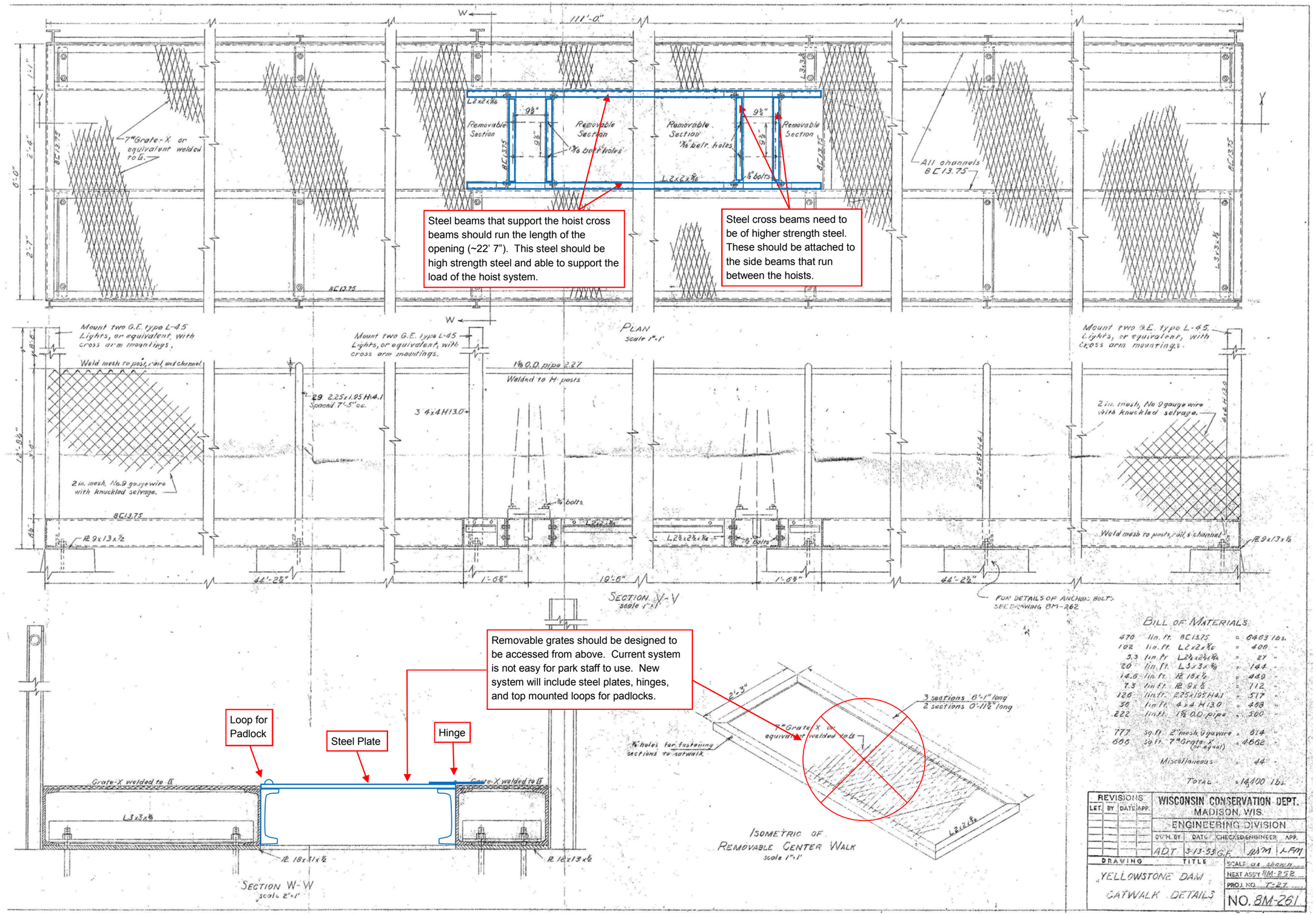
Yellowstone Dam
Yellowstone Lake State Park
Vertical Slide Gate Gear Box and Motor Repair

Revisions:

No.	Date	Description

Graphic Scale	As Shown
DSF Number	13H3H
Set Type	PR
Dade Issued	05/01/14
Sheet Number	4

Note: This drawing is from the original design. Components listed may not be present currently and was used for replacement parts general location reference.



Note: This drawing is from the original design. Components listed may not be present currently and was used for replacement parts general location reference.

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Yellowstone Dam
Yellowstone Lake State Park
Vertical Slide Structural Steel Upgrade

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No.	Date	Description

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Note: Map created with Google Earth Pro
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RIP RAP ANDTREE REMOVAL

YELLOWSTONE DAM

YELLOWSTONE LAKE STATE PARK

BLANCHARDVILLE, WI

Drawn: DEH 04/01/14

Checked: GAK 4/30/14

Approved: GAK 4/30/13

Project No. 60311420

Figure No. 3

Source: Wisconsin DNR Surface Water Data Viewer

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Department of Administration
Division of Facilities Development

Yellowstone Dam
Yellowstone Lake State Park
Wetland Areas

Revisions:

No.	Date	Description

Graphic Scale	As Shown
DSF Number	13H3H
Set Type	PR
Dade Issued	5/01/14
Sheet Number	6

Appendix B

Photographic Log

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PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
1	10-15-13

Description:
Downstream slope of northern half of embankment.
Seepage occurring between the toe and the road.

Photo No.	Date:
2	10-15-13

Description:
Downstream slope of southern half of embankment.
Seepage occurring between the toe and the road.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
3	11-20-13

Description:
View downstream of the roadway to the parking lot.

Photo No.	Date:
4	10-15-13

Description:
Downstream view of the spillway and vertical slide gate.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
5	11-20-13

Description:
Vertical slide gate controls including motor, gears, and electrical wiring.

Photo No.	Date:
6	11-20-13

Description:
Low level lake drain access structure on crest of dam near spillway.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
7	11-20-13

Description:
Inside low level lake drain access structure.
Note slots for installing stop logs.

Photo No.	Date:
8	11-25-13

Description:
Upstream slope of the embankment.
Rip rap protection is sparse.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
9	11-25-13

Description:
Downstream right spillway wing wall. Note trees on right embankment.

Photo No.	Date:
10	11-25-13

Description:
Unwanted brush and trees on right embankment.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
11	3-17-14

Description:
Unwanted trees and brush on downstream left groin.

Photo No.	Date:
12	11-20-13

Description:
South of downstream right spillway wing wall looking upstream.
Note unwanted brush and trees.

AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	Yellowstone Dam	60311420

Photo No.	Date:
13	02-03-14

Description:
Drill crew at boring B-4 downstream right side of embankment.

Photo No.	Date:
14	02-13-14

Description:
AECOM on-site monitoring of water levels and performing hydraulic conductivity tests

AECOM

PHOTOGRAPHIC LOG

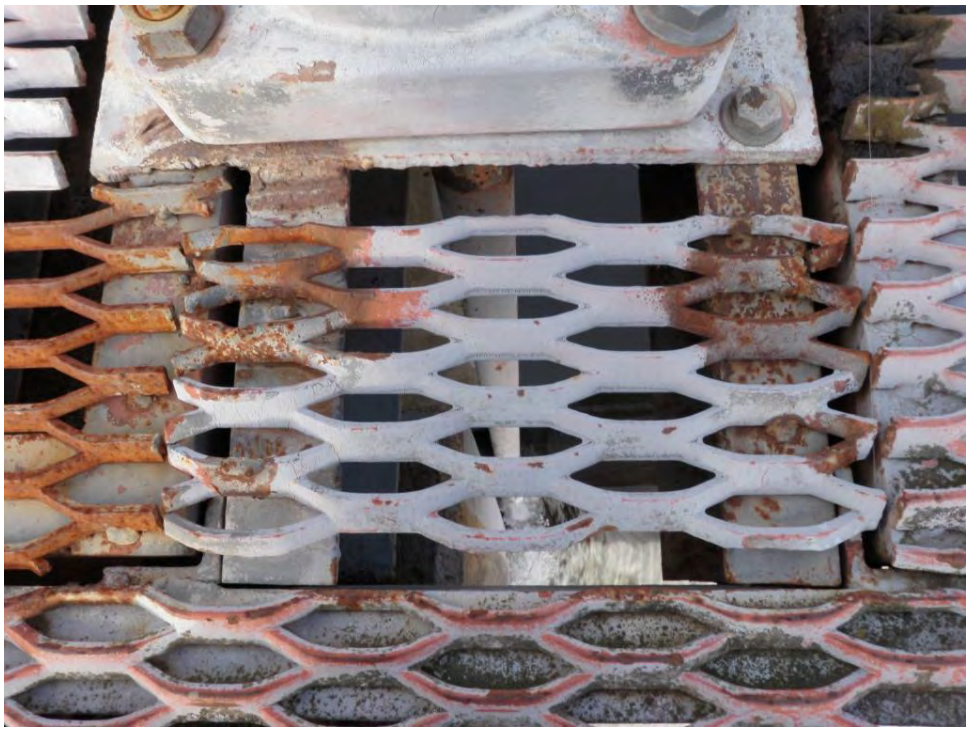
Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
15	3-17-14

Description:
Operation and testing was performed to assess sluiceway gate and hoist condition.

Photo No.	Date:
16	3-17-14

Description:
Structural support beams for left hoist stand on vertical slide gate.



AECOM

PHOTOGRAPHIC LOG

Client Name:	Site Location:	Project No.
Wisconsin Division of State Facilities	**Yellowstone Dam**	60311420

Photo No.	Date:
17	3-17-14

Description:
Rip rap on upstream slope is sparse and extends approximately 15 feet upslope.

Photo No.	Date:
18	3-17-14

Description:
Road slopes toward left groin of the dam causing excess water runoff to low area.

Appendix C

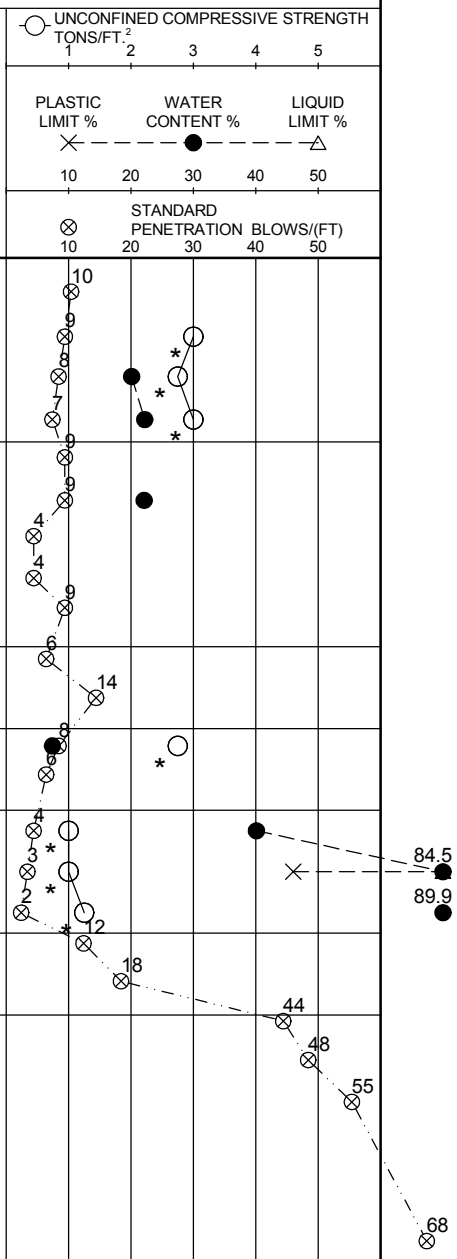
Boring Logs, Well Logs, Hydraulic Conductivity Tests, and Soil Laboratory Test Results

AECOM	CLIENT: Wisconsin Department of Natural Resources	LOG OF BORING NUMBER: B-1
	PROJECT NAME: Yellowstone Dam Evaluation	ARCHITECT-ENGINEER: AECOM

SITE LOCATION: Dodgeville, Wisconsin

SURFACE ELEVATION +840.7 Feet

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.³
		1	SS			Fill: Silty Clay, trace fine gravel, fine to coarse sand, roots and organic matter - brown and gray - dry to moist - very stiff (Fill: CL)	
5.0		2	SS				
		3	SS				
		4	SS			9.0	
10.0		5	SS			Fill: Silty Fine to Medium Sand, trace fine to coarse gravel, some clay - dark gray - moist - loose (Fill: SM) ***Sample No. 6: 0% gravel, 35.0% sand, 46.1% silt, 18.9% clay***	
		6	SS				
15.0		7	SS				
		8	SS				
		9	SS			19.0	
20.0		10	SS			Fine to Medium Sand, trace fine gravel and silt - gray - moist - loose to medium dense (SP-SM)	
		11	SS			23.0	
25.0		12	SS			Silty Clay, trace fine gravel and fine sand - blueish gray with seams of green - moist - very stiff (CL) ***Note: Sample No. 13 was disturbed; no Qp obtained***	
		13	SS			27.0	
30.0		14	SS			Organic Silty Clay, trace roots and peat - dark gray - moist - stiff (OH) ***Sample No. 15: 12.0% organic content***	
		15	SS				
		16	SS			33.0	
35.0		17	SS			Fine to Coarse Gravel, little medium to coarse sand - brown - wet - medium dense (GP)	
		18	SS			37.0	
40.0		19	SS			Weathered Bedrock: Fine to Coarse Gravel and Fine to Coarse Sand - brown - moist - dense to very dense (GP)	
		20	SS			***Note: 30% drilling fluid loss observed from 34.5' to 48.0'***	
		21	SS				
45.0							
50.0		22	SS			50.0	
						End of Boring	



* Calibrated Penetrometer

Boring advanced to 3.0 ft. by solid stem auger.
Boring advanced from 3.0 ft. to 50.0 ft. by rotary bit and fluid. 5.0 ft. of casing installed.
Standard Penetration Tests performed with an automatic hammer.
Groundwater monitoring well installed to 38.0 ft. on 2/5/14. (See Diagram for details.)

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING	BORING STARTED 2/5/14	AECOM OFFICE Middleton, WI	
EASTING	BORING COMPLETED 2/5/14	ENTERED BY LJE	SHEET NO. 1 OF 1
WL DRY BCI	RIG/FOREMAN CME-850/JT	APP'D BY JDW	AECOM JOB NO. 60311420

AECOM	CLIENT: Wisconsin Department of Natural Resources	LOG OF BORING NUMBER: B-2
	PROJECT NAME: Yellowstone Dam Evaluation	ARCHITECT-ENGINEER: AECOM

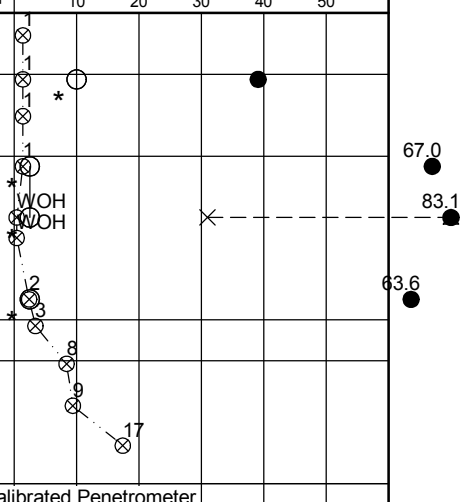
SITE LOCATION: **Dodgeville, Wisconsin**

SURFACE ELEVATION +823.9 Feet

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}	UNCONFINED COMPRESSIVE STRENGTH TONS/FT.^{2} (1 2 3 4 5)	PLASTIC LIMIT % / WATER CONTENT % / LIQUID LIMIT % (10 20 30 40 50)	STANDARD PENETRATION BLOWS/(FT) (10 20 30 40 50)
		1	SS			Organic Silty Clay, trace fine sand - dark gray and black - wet - very soft (OL) 3.0				
5.0		2	SS			Silty Clay, little fine to coarse gravel, some organic matter - dark gray and black - moist - stiff (CL)				
		3	SS			7.0 ***Note: Sample No. 3 was disturbed; no Qp obtained***				
		4	SS			Orgainic Silty Clay, trace roots and peat - dark gray - moist - very soft (OH)				
10.0		5	SS			***Sample No. 5: 10.3% organic content***				
		6	SS							
15.0		7	SS			15.0				
		8	SS			Silty Fine to Medium Sand - trace fine to coarse gravel - gray - moist - very loose (SM) 17.0				
		9	SS			Fine to Coarse Gravel, some fine to coarse sand, trace silt - brown - wet - loose to medium dense (GP)				
20.0		10	SS							
23.0		11	SS			***Note: 30% drilling fluid loss observed from 17.0' to 21.0'*** 23.0				

End of Boring

Boring advanced to 7.0 ft. by solid stem auger.
Boring advanced from 7.0 ft. to 23.0 ft. by rotary bit and fluid. 7.0 ft. of casing installed.
Standard Penetration Tests performed with an automatic hammer.
Groundwater monitoring well installed to 17.0 ft. on 2/6/14. (See Diagram for details.)



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING	BORING STARTED 2/6/14	AECOM OFFICE Middleton, WI	
EASTING	BORING COMPLETED 2/6/14	ENTERED BY LJE	SHEET NO. 1 OF 1
WL 1.0' WS	RIG/FOREMAN CME-850/JT	APP'D BY JDW	AECOM JOB NO. 60311420

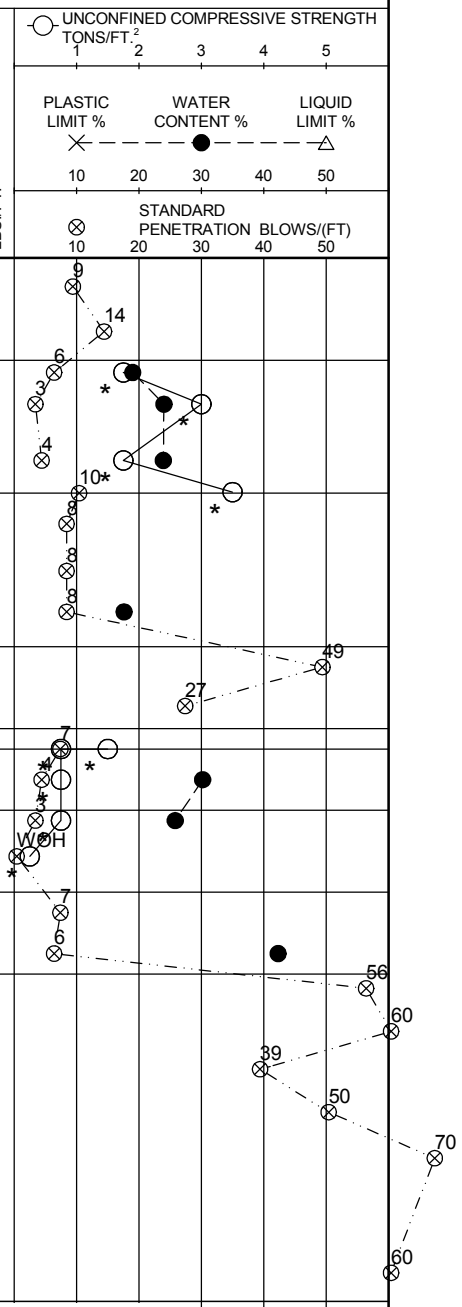
AECOM	CLIENT: Wisconsin Department of Natural Resources	LOG OF BORING NUMBER: B-3
	PROJECT NAME: Yellowstone Dam Evaluation	ARCHITECT-ENGINEER: AECOM

SITE LOCATION: Dodgeville, Wisconsin

SURFACE ELEVATION +840.8 Feet

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}
		1	SS			Fill: Silt, trace fine sand, clay and roots - brown - dry - loose to medium dense (Fill: ML)	
5.0		2	SS				
		3	SS			Fill: Silty Clay, trace fine gravel, trace to little fine to coarse sand, trace clay, roots and organic matter - brown to light gray - moist - stiff to very stiff (Fill: CL)	
		4	SS				
10.0		5	SS				
		6A	SS				
		6B	SS			Fill: Silty Fine to Medium Sand, trace fine to coarse gravel, some clay - brown to grayish brown - moist - medium dense to loose (Fill: SM)	
15.0		7	SS				
		8	SS				
		9	SS				
20.0		10	SS			Fine to Medium Sand, trace fine to coarse gravel and silt - grayish brown - moist - dense to medium dense (SP-SM)	
		11	SS			***Sample No. 10: 0% gravel, 90.2% sand, 9.8% fines***	
		12A	SS			Fine to Coarse Sand, trace fine to coarse gravel - brown to dark gray - moist - loose (SP)	
25.0		12B	SS				
		13	SS			Silty Clay, trace organic matter - dark gray - moist - medium (firm) to stiff (CL)	
		14	SS				
30.0		15	SS			Silty Clay, little fine to medium sand - dark gray - moist - medium (firm) to soft (CL)	
		16	SS			Silty Fine to Medium Sand, trace fine to coarse gravel and clay - dark gray - wet - loose (SM)	
35.0		17	SS				
		18	SS			Weathered Bedrock: Fine to Coarse Gravel, some fine to coarse sand - brown - moist - dense to very dense (GP)	
		19	SS				
40.0		20	SS			***Note: 40% drilling fluid loss observed from 35.0' to 49.0'***	
		21	SS				
45.0		22	SS				
50.0		23	SS				
51.0						End of Boring	

Boring advanced to 7.0 ft. by solid stem auger.
Boring advanced from 7.0 ft. to 51.0 ft. by rotary bit and fluid. 7.0 ft. of casing installed.
Standard Penetration Tests performed with an automatic hammer.
Groundwater monitoring well installed to 40.2 ft. on 2/4/14. (See Diagram for details.)



* Calibrated Penetrometer

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

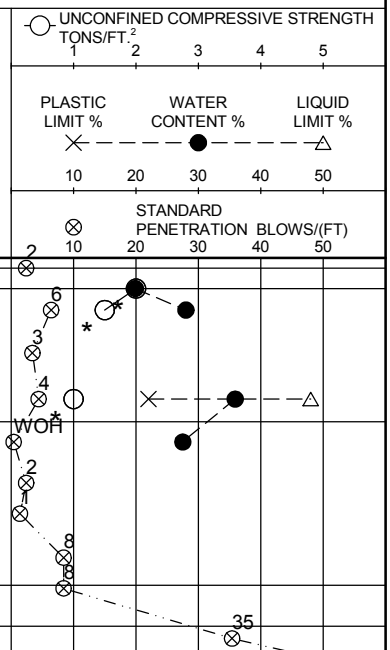
NORTHING	BORING STARTED 2/4/14	AECOM OFFICE Middleton, WI	
EASTING	BORING COMPLETED 2/4/14	ENTERED BY LJE	SHEET NO. 1 OF 1
WL DRY BCI	RIG/FOREMAN CME-850/JT	APP'D BY JDW	AECOM JOB NO. 60311420

AECOM	CLIENT: Wisconsin Department of Natural Resources	LOG OF BORING NUMBER: B-4
	PROJECT NAME: Yellowstone Dam Evaluation	ARCHITECT-ENGINEER: AECOM

SITE LOCATION: **Dodgeville, Wisconsin**

SURFACE ELEVATION +823.2 Feet

DEPTH(FT)	ELEVATION(FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY	DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.^{3}
		1	SS			0.5 Topsoil: Silt, some organic matter, trace fine to coarse gravel, fine to medium sand and clay - black - moist - very loose (Topsoil: OL)	
		1A	SS				
		1B	SS			1.5 Possible Fill: Silty Fine to Medium Sand, trace organic matter - brown - moist - very stiff (Possible Fill: SM)	
		2	SS				
5.0		3	SS				
		4	SS			8.0 Silty Clay, trace fine sand and organic matter - brown and black - moist - stiff (CL)	
						Sample No. 4: 2.9% organic content	
10.0		5	SS			Silty Fine to Medium Sand, trace clay - dark gray - moist - very loose to loose (SM)	
		6	SS				
		7	SS				
15.0		8	SS			16.0	
		9	SS			18.0 Fine to Coarse Sand, some fine to coarse gravel, trace silt - dark brown - wet - loose (SP)	
20.0		10	SS			Weathered Bedrock: Fine to Coarse Gravel, some fine to coarse sand - brown - moist - dense to very dense (GP)	
22.0		11	SS			22.0	



* Calibrated Penetrometer

End of Boring

Boring advanced to 4.0 ft. by solid stem auger.
Boring advanced from 4.0 ft. to 22.0 ft. by rotary bit and fluid. 4.5 ft. of casing installed.
Standard Penetration Tests performed with an automatic hammer.
Groundwater monitoring well installed to 17.0 ft. on 2/3/14. (See Diagram for details.)

The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

NORTHING	BORING STARTED 2/3/14	AECOM OFFICE Middleton, WI	
EASTING	BORING COMPLETED 2/3/14	ENTERED BY LJE	SHEET NO. 1 OF 1
WL 4.5' WS	RIG/FOREMAN CME-850/JT	APP'D BY JDW	AECOM JOB NO. 60311420

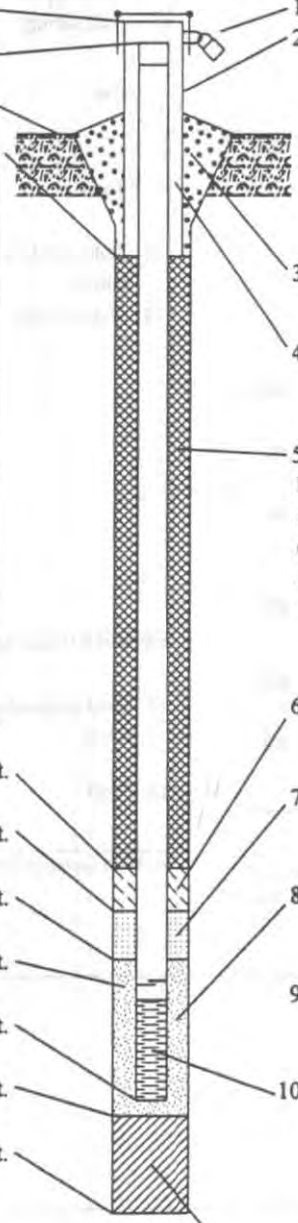
State of Wisconsin
Department of Natural Resources

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 6/04

Facility/Project Name: Yellowstone Dam	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: 140107
Facility License, Permit or Monitoring No.	Grid Origin Location (Check if estimated: ☐) Lat. ___° ___' ___" Long. ___° ___' ___" or	Wis. Unique Well No. / DNR Well Number
Facility ID: B-1	St. Plane ____ ft. N, ____ ft. E. S/C/N	Date Well Installed: 2-5-14
Type of Well: Monitoring	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm): JV
Distance Well Is From Waste/Source Boundary ____ ft.	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	



A. Protective pipe, top elevation: Flushmount ft. MSL

B. Well casing, top elevation: -0.3' ft. MSL

C. Land surface elevation: — ft. MSL

D. Surface seal, bottom: ____ ft. MSL or Surface ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☑ 5 0
Hollow Stem Auger ☐ 4 1
____ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ 0 1
Drilling Mud ☑ 0 3 None ☐ 9 9

16. Drilling additives used? ☑ Yes ☐ No
Describe: Quick Gel

17. Source of water (attach analysis):
____

E. Bentonite seal, top: ____ ft. MSL or ____ ft.

F. Fine sand, top: ____ ft. MSL or — ft.

G. Filter pack, top: ____ ft. MSL or 25.8' ft.

H. Screen joint, top: ____ ft. MSL or 28 ft.

I. Well bottom: ____ ft. MSL or 38 ft.

J. Filter pack, bottom: ____ ft. MSL or 38.6 ft.

K. Borehole, bottom: ____ ft. MSL or 50 ft.

L. Borehole, diameter: 4 in.

M. O.D. well casing: 2.25 in.

N. I.D. well casing: 2 in.

1. Cap and lock? ☑ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 8 in.
b. Length: 1 ft.
c. Material: Steel ☑ 0 4
____ Other ☐
d. Additional protection? ☐ Yes ☐ No
If yes, describe: ____

3. Surface seal: Bentonite ☑ 3 0
Concrete ☐ 0 1
____ Other ☐

4. Material between well casing and protective pipe:
N/A Bentonite ☐ 3 0
____ Other ☑

5. Annular space seal: a. Granular Bentonite ☑ 3 3
b. ____ Lbs/gal mud weight . Bentonite-sand slurry ☐ 3 5
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐ 3 1
d. ____ % Bentonite . . . Bentonite-cement grout ☐ 5 0
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ 0 1
Tremie pumped ☐ 0 2
Gravity ☑ 0 8

6. Bentonite seal: a. Bentonite granules ☐ 3 3
b. ☐ 1/4 in. ☑ 3/8 in. ☐ 1/2 in. Bentonite pellets ☑ 3 2
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name and mesh size
a. —
b. Volume added ____ ft^3

8. Filter pack material: Manufacturer, product name and mesh size
a. Filter Sil #65
b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☑ 2 3
Flush threaded PVC schedule 80 ☐ 2 4
____ Other ☐

10. Screen material: PVC
a. Screen Type: Factory cut ☑ 1 1
Continuous slot ☐ 0 1
____ Other ☐
b. Manufacturer: Johnson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10 ft.

11. Backfill material (below filter pack): None ☐ 1 4
Bentonite chips Other ☑

I hereby certify that the information on this form is true and correct to the best of my knowledge. SES

Signature	Firm: [redacted] Green Bay, Wisconsin 54311-8320	Tel: [redacted] Fax: [redacted]

Please complete both Forms 4400-113A and 4400-113B and return to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 298, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be

State of Wisconsin
Department of Natural Resources

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 6/04

Facility/Project Name: Yellowstone Dam	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: 140107
Facility License, Permit or Monitoring No.	Grid Origin Location (Check if estimated: ☐) Lat. ° ' " Long. ° ' " or	Wis. Unique Well No. / DNR Well Number
Facility ID: B-2	St. Plane ____ ft. N, ____ ft. E. S/C/N	Date Well Installed: 2-6-14
Type of Well: monitoring	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm): JV
Distance Well Is From Waste/Source Boundary ____ ft.	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	

A. Protective pipe, top elevation 3.2' stick up ft. MSL

B. Well casing, top elevation 3' sticky ft. MSL

C. Land surface elevation — ft. MSL

D. Surface seal, bottom ____ ft. MSL or 4.7 ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☑ 5 0
Hollow Stem Auger ☐ 4 1
____ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ 0 1
Drilling Mud ☑ 0 3 None ☐ 9 9

16. Drilling additives used? ☑ Yes ☐ No
Describe Quick Gel

17. Source of water (attach analysis):

E. Bentonite seal, top ____ ft. MSL or Surface ft.

F. Fine sand, top ____ ft. MSL or — ft.

G. Filter pack, top ____ ft. MSL or 4.7 ft.

H. Screen joint, top ____ ft. MSL or 7' ft.

I. Well bottom ____ ft. MSL or 17' ft.

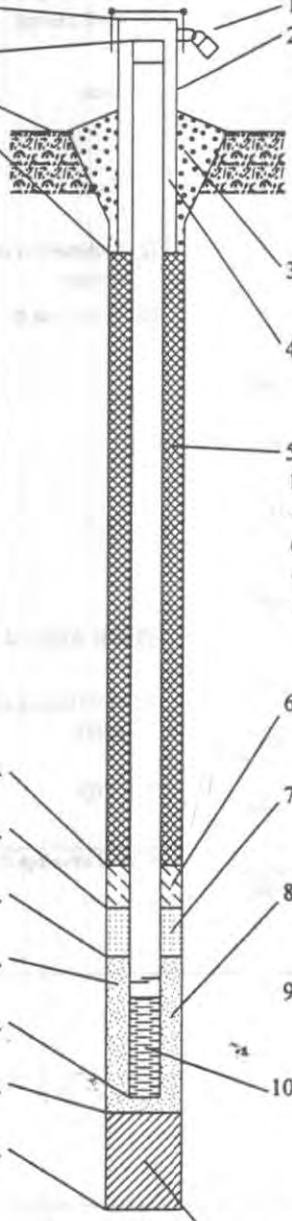
J. Filter pack, bottom ____ ft. MSL or 17.6' ft.

K. Borehole, bottom ____ ft. MSL or 21 ft.

L. Borehole, diameter 4 in.

M. O.D. well casing 2.25 in.

N. I.D. well casing 2 in.



1. Cap and lock? ☑ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4 in.
b. Length: 5 ft.
c. Material: Steel ☑ 0 4
____ Other ☐
d. Additional protection? ☐ Yes ☐ No
If yes, describe: ____

3. Surface seal: Bentonite ☑ 3 0
Concrete ☐ 0 1
____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐ 3 0
N/A Other ☑

5. Annular space seal: a. Granular Bentonite ☑ 3 3
b. ____ Lbs/gal mud weight . Bentonite-sand slurry ☐ 3 5
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐ 3 1
d. ____ % Bentonite . . . Bentonite-cement grout ☐ 5 0
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ 0 1
Tremie pumped ☐ 0 2
Gravity ☑ 0 8

6. Bentonite seal: a. Bentonite granules ☐ 3 3
b. ☐ 1/4 in. ☑ 3/8 in. ☐ 1/2 in. Bentonite pellets ☐ 3 2
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name and mesh size
a. —
b. Volume added — ft^3

8. Filter pack material: Manufacturer, product name and mesh size
a. Filtersil .65
b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☑ 2 3
Flush threaded PVC schedule 80 ☐ 2 4
____ Other ☐

10. Screen material: PVC
a. Screen Type: Factory cut ☑ 1 1
Continuous slot ☐ 0 1
____ Other ☐
b. Manufacturer Jakson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10 ft.

11. Backfill material (below filter pack): None ☐ 1 4
Holeplug Other ☑

I hereby certify that the information on this form is true and correct to the best of my knowledge. SES

Signature	Firm: [redacted] 1[redacted] Green Bay, Wisconsin 54311-8320	Tel: [redacted] Fax: [redacted]

Please complete both Forms 4400-113A and 4400-113B and return to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

State of Wisconsin
Department of Natural Resources

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION

Form 4400-113A Rev. 6/04

Facility/Project Name: Yellowstone Dam	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: 140107
Facility License, Permit or Monitoring No.	Grid Origin Location (Check if estimated: ☐) Lat. ___° ___' ___" Long. ___° ___' ___" or	Wis. Unique Well No / DNR Well Number
Facility ID: B-3	St. Plane ____ ft. N, ____ ft. E. S/C/N	Date Well Installed: 2-4-14
Type of Well: Monitoring	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____ T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm): JW
Distance Well Is From Waste/Source Boundary ft.	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	

A. Protective pipe, top elevation: Flushmount ft. MSL

B. Well casing, top elevation: -0.2' ft. MSL

C. Land surface elevation: ____ ft. MSL

D. Surface seal, bottom: ____ ft. MSL or 28' ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☒ 50; Hollow Stem Auger ☐ 41; Other ☐

15. Drilling fluid used: Water ☐ 02; Air ☐ 01; Drilling Mud ☒ 03; None ☐ 99

16. Drilling additives used? ☒ Yes ☐ No
Describe: Quick Gel

17. Source of water (attach analysis):

E. Bentonite seal, top: ____ ft. MSL or Surface ft.

F. Fine sand, top: ____ ft. MSL or — ft.

G. Filter pack, top: ____ ft. MSL or 28' ft.

H. Screen joint, top: ____ ft. MSL or 30.2 ft.

I. Well bottom: ____ ft. MSL or 40.2 ft.

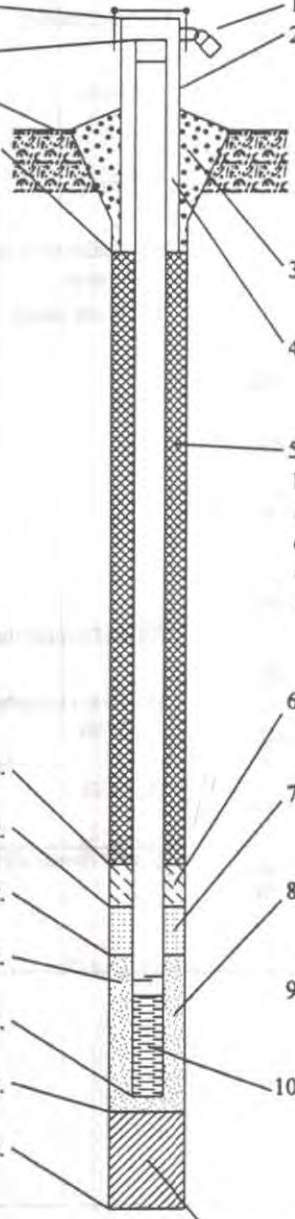
J. Filter pack, bottom: ____ ft. MSL or 40.7' ft.

K. Borehole, bottom: ____ ft. MSL or 51' ft.

L. Borehole, diameter: 4 in.

M. O.D. well casing: 2.25 in.

N. I.D. well casing: 2 in.



1. Cap and lock? ☒ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 8 in.
b. Length: 1 ft.
c. Material: Steel ☒ 04; Other ☐
d. Additional protection? ☐ Yes ☒ No
If yes, describe:

3. Surface seal: Bentonite ☒ 30; Concrete ☐ 01; Other ☐

4. Material between well casing and protective pipe: N/A
Bentonite ☐ 30; Other ☒

5. Annular space seal:
a. Granular Bentonite ☒ 33
b. ____ Lbs/gal mud weight . Bentonite-sand slurry ☐ 35
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐ 31
d. ____ % Bentonite . . . Bentonite-cement grout ☐ 50
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ 01; Tremie pumped ☐ 02; Gravity ☒ 08

6. Bentonite seal:
a. Bentonite granules ☐ 33
b. ☐ 1/4 in. ☒ 3/8 in. ☐ 1/2 in. Bentonite pellets ☒ 32
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name and mesh size
a. —
b. Volume added — ft^3

8. Filter pack material: Manufacturer, product name and mesh size
a. Filter sil #65
b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☒ 23; Flush threaded PVC schedule 80 ☐ 24; Other ☐

10. Screen material: PVC
a. Screen Type: Factory cut ☒ 11; Continuous slot ☐ 01; Other ☐
b. Manufacturer: Johson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10 ft.

11. Backfill material (below filter pack): None ☐ 14; Other ☒
Bentonite chips

I hereby certify that the information on this form is true and correct to the best of my knowledge. SES

Signature: ____ Firm: [redacted], Green Bay, Wisconsin 54311-8320 Tel: [redacted] Fax: [redacted]

Please complete both Forms 4400-113A and 4400-113B and return to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

State of Wisconsin
Department of Natural Resources

Route To: Watershed/Wastewater ☐ Waste Management ☐ Remediation/Redevelopment ☐ Other ☐

MONITORING WELL CONSTRUCTION
Form 4400-113A Rev. 6/04

Facility/Project Name: Yellowstone Dam	Local Grid Location of Well: ____ ft. ☐ N. ☐ S. ____ ft. ☐ E. ☐ W.	Well Name: 140107
Facility License, Permit or Monitoring No.	Grid Origin Location (Check if estimated: ☐) Lat. ___ ° ___ ' ___ " Long. ___ ° ___ ' ___ " or	Wis. Unique Well No / DNR Well Number
Facility ID: B-4	St. Plane ____ ft. N, ____ ft. E. S/C/N	Date Well Installed: 2-3-14
Type of Well: Monitoring	Section Location of Waste/Source: ____ 1/4 of ____ 1/4 of Sec. ____, T. ____ N, R. ____ ☐ E ☐ W	Well Installed By: (Person's Name and Firm): JW
Distance Well Is From Waste/Source Boundary ft.	Location of Well Relative to Waste/Source: u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	

A. Protective pipe, top elevation 3.1' stick up ft. MSL

B. Well casing, top elevation 3' stick up ft. MSL

C. Land surface elevation — ft. MSL

D. Surface seal, bottom ____ ft. MSL or 2' ft.

12. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

13. Sieve analysis attached? ☐ Yes ☐ No

14. Drilling method used: Rotary ☑ 5 0
Hollow Stem Auger ☐ 4 1
____ Other ☐

15. Drilling fluid used: Water ☐ 0 2 Air ☐ 0 1
Drilling Mud ☑ 0 3 None ☐ 9 9

16. Drilling additives used? ☑ Yes ☐ No
Describe Quick Gel

17. Source of water (attach analysis):
____

E. Bentonite seal, top ____ ft. MSL or 2 ft.

F. Fine sand, top ____ ft. MSL or — ft.

G. Filter pack, top ____ ft. MSL or 5.5' ft.

H. Screen joint, top ____ ft. MSL or 7 ft.

I. Well bottom ____ ft. MSL or 17 ft.

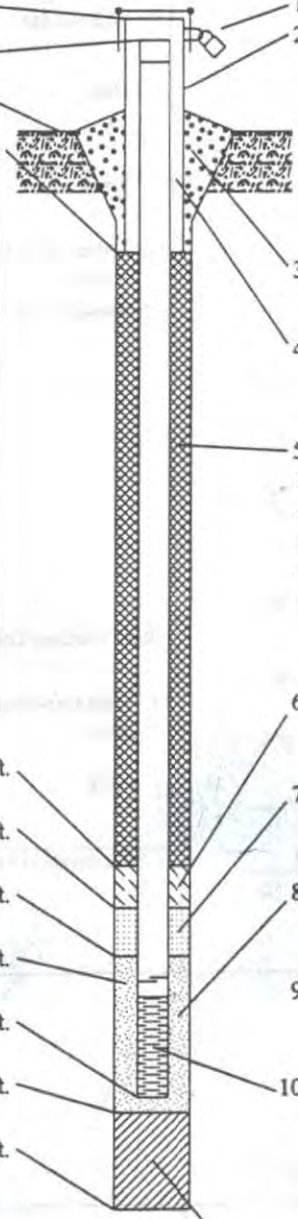
J. Filter pack, bottom ____ ft. MSL or 22' ft.

K. Borehole, bottom ____ ft. MSL or 22' ft.

L. Borehole, diameter 4" in.

M. O.D. well casing 2.25 in.

N. I.D. well casing 2 in.



1. Cap and lock? ☑ Yes ☐ No

2. Protective cover pipe:
a. Inside diameter: 4 in.
b. Length: 5 ft.
c. Material: Steel ☑ 0 4
____ Other ☐
d. Additional protection? ☐ Yes ☐ No
If yes, describe: ____

3. Surface seal: Bentonite ☑ 3 0
Concrete ☐ 0 1
____ Other ☐

4. Material between well casing and protective pipe:
Bentonite ☐ 3 0
N/A Other ☑

5. Annular space seal: a. Granular Bentonite ☐ 3 3
b. ____ Lbs/gal mud weight . Bentonite-sand slurry ☐ 3 5
c. ____ Lbs/gal mud weight . . . Bentonite slurry ☐ 3 1
d. ____ % Bentonite . . . Bentonite-cement grout ☐ 5 0
e. ____ Ft^3 volume added for any of the above
f. How installed: Tremie ☐ 0 1
Tremie pumped ☐ 0 2
Gravity ☑ 0 8

6. Bentonite seal: a. Bentonite granules ☐ 3 3
b. ☐ 1/4 in. ☑ 3/8 in. ☐ 1/2 in. Bentonite pellets ☑ 3 2
c. ____ Other ☐

7. Fine sand material: Manufacturer, product name and mesh size
a. —
b. Volume added — ft^3

8. Filter pack material: Manufacturer, product name and mesh size
a. Filter Sand .65
b. Volume added ____ ft^3

9. Well casing: Flush threaded PVC schedule 40 ☑ 2 3
Flush threaded PVC schedule 80 ☐ 2 4
____ Other ☐

10. Screen material: PVC
a. Screen Type: Factory cut ☑ 1 1
Continuous slot ☐ 0 1
____ Other ☐
b. Manufacturer Johson Screens
c. Slot size: 0.010 in.
d. Slotted length: 10 ft.

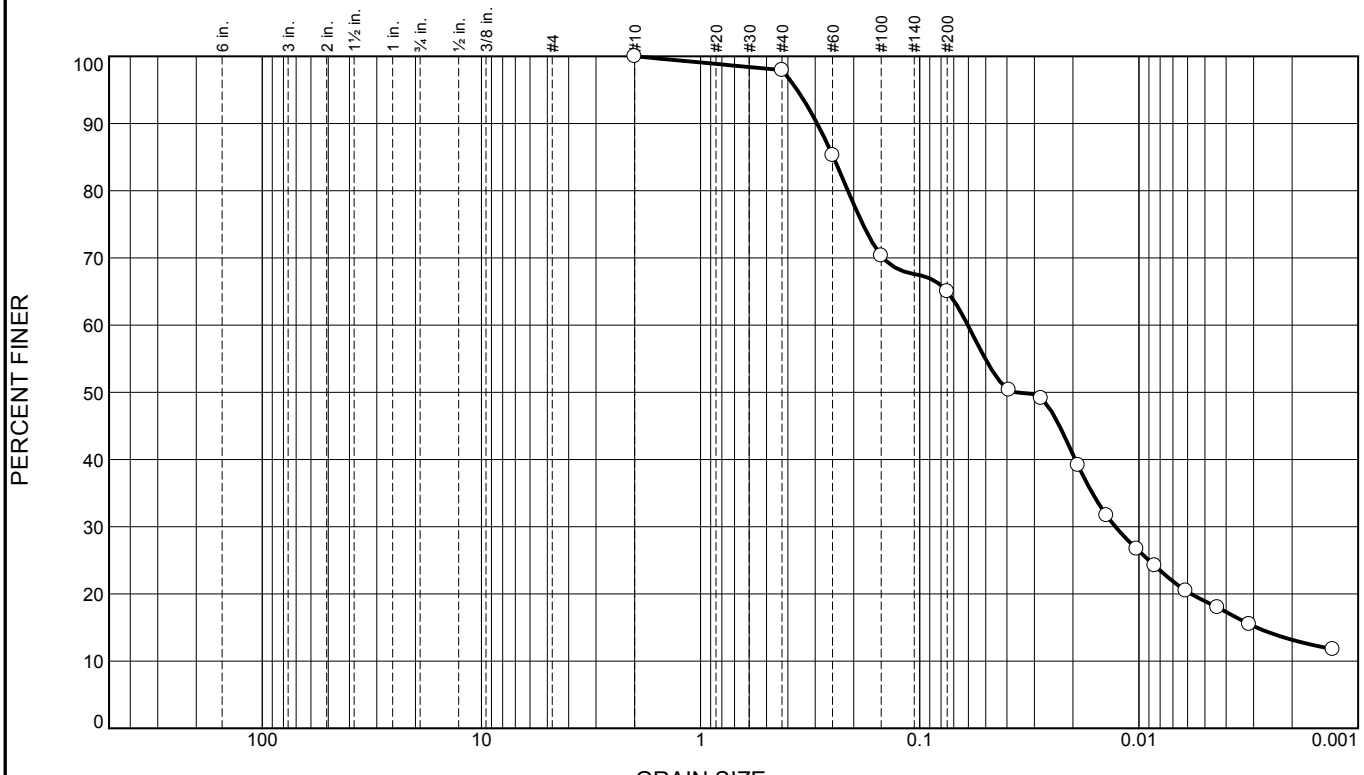
11. Backfill material (below filter pack): None ☑ 1 4
____ Other ☐

I hereby certify that the information on this form is true and correct to the best of my knowledge. SES

Signature ____ Firm [redacted], Green Bay, Wisconsin 54311-8320 Tel: [redacted] Fax: [redacted]

Please complete both Forms 4400-113A and 4400-113B and return to the appropriate DNR office and bureau. Completion of these reports is required by chs. 160, 281, 283, 289, 291, 292, 293, 295, and 299, Wis. Stats., and ch. NR 141, Wis. Adm. Code. In accordance with chs. 281, 289, 291, 292, 293, 295, and 299, Wis. Stats., failure to file these forms may result in a forfeiture of between $10 and $25,000, or imprisonment for up to one year, depending on the program and conduct involved. Personally identifiable information on these forms is not intended to be used for any other purpose. NOTE: See the instructions for more information, including where the completed forms should be sent.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.0	2.1	32.9	46.1	18.9

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#10	100.0		
#40	97.9		
#60	85.3		
#100	70.3		
#200	65.0		

* (no specification provided)

Material Description

GRAY BROWN SANDY SILT - SOME CLAY - TRACE ORGANICS

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.2939 D_{85}= 0.2478 D_{60}= 0.0604
D_{50}= 0.0367 D_{30}= 0.0128 D_{15}= 0.0029
D_{10}= C_u= C_c=

Classification

USCS= AASHTO=

Remarks

Sample Number: B-1 S-6 **Depth:** 11.0 - 13.0 ft.

Date: 2/26/14

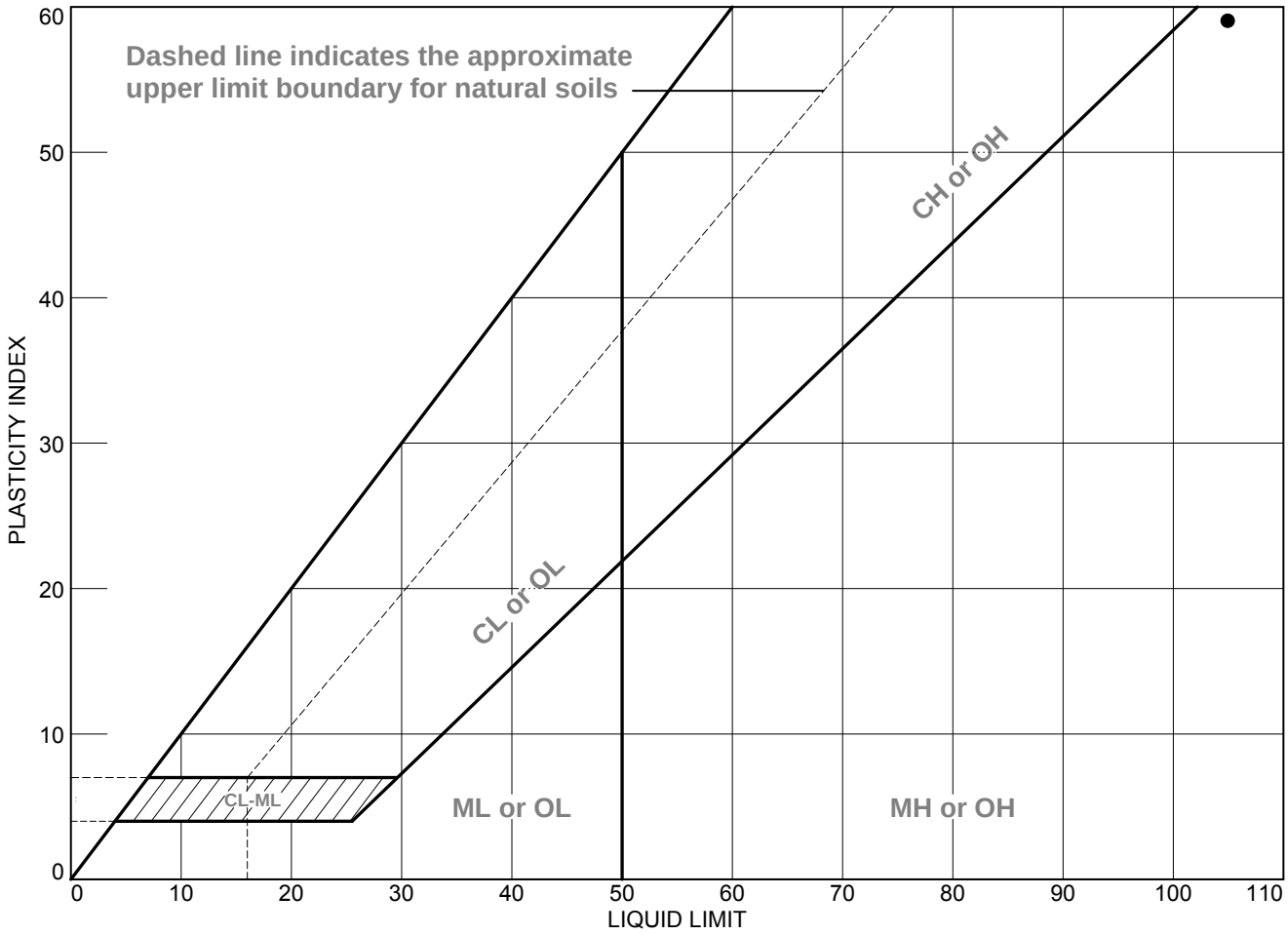
AECOM

Client: WDOA - DIVISION OF STATE FACILITIES
Project: WDNR DAMS STUDIES, YELLOWSTONE DAM

Project No: 60311420 **Figure**

Tested By: BOB PEETERS

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●		B-1 S-15	29.0 - 31.0 ft.	73.0	46	105	59	OH

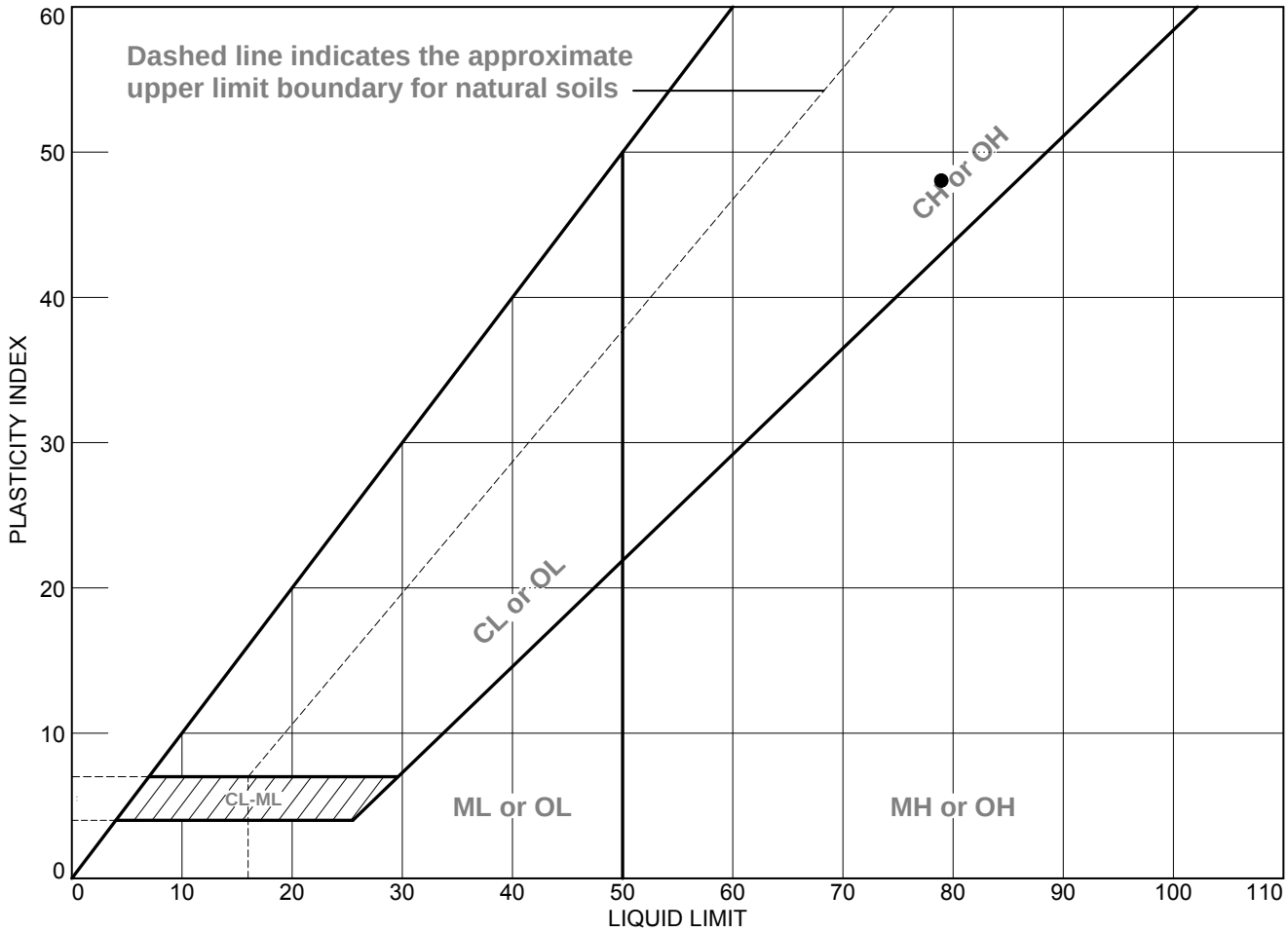
AECOM

Client: WDOA - DIVISION OF STATE FACILITIES
Project: WDNR DAMS STUDIES, YELLOWSTONE DAM

Project No.: 60311420 **Figure**

Tested By: BOB PEETERS

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●		B-2 S-5	9.0 - 11.0 ft.	85.6	31	79	48	OH

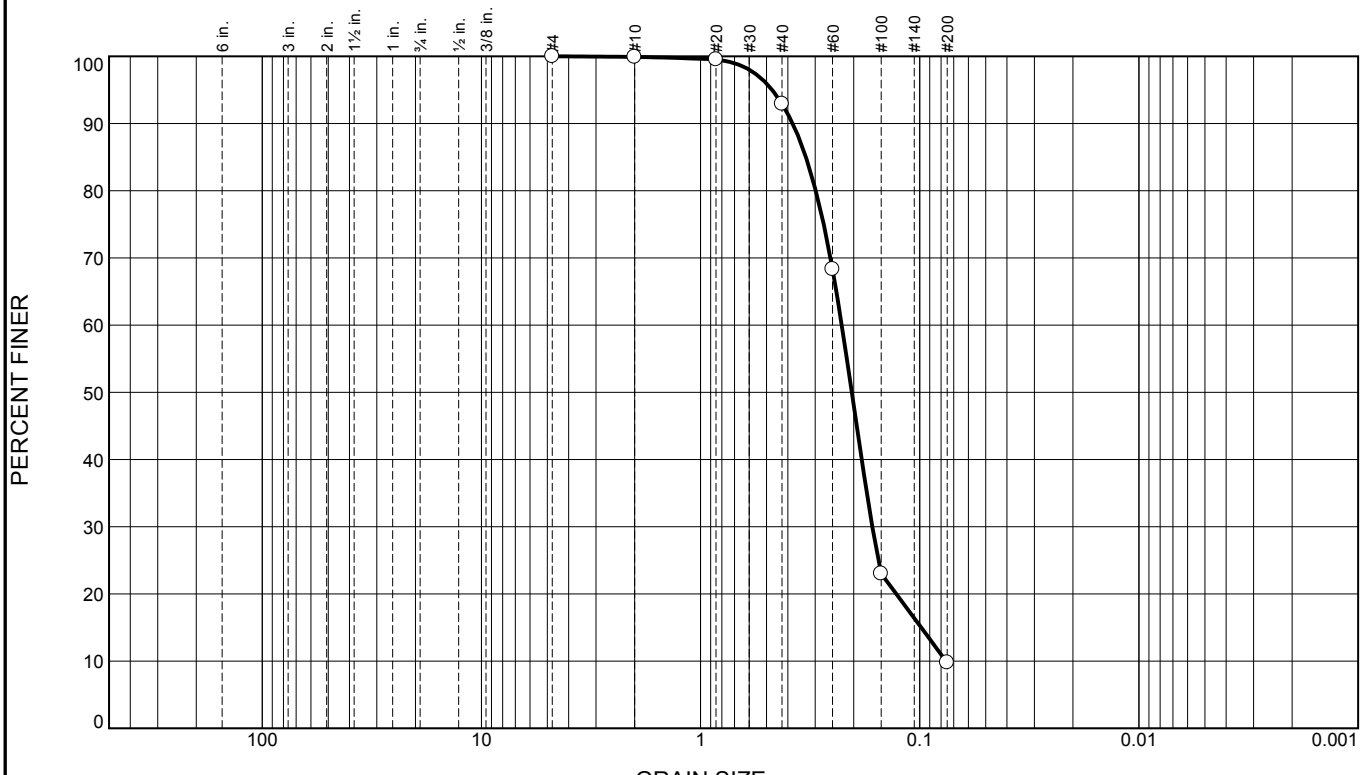
AECOM

Client: WDOA - DIVISION OF STATE FACILITIES
Project: WDNR DAMS STUDIES, YELLOWSTONE DAM

Project No.: 60311420 **Figure**

Tested By: BOB PEETERS

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.0	0.1	7.0	83.1	9.8	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100.0		
#10	99.9		
#20	99.5		
#40	92.9		
#60	68.3		
#100	23.0		
#200	9.8		

* (no specification provided)

Material Description

LIGHT BROWN SILTY FINE SAND

Atterberg Limits

PL= LL= PI=

Coefficients

D_{90}= 0.3802 D_{85}= 0.3308 D_{60}= 0.2269
D_{50}= 0.2042 D_{30}= 0.1645 D_{15}= 0.0986
D_{10}= 0.0758 C_u= 2.99 C_c= 1.57

Classification

USCS= AASHTO=

Remarks

Sample Number: B-3 S-10 **Depth:** 19.0 - 21.0 ft.

Date: 2/26/14

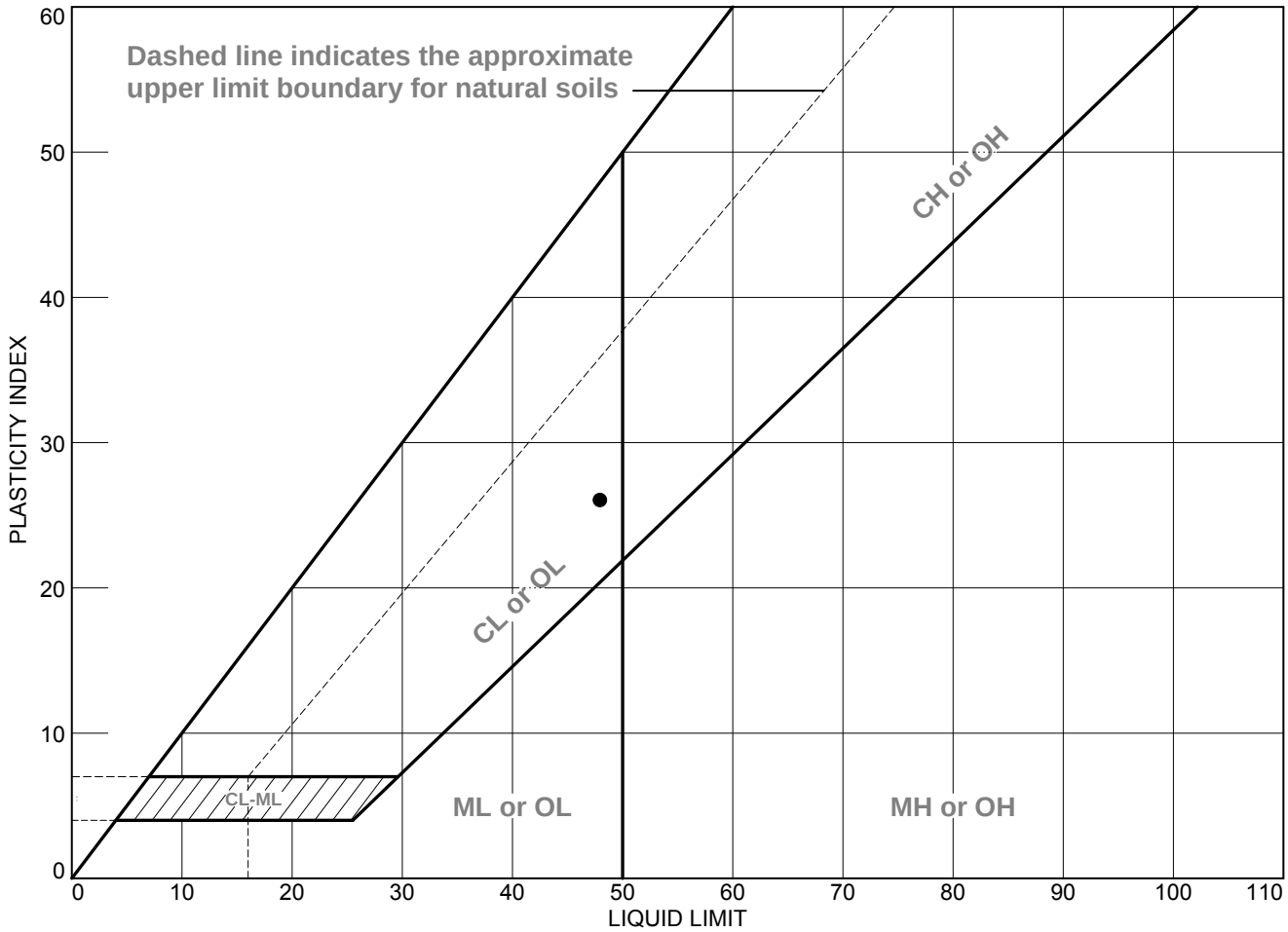
AECOM

Client: WDOA - DIVISION OF STATE FACILITIES
Project: WDNR DAMS STUDIES, YELLOWSTONE DAM

Project No: 60311420 **Figure**

Tested By: BOB PEETERS

LIQUID AND PLASTIC LIMITS TEST REPORT



SOIL DATA

SYMBOL	SOURCE	SAMPLE NO.	DEPTH	NATURAL WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)	USCS
●		B-4 S-4	6.0 - 8.0 ft.	30.6	22	48	26	CL

AECOM

Client: WDOA - DIVISION OF STATE FACILITIES
Project: WDNR DAMS STUDIES, YELLOWSTONE DAM

Project No.: 60311420 **Figure**

Tested By: BOB PEETERS

Water Content Determination Data & Computation Sheet

AECOM

Job No.: 60311420 Name: WDNR Dams Studies, Yellowstone Dam
Date: 02/26/14 Sheet Number: 1 or 1

NOTES: Tare is weight of container (watch glasses and clip, Petri dishes, can, etc.)

$$\text{Water Content} = w = \frac{\text{Weight Of Water}}{\text{Weight Of Dry Soil}} \times 100\%$$

Boring Number	1	2	4				
Sample Number	15	5	4				
Container Number	1	M	3				
Wt. Sample + Tare Wet	82.14	66.07	79.98				
Wt. Sample + Tare Dry	60.29	49.30	67.71				
Wt. of Water	21.85	16.77	12.27				
Tare	30.36	29.72	27.56				
Wt. Of Dry Soil (1)	29.93	19.58	40.15				
Water Content	73.0	85.6	30.6				

$$\text{Organic Content Data} = \frac{\text{Weight of Dry Soil (1) - Wt. of Residue (2)}}{\text{Weight Of Dry Soil (1)}}$$

Test Conditions Time in Furnace: _____ Hr. at Temp. _____

Residue & Tare	56.71	47.29	66.54				
Tare	30.36	29.72	27.56				
Wt. Residue (2)	26.35	17.57	39.98				
Wt. Organic Material	3.58	2.01	1.17				
Organic Content (%)	12.00	10.30	2.9				

Appendix D

Seepage and Slope Stability Results

Appendix D.1

Existing Condition Results

PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

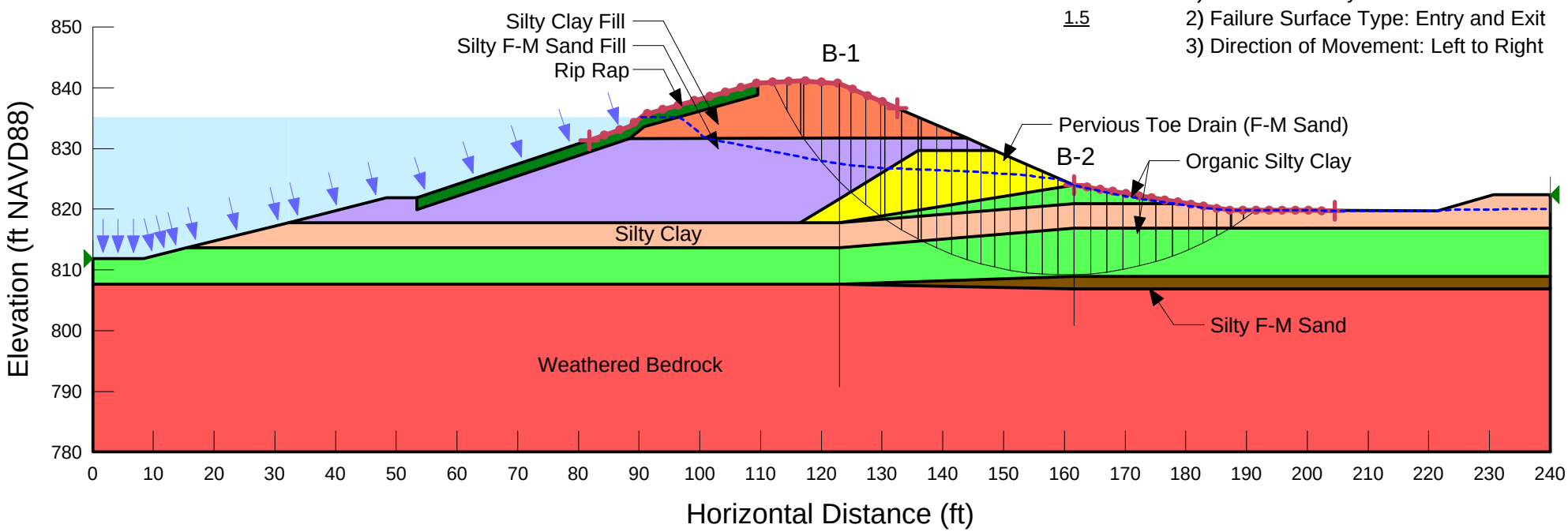
SECTION NO.: A-A' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Normal
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.5
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

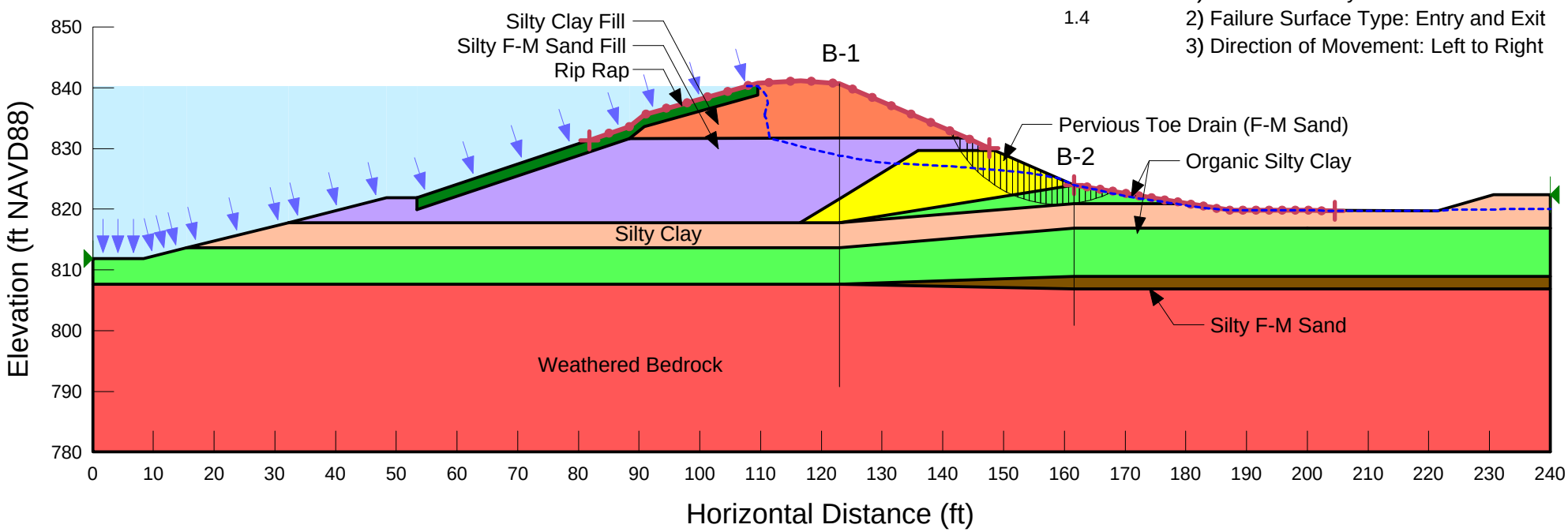
SECTION NO.: A-A' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.4
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

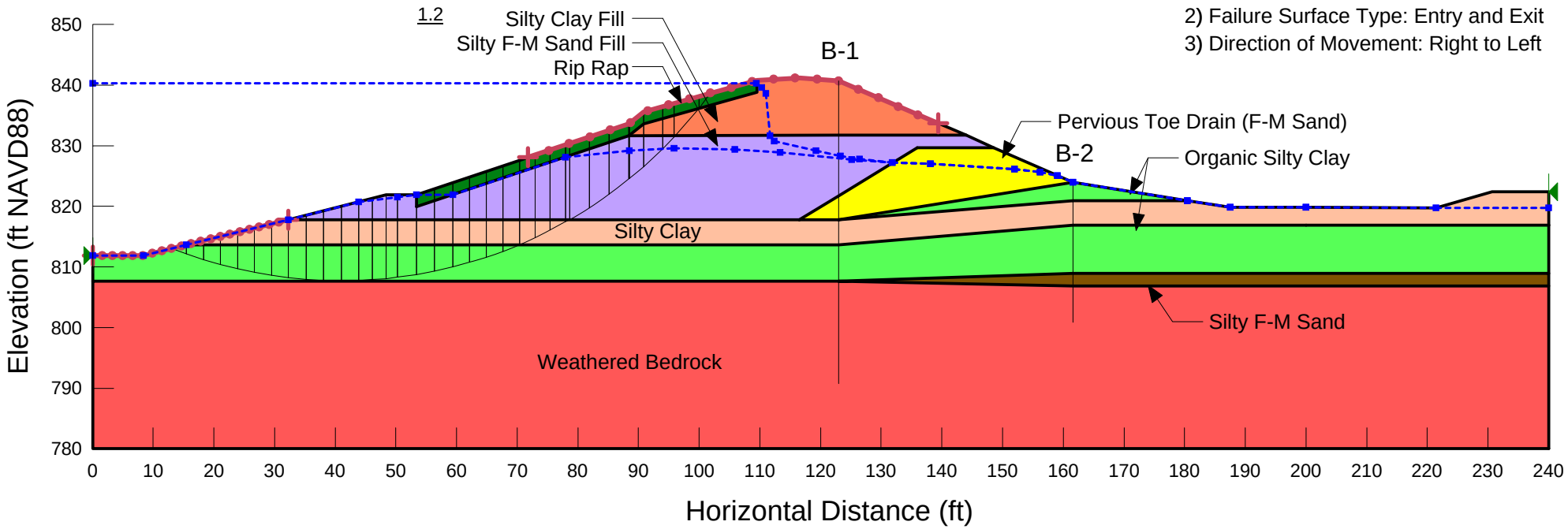
SECTION NO.: A-A' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 811.9 feet
PHREATIC SURFACE: From Transient Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.2
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Right to Left



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

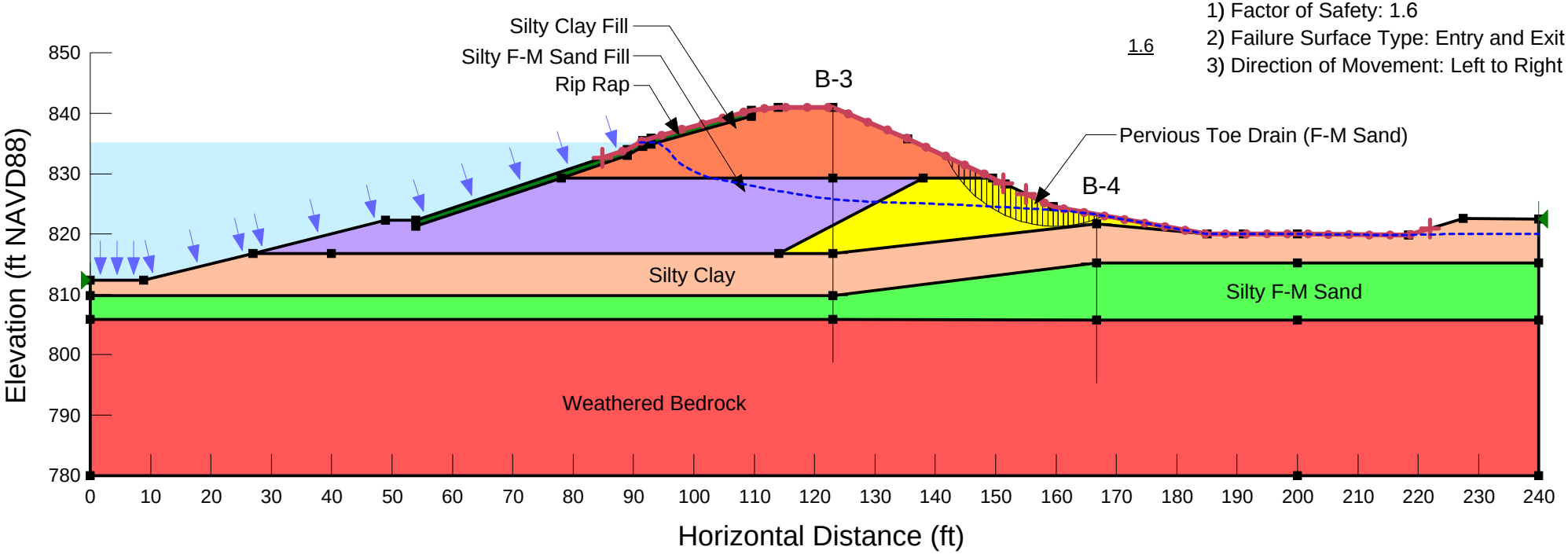
SECTION NO.: C-C' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 07/17/2013
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.6
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

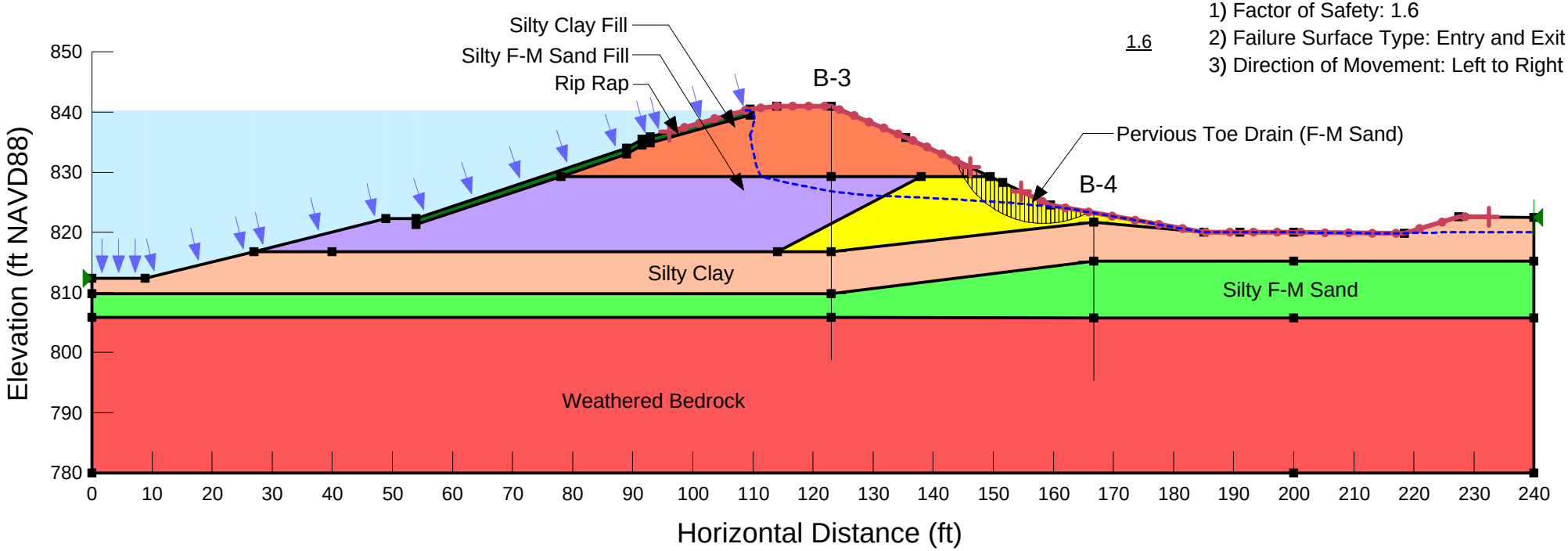
SECTION NO.: C-C' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 07/17/2013
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.6
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

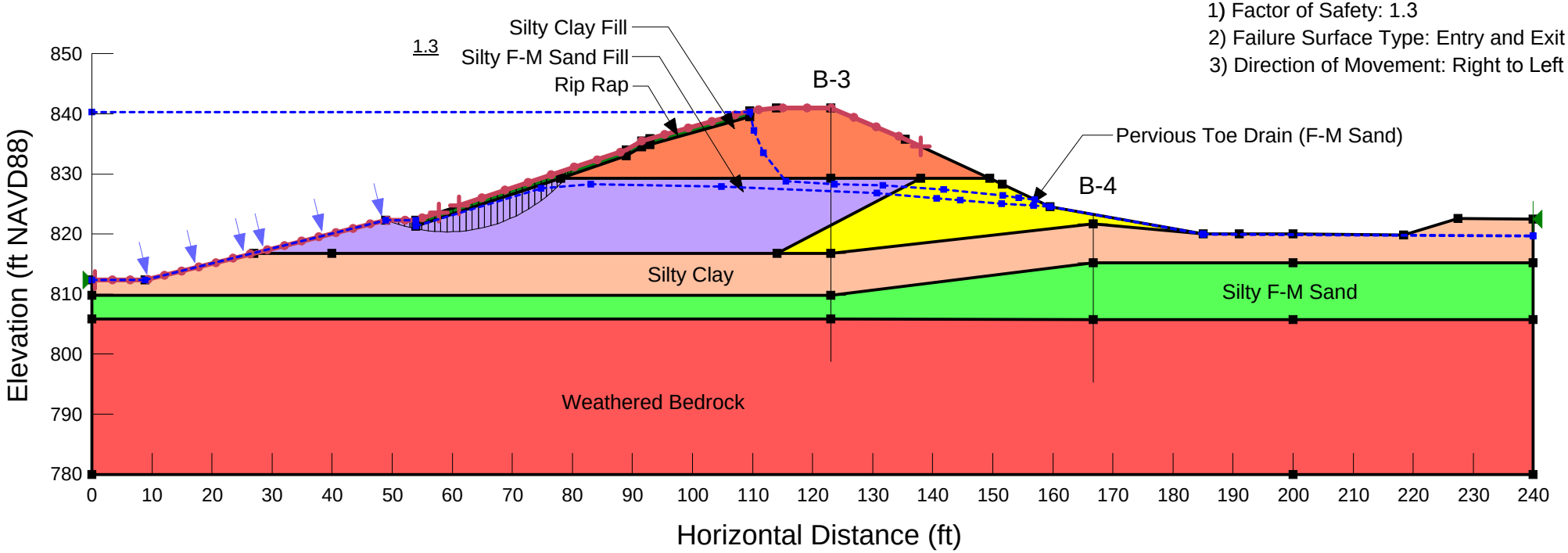
SECTION NO.: C-C' - Existing Condition
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 811.9 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 07/17/2013
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.3
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Right to Left



Appendix D.2

Alternative 2 Results

(Grade Fill and Toe Drain)

PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

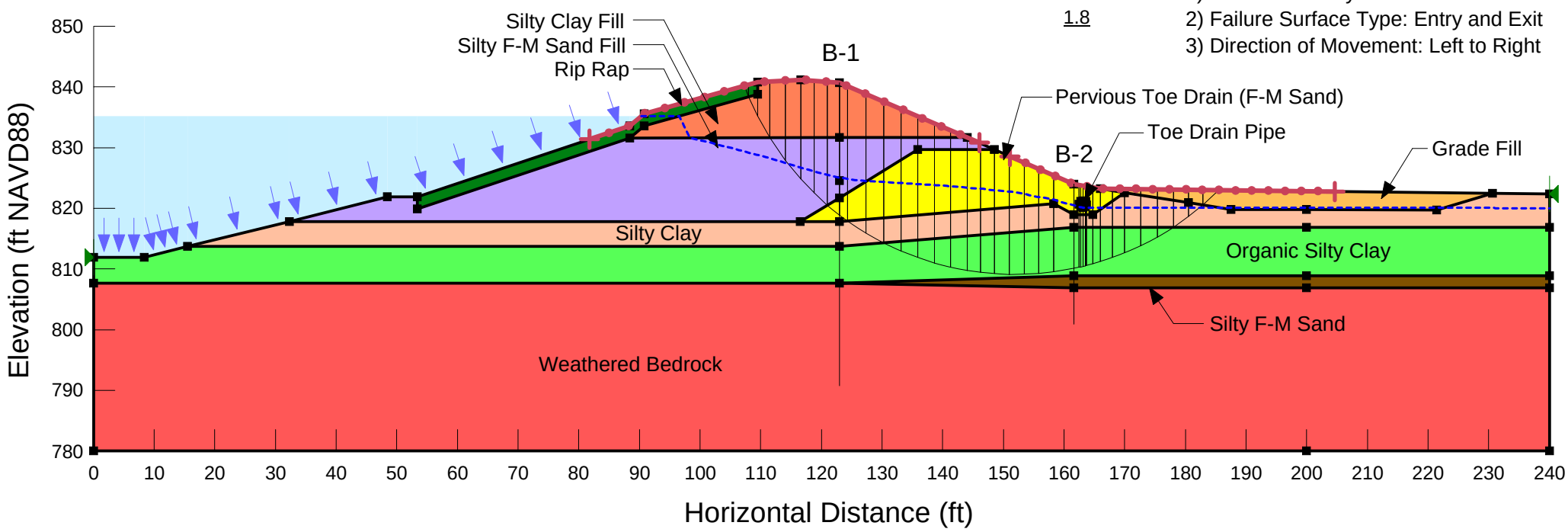
SECTION NO.: A-A' - Alternative 2
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.8
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

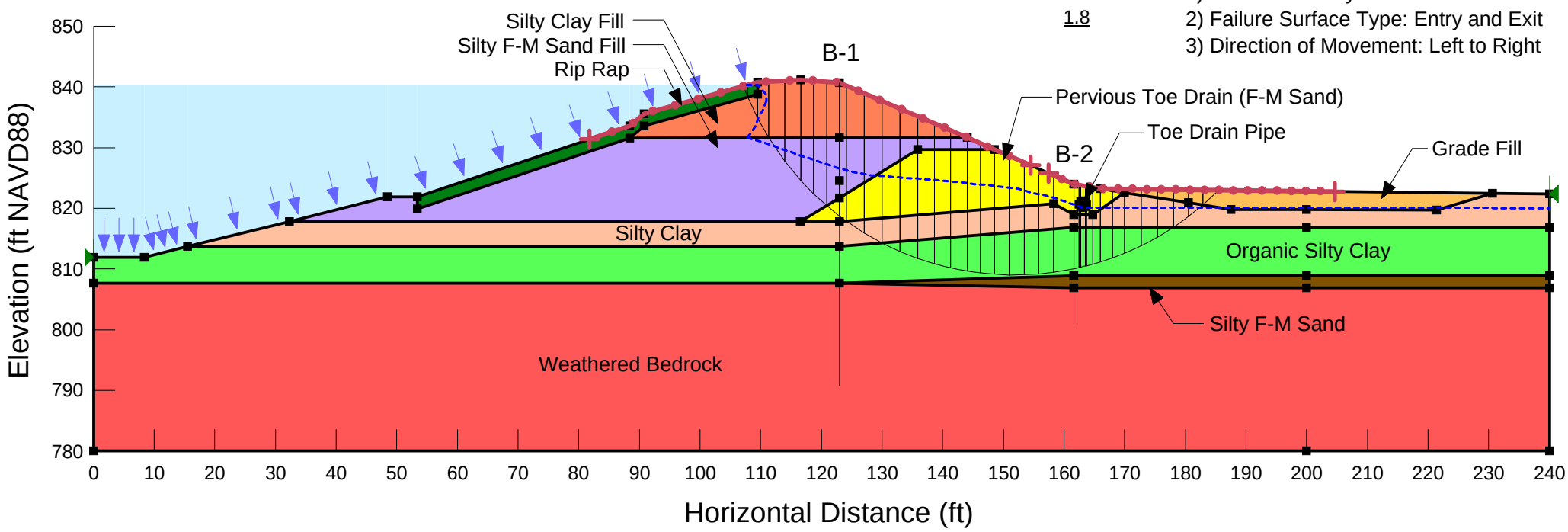
SECTION NO.: A-A' - Alternative 2
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.8
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

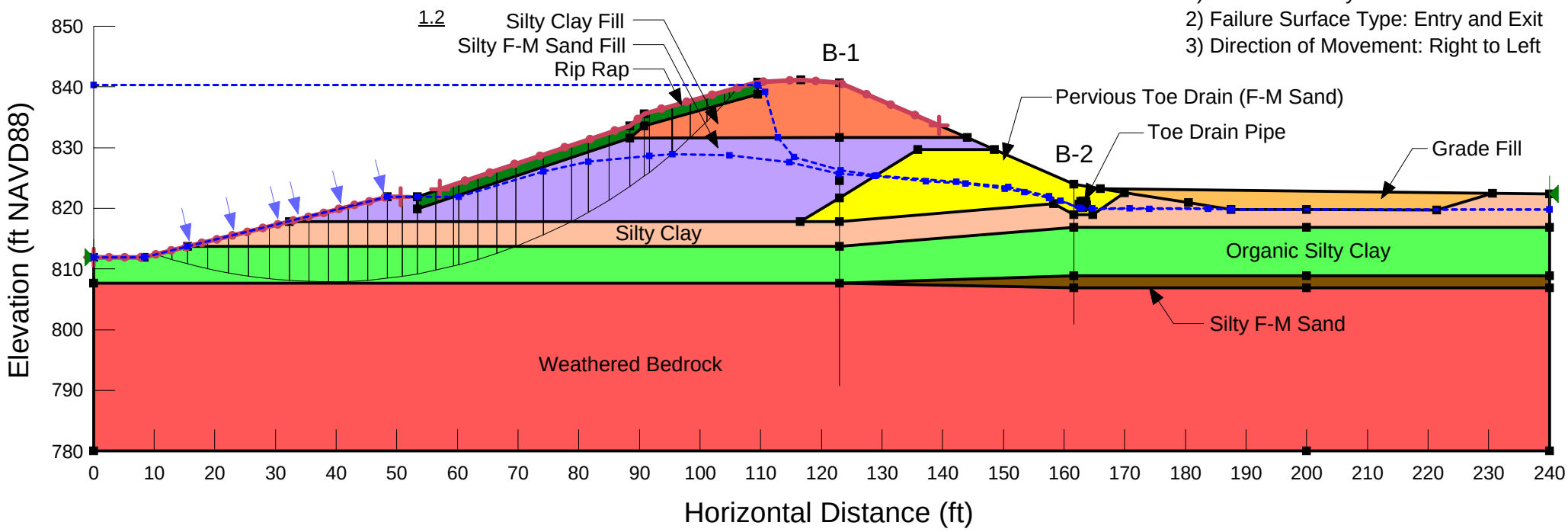
SECTION NO.: A-A' - Alternative 2
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 811.9 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.2
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Right to Left



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

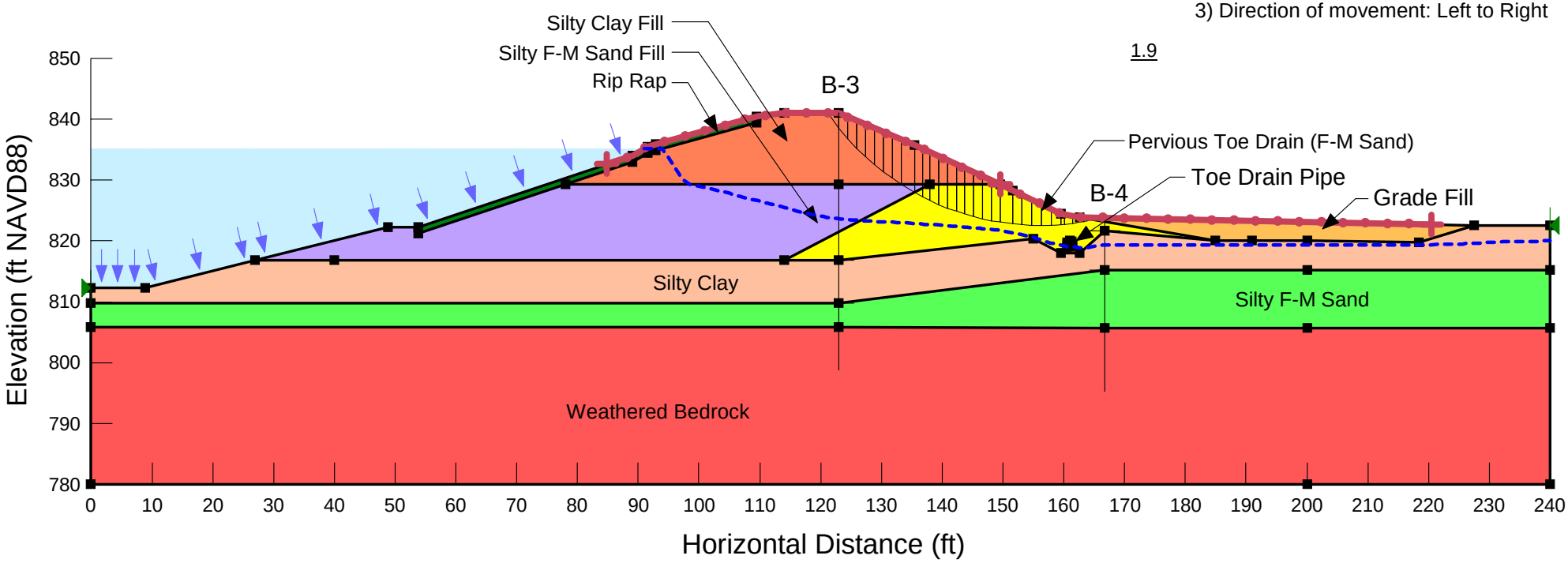
SECTION NO.: C-C' - Alternative 2
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.9
2) Failure Surface Type: Entry and Exit
3) Direction of movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

SECTION NO.: C-C' - Alternative 2

ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet

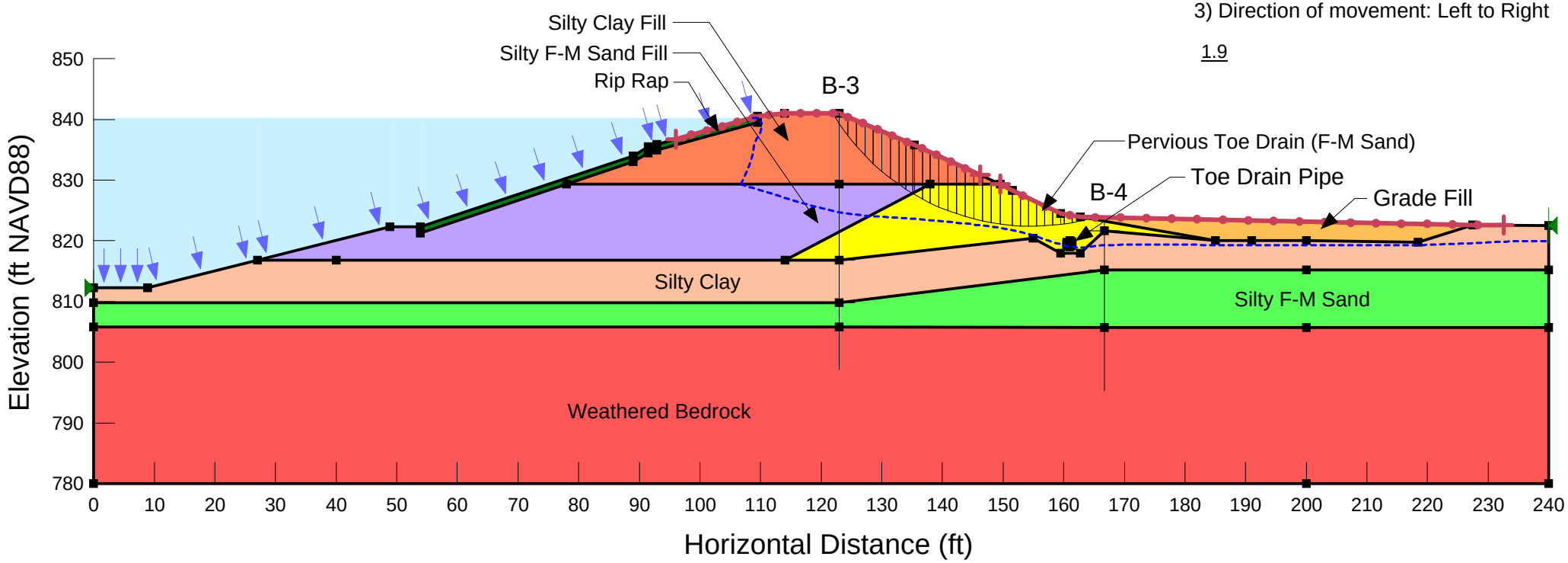
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.9
2) Failure Surface Type: Entry and Exit
3) Direction of movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

SECTION NO.: C-C' - Alternative 2
ANALYSIS TYPE: Morgenstern-Price

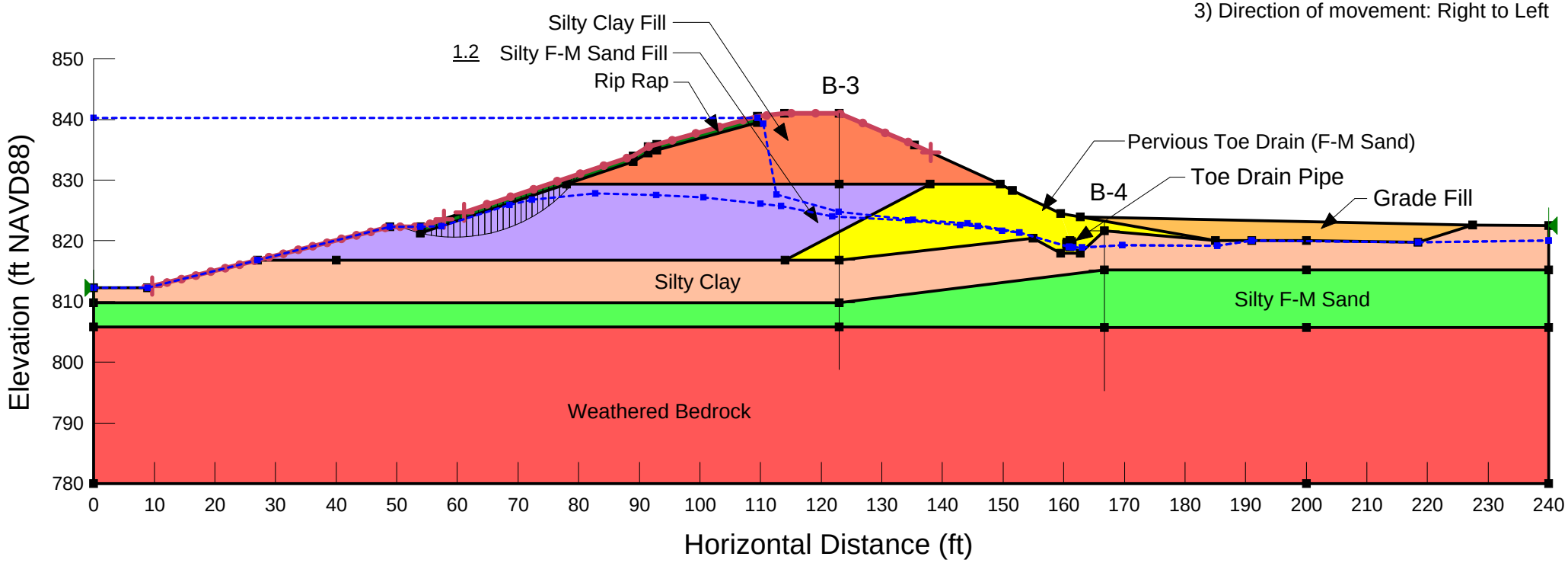
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 811.9 feet

PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES								
					Drained Strength Properties		Drained Strength Properties	
Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Undrained Shear Strength, s_u (lb/ft^2)	Total Angle of Friction, ϕ (deg.)	Effective Cohesion, c' (lb/ft^2)	Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40
Grade Fill	SM		120	1.00E-01	0	31	0	31

NOTES:
1) Factor of Safety: 1.2
2) Failure Surface Type: Entry and Exit
3) Direction of movement: Right to Left



Appendix D.3

Alternative 3 Results

(Toe Drain Only)

PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

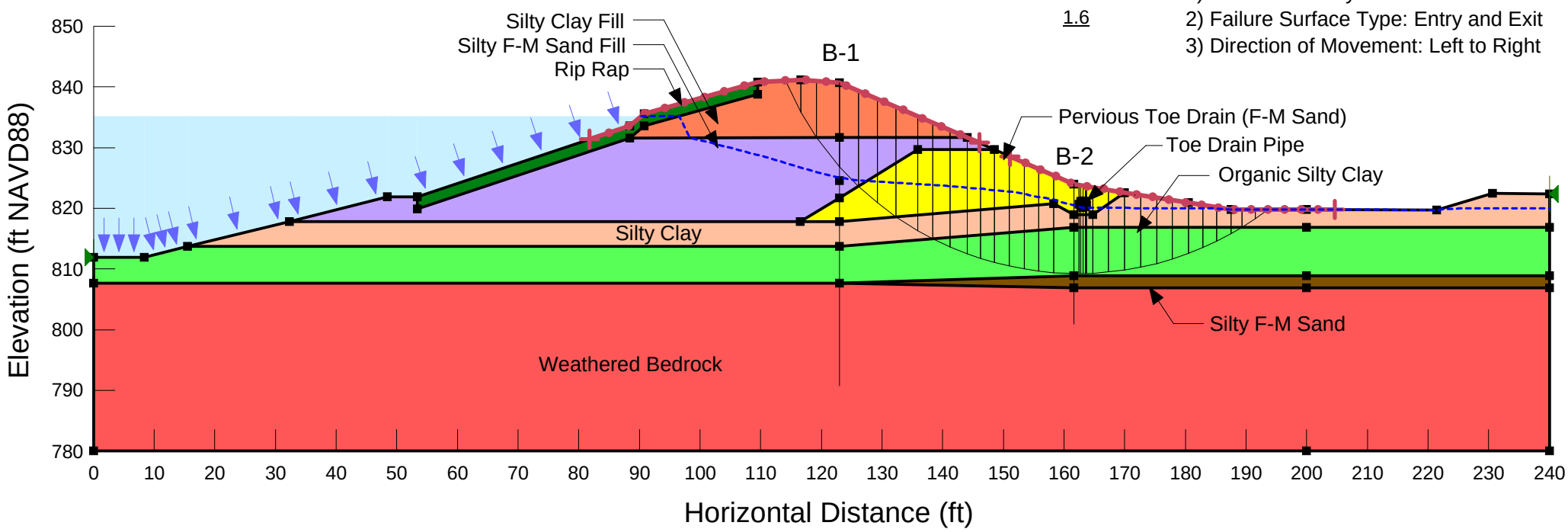
SECTION NO.: A-A' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.6
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

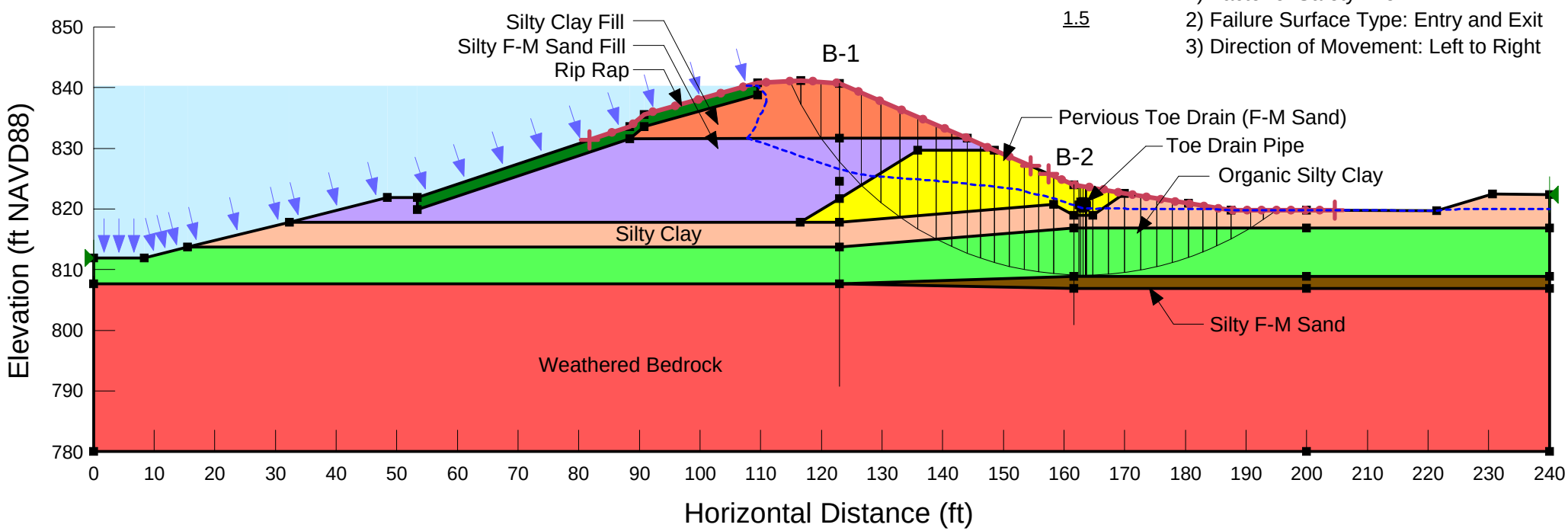
SECTION NO.: A-A' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.5
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

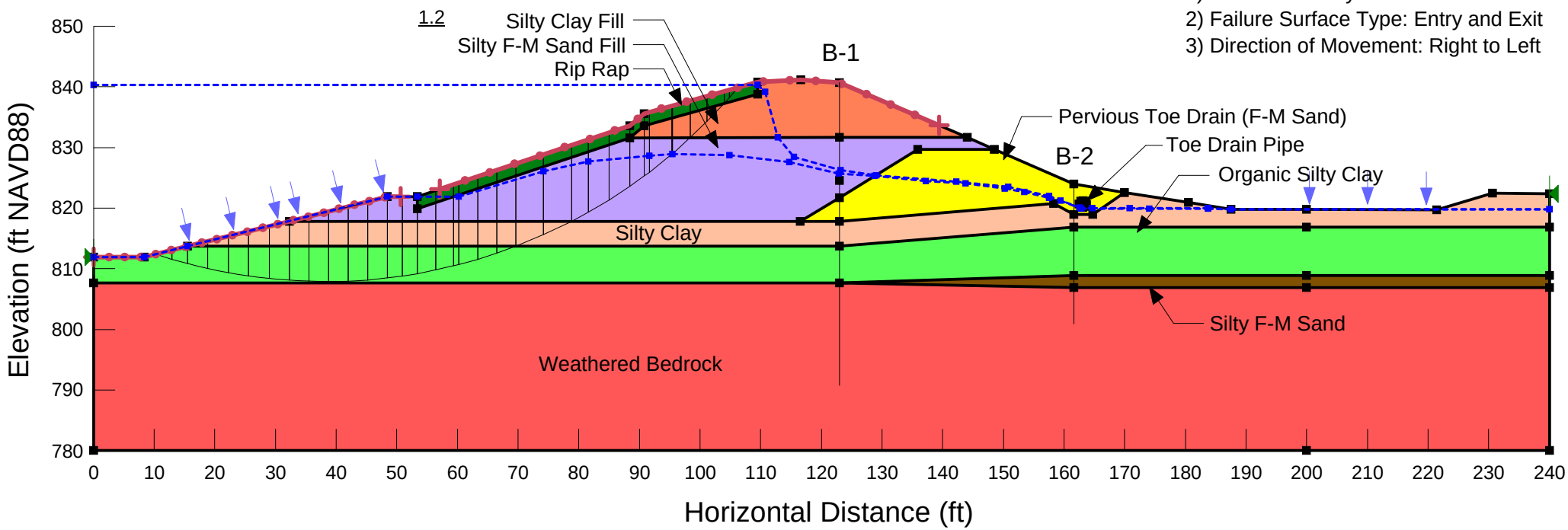
SECTION NO.: A-A' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 811.9 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Organic Silty Clay	OL, OH		90	1.00E-06	250	0	100	20
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Native Silty F-M Sand	SM		110	1.00E-02	0	28	0	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.2
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Right to Left



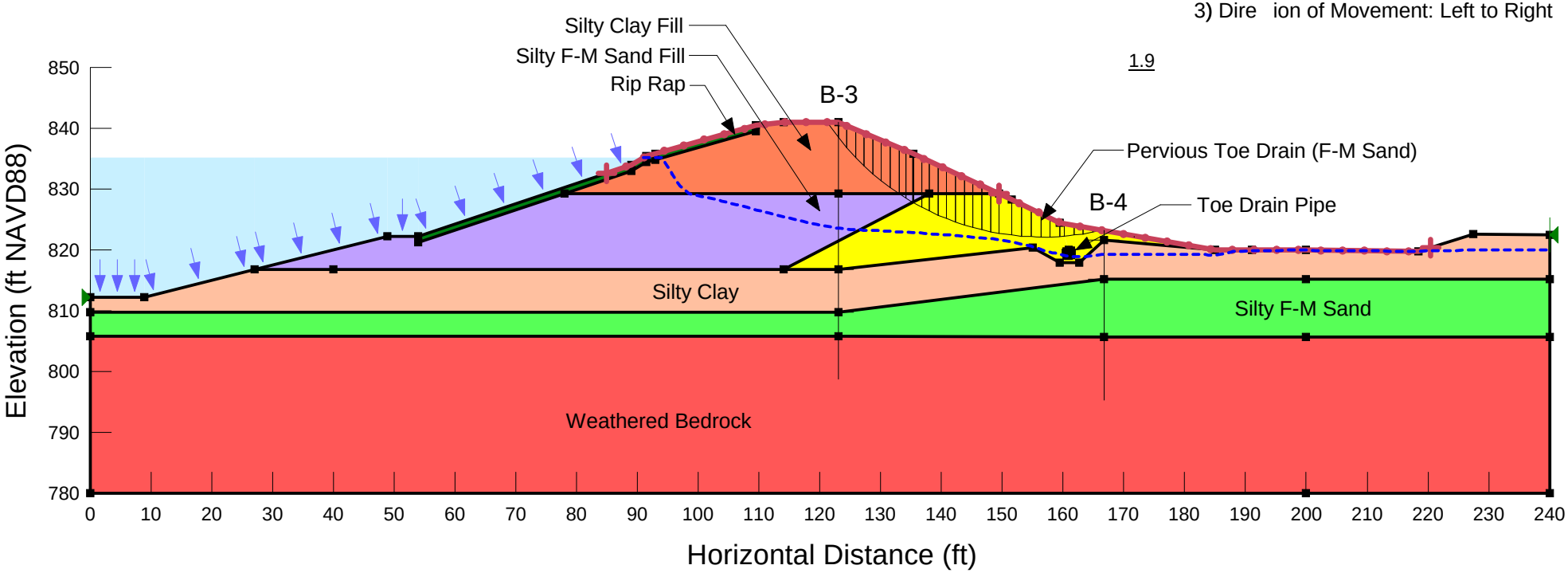
PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

SECTION NO.: C-C' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES								
					Drained Strength Properties		Drained Strength Properties	
Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Undrained Shear Strength, s_u (lb/ft^2)	Total Angle of Friction, ϕ (deg.)	Effective Cohesion, c' (lb/ft^2)	Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.9
2) ailure Surface Type: Entry and Exit
3) Dire ion of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

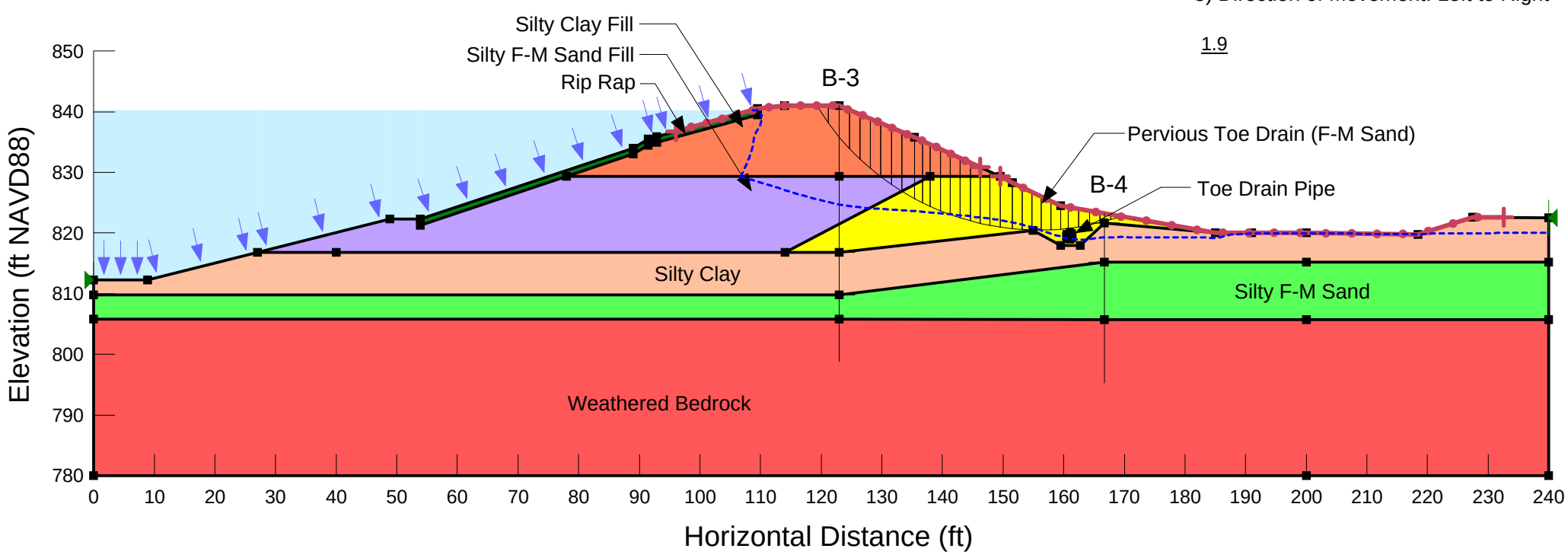
SECTION NO.: C-C' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Flood
RESERVOIR ELEVATION: 840.3 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 02/17/2014
CHECKED BY: JDW
DATE: 04/10/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.9
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Left to Right



PROJECT: Yellowstone Lake Dam Seepage & Stability Evaluation
PROJECT NO.: 60311420
SUBJECT: Global Stability

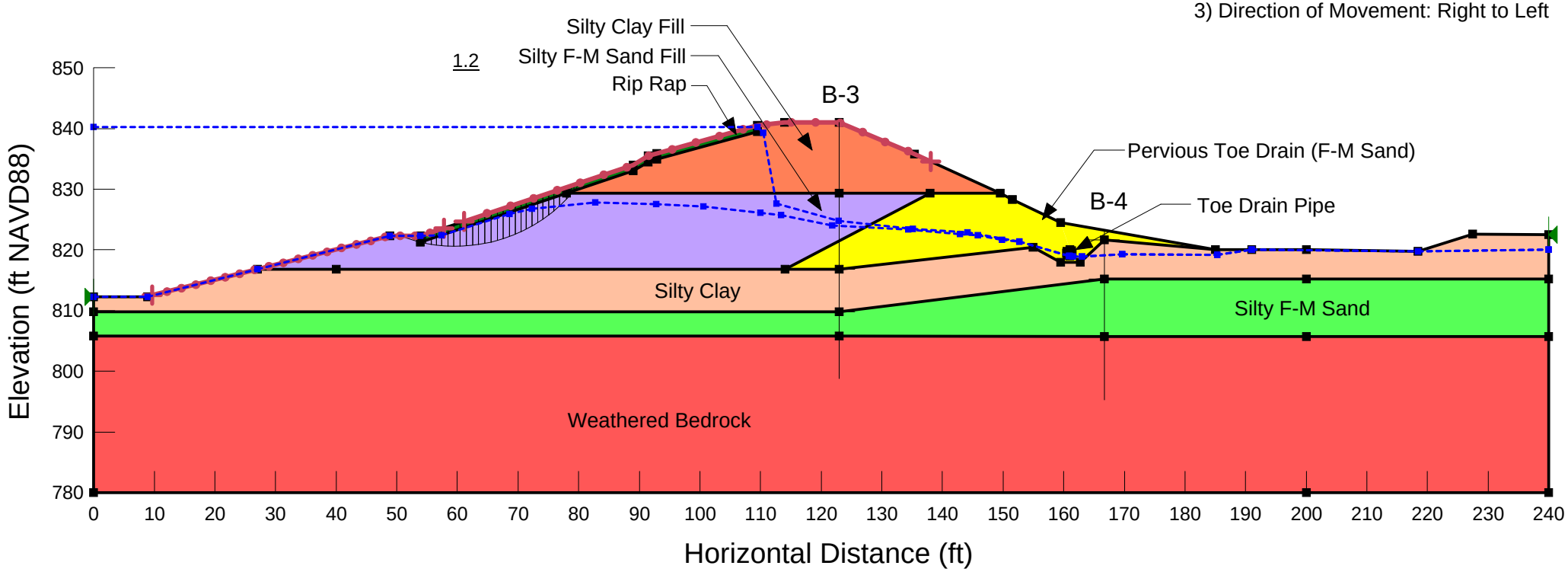
SECTION NO.: C-C' - Alternative 3
ANALYSIS TYPE: Morgenstern-Price
RESERVOIR CONDITION: Slope Stability-Drawdown
RESERVOIR ELEVATION: 835.0 feet
PHREATIC SURFACE: From Steady-State Seepage
VERTICAL EXAGGERATION: 1H:1V

ORIGINATED BY: DEH
DATE: 07/17/2013
CHECKED BY: JDW
DATE: 04/08/2014

MATERIAL PROPERTIES

Material Description	USCS Class.	Material Color	Unit Weight, γ (lb/ft^3)	Sat. Hydraulic Conductivity, k (cm/sec)	Drained Strength Properties: Undrained Shear Strength, s_u (lb/ft^2)	Drained Strength Properties: Total Angle of Friction, ϕ (deg.)	Drained Strength Properties: Effective Cohesion, c' (lb/ft^2)	Drained Strength Properties: Internal Angle of Friction, ϕ' (deg.)
Fill: Silty Clay	CL		130	1.00E-06	2500	0	250	29
Fill: Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Fine to Medium Sand	SP-SM, SP		120	1.00E-01	0	31	0	31
Silty F-M Sand	SM		120	1.00E-02	0	31	0	31
Native Silty Clay	CL		125	1.00E-07	1500	0	150	28
Weathered Bedrock	GP		135	1.52E-01	0	38	0	38
Rip Rap	--		135	10	0	40	0	40

NOTES:
1) Factor of Safety: 1.2
2) Failure Surface Type: Entry and Exit
3) Direction of Movement: Right to Left



Appendix E

Opinion of Probable Costs

Opinion of Probable Cost

Project:	Yellowstone Dam	Date:	5/20/2014
Client:	Wisconsin Division of State Facilities	AECOM Project No.:	60311420
Location:	Yellowstone Lake State Park	DFD Project No.:	13H3H
Prepared by:	AECOM	Estimator:	D. Hesse
		Checked by:	G. Krueger

Deficiency	Alternative	DESCRIPTION	SUBTOTALS 2016	TOTAL 2016
Embankment Seepage				
	Alternative 1A	Quarterly Observation / Monitoring Plan (Annual Cost)	$ 4,410	
	Alternative 1B	Weir and Drain	$ 35,131	
	Alternative 2	Raise grades in the low area and install toe drain	$ 415,471	
(Preferred)	Alternative 3	Install a toe drain only	$ 120,887	
Vertical Slide Gate				**$ 183,008**
		Upgrade the gear reduction boxes, motor, and structural steel support.		
Low Level Lake Drain Observation				**$ 14,685**
		Observe the vertical gate, access structure, and conduits every 10 years.		
Low Level Lake Drain Slip Lining				**$ 432,679**
		Future repair alternative for the CMPs includes slip lining using rigid HDPE pipe.		
Rip Rap				**$ 143,735**
		Place rip rap along the upstream slope of the embankment.		
Tree and Brush Removal				**$ 27,726**
		Remove trees and woody vegetation from the right groin and left embankment.		
Benchmarks				**$ 9,692**
		Install two benchmarks remote from the dam.		

With Alternative 1:	$ 413,978	
With Alternative 2:	$ 794,318	
With Alternative 3:	$ 499,735	(Preferred)
Future Slip Lining	$ 432,679	

Notes:

1. Total with Alternative 1 does not include annual mointoring cost of $4,410/yr
2. Information presented on this sheet represent our opinion of probable costs in 2014 dollars with a 5% year to year escalation to 2016. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.

Opinion of Probable Cost Date: 5/20/2014

Embankment Alternatives

Project: Yellowstone Dam AECOM Project No.: 60311420

Client: Wisconsin Division of State Facilities DFD Project No.: 13H3H

Location: Yellowstone Lake State Park Estimator: D. Hesse

Prepared by: AECOM Checked by: G. Krueger

						Cost Totals								
						Subtotal	**Mobilization**	**Contingency**	**Remote Access**	**Final Design**	**DFD Fee**	**Construction Resident Engineering**	**Total Cost**	**Total Cost (5%/yr)**
Alternative	Description	Quantity	Units	Unit Cost	Item Total		10%	10%	10%	8%	4%	8%	2014	2016
1A	**Quarterly Observation / Monitoring Plan (Annual Cost)**					$4,000	$0	$0	$0	$0	$0	$0	**$4,000**	**$4,410**
1A.1	Site Visit \ Investigation	4	each	$400.00	$1,600									
1A.2	Report Generation and Review	4	each	$600.00	$2,400									
1B	**Weir and Drain**					$20,400	$2,040	$2,244	$2,244	$1,974.72	$987.36	$1,974.72	**$31,865**	**$35,131**
1B.1	Weir	1	ls	$500.00	$500									
1B.2	Stilling Basin	1	ls	$4,500.00	$4,500									
1B.3	Outfall Apron	4	cy	$800.00	$3,200									
1B.4	Excavation	200	cy	$25.00	$5,000									
1B.5	Backfill trench with borrow	200	cy	$5.00	$1,000									
1B.6	Asphalt Repair (Parking Lot)	12	ton	$100.00	$1,200									
1B.7	Drain Pipe - 12"	200	lf	$25.00	$5,000									
2	**Raise grades in the low area and install toe drain**					$241,258	$24,125.75	$26,538	$26,538	$23,354	$11,677	$23,354	**$376,844**	**$415,471**
2.1	Silt Fence	1450	lf	$1.75	$2,538									
2.2	Silt Fence Maintenance	1450	lf	$0.20	$290									
2.3	Turbidity Barrier (6' Height)	50	sy	$25.00	$1,250									
2.4	Clear vegetation between toe and roadway	1	ls	$2,000.00	$2,000									
2.5	New Fill for Raising Grades	9800	cy	$15.75	$154,350									
2.6	Excavation and haul	500	cy	$25.00	$12,500									
2.7	Dewatering Trench	14	day	$200.00	$2,800									
2.8	Fine Filter Material	275	cy	$25.00	$6,875									
2.9	Coarse Filter Material	150	cy	$25.00	$3,750									
2.10	Drain Pipe - 12"	1250	lf	$28.00	$35,000									
2.11	Backfill trench with borrow	535	cy	$5.00	$2,675									
2.12	Asphalt Repair (Parking Lot)	12	ton	$100.00	$1,200									
2.13	Outfall Apron	4	cy	$800.00	$3,200									
2.14	Topsoil (2")	500	cy	$20.00	$10,000									
2.15	Fertilizer	5.5	cwt	$60.00	$330									
2.16	Seed	80	lbs	$20.00	$1,600									
2.17	Mulch	9000	sy	$0.10	$900									
3	**Install a toe drain only**					$70,198	$7,019.75	$7,722	$7,722	$6,795	$3,398	$6,795	**$109,648**	**$120,887**
3.1	Silt Fence	1450	lf	$1.75	$2,538									
3.2	Silt Fence Maintenance	1450	lf	$0.20	$290									
3.3	Turbidity Barrier (6' Height)	50	sy	$25.00	$1,250									
3.4	Excavation and haul	470	cy	$25.00	$11,750									
3.5	Dewatering Trench	14	day	$200.00	$2,800									
3.6	Fine Filter Material	275	cy	$25.00	$6,875									
3.7	Coarse Filter Material	150	cy	$25.00	$3,750									
3.8	Drain Pipe - 12"	1250	lf	$28.00	$35,000									
3.9	Backfill trench with borrow	255	cy	$5.00	$1,275									
3.10	Asphalt Repair (Parking Lot)	12	ton	$100.00	$1,200									
3.11	Outfall Apron	4	cy	$800.00	$3,200									
3.12	Seed	10	lbs	$20.00	$200									
3.13	Mulch	700	sy	$0.10	$70									

Information presented on this sheet represent our opinion of probable costs in 2014 dollars. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.

Opinion of Probable Cost Date: 5/20/2014

Vertical Slide Gate Recommendations

Project: Yellowstone Dam AECOM Project No.: 60311420

Client: Wisconsin Division of State Facilities DFD Project No.: 13H3H

Location: Yellowstone Lake State Park Estimator: D. Hesse

Prepared by: AECOM Checked by: G. Krueger

						Cost Totals								
						Subtotal	Mobilization	Contingency	Remote Access	Final Design	DFD Fee	Construction Resident Engineering	Total Cost	Total Cost (5%/yr)
Item	Description	Quantity	Units	Unit Cost	Item Total		10%	10%	10%	8%	4%	8%	2014	2016
1.0	**Replace the motor and gear boxes.**					$100,000	$10,000	$11,000	$11,000	$9,680	$4,840	$9,680	**$156,200**	**$172,211**
1.1	New Motor and Gear Box Equipment	1	ls	$60,000.00	$60,000.00									
1.2	Installation	1	ls	$40,000.00	$40,000.00									
2.0	**Upgrade structural steel support and replace access panels.**					$6,270	$627	$689.70	$689.70	$607	$303	$607	**$9,794**	**$10,798**
2.1	C channel steel (C 8x18.75)	60	lf	$41.00	$2,460.00									
2.2	Steel access plates (1/4")	50	sf	$15.00	$750.00									
2.3	Steel Support Plates (1/2")	2	sf	$30.00	$60.00									
2.4	Locks and Hinges	1	ls	$500.00	$500.00									
2.5	Misc (Paint/Safety)	1	ls	$2,500.00	$2,500.00									

Information presented on this sheet represent our opinion of probable costs in 2014 dollars. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.

Opinion of Probable Cost Date: 5/20/2014

**Low Level Lake Drain Monitoring **
Observation and Future Repair

Project: Yellowstone Dam AECOM Project No.: 60311420
Client: Wisconsin Division of State Facilities DFD Project No.: 13H3H
Location: Yellowstone Lake State Park Estimator: D. Hesse
Prepared by: AECOM Checked by: G. Krueger

Item	Description	Quantity	Units	Unit Cost	Item Total	Cost Totals: Subtotal	Mobilization 10%	Contingency 10%	Remote Access 10%	Final Design 8%	DFD Fee 4%	Construction Resident Engineering 8%	Total Cost 2014	Total Cost (5%/yr) 2016
1.0	**Investigate every 10 years**					$10,000	$0	$1,000.00	$1,000.00	$880	$440	$0	**$13,320**	**$14,685**
1.1	ROV \ Dive Team	1	ls	$10,000.00	$10,000									
2.0	**CMP pipe lining (HDPE)**					$276,375	$0	$27,637.50	$27,637.50	$12,161	$24,321	$24,321	**$392,453**	**$432,679**
2.1	U/S, HDPE 48"	90	lf	$1,565.00	$140,850									
2.2	U/S, Installation		Included		$0									
2.3	U/S, Annulus Grouting		Included		$0									
2.4	D/S, HDPE 48"	85	lf	$1,565.00	$133,025									
2.5	D/S, Installation		Included		$0									
2.6	D/S, Annulus Grouting		Included		$0									
2.7	New Upstream Grate for 48" pipe	1	ls	$2,500.00	$2,500									

Information presented on this sheet represent our opinion of probable costs in 2014 dollars. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.

Opinion of Probable Cost Date: 5/20/2014

Other Recommendations

Project: Yellowstone Dam AECOM Project No.: 60311420

Client: Wisconsin Division of State Facilities DFD Project No.: 13H3H

Location: Yellowstone Lake State Park Estimator: D. Hesse

Prepared by: AECOM Checked by: G. Krueger

						Cost Totals								
						Subtotal	**Mobilization**	**Contingency**	**Remote Access**	**Final Design**	**DFD Fee**	**Construction Resident Engineering**	**Total Cost**	**Total Cost (5%/yr)**
Item	Description	Quantity	Units	Unit Cost	Item Total		10%	10%	10%	8%	4%	8%	2014	2016
1.0	**Rip Rap**					$83,465	$8,346.50	$9,181.15	$9,181.15	$8,079	$4,040	$8,079	**$130,372**	**$143,735**
1.1	Rip-Rap Bedding (U\S) 6" D x 12' W x 1250' L	275	cy	$25.00	$6,875									
1.2	Rip-Rap (U\S) 2' D x 12' W x 1260' L	1110	cy	$69.00	$76,590									
2.0	**Tree and Brush Removal**					$16,100	$1,610	$1,771.00	$1,771.00	$1,558	$779	$1,558	**$25,148**	**$27,726**
2.1	Clearing and Grubbing (L Groin, R Embankment)	1400	sy	$10.00	$14,000									
2.2	Replace Topsoil (2")	80	cy	$20.00	$1,600									
2.3	Fertilizer	1	cwt	$60.00	$60									
2.4	Seed	15	lbs	$20.00	$300									
2.5	Mulch	1400	sy	$0.10	$140									
3.0	**Benchmarks**					$6,000	$600	$660.00	$660.00	$581	$290	$0	**$8,791**	**$9,692**
3.1	Install Two Benchmarks Off-Site	2	each	$3,000.00	$6,000									

Information presented on this sheet represent our opinion of probable costs in 2014 dollars. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.