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Conceptual Design Basis Report
Rehabilitation of Smallwood Dam

Gladwin County, Michigan

Submitted to:
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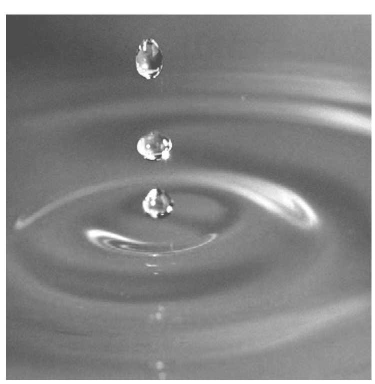
GEI Project No. 2002879, Task 4



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1. Introduction

1.1 Background

Following the May 19, 2020, storm event that resulted in severe damage to the Smallwood Dam, minor downstream erosion damage to Secord Dam, and a catastrophic failure (breach) of the Edenville and Sanford Dams, the Four Lakes Task Force (FLTF) requested GEI Consultants of Michigan, P.C. (GEI) to provide "planning-level" opinions of probable construction costs to reconstruct and/or rehabilitate the four dams without hydroelectric power formerly owned by Boyce Hydro, LLC (Boyce) and licensed by the Federal Energy Regulatory Commission (FERC).

As documented in the July 2020 Post Failure Reconstruction Cost Analysis prepared by GEI (Ref. GEI, 2020a), we developed engineer's opinion of construction cost estimates assuming repair or reconstruction of the dams without hydropower generation and increasing spillway capacity to pass the ½ Probable Maximum Flood (PMF) in accordance with the Michigan Department of Environment, Great Lakes and Energy (EGLE) requirement for high hazard dams. The FLTF also requested that GEI develop cost estimates to pass the full PMF in the event the State of Michigan EGLE, at a future date, increases the high hazard dam minimum spillway capacity requirement above the ½ PMF, or if the probable maximum precipitation (PMP) estimates for a Michigan site-specific region increase. These high-level cost estimates were used to begin budgetary planning for the reconstruction / rehabilitation of the four projects.

As follow-up to our Post Failure Reconstruction Cost Study, the FLTF requested two additional engineering studies be undertaken. The first (Task Order No. 3) is a Tobacco and Tittabawassee River hydrologic and hydraulic flood study to update and finalize the design storms at each of the four dams and determine the additional minimum spillway capacity required to safely pass the ½ PMF. This study is a collaborative effort being performed by GEI, Ayres Associates (Ayres) and the Spicer Group, Inc. (SGI). The results of this Task Order No. 3 study are being provided in a separate report titled "GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam" (Ref. GEI, 2021).

The second engineering study (Task Order No. 4), the subject of this Report for Smallwood Dam, provides the study results, which involved "value engineering" and further development of the concept designs, construction sequencing and cost estimates, presented in the July 2020 Post Failure Reconstruction Cost Analysis (Ref. GEI, 2020a).

Based on previous FERC orders to Boyce that pre-dated the May 2020 flood, the initial results of GEI's (Task Order No. 3) flood study (still in progress), visual inspection of the four dams during October 2020 (Task Order No. 5) and follow-on discussions with FLTF, SGI, Essex

Partnership (Essex), the FERC and EGLE, the following dam safety-related issues were identified:

- The dam in its current condition can pass approximately 8,700 cubic feet per second (cfs) of flow before water begins spilling over the left (east) embankment overflow section. According to the latest flood analysis, a total spillway capacity of approximately 19,065 cfs is needed to safely pass the ½ PMF as currently required by the Michigan EGLE without overtopping the dam structures or east abutment and rim areas.
- The gated spillways and integral to a single powerhouse are reinforced concrete hollow, buttress-type structures constructed on glacial till soil foundations that were more common pre-1940s when materials were expensive and labor inexpensive. This style of dam does not currently meet industry standards of design practice in terms of long-term durability and ductility. Furthermore, the dams were constructed of non-air entrained concrete and exhibit extensive deterioration along the waterlines were exposed to freeze-thaw conditions.
- The existing Tainter gates are likely beyond the end of their design life and exhibit signs of age and corrosion. The Tainter gate hoisting mechanisms are insufficiently sized for the range of design service loads including ice and do not meet current industry design standards for wire rope cable reels, hoists, and gate operators.
- Without hydropower operation, there is no low-level outlet to draw down or drain the impoundment below the invert of the spillway sill. Passing flow over the spillway crest during winter has also led to significant 2021 ice-buildup on the spillway walls.
- At the time of the 2020 flood event the downstream riprap erosion protection was inadequate to prevent erosion during high flows. *Note, armor stone was recently (February 2021) installed on the left and right embankment to EL. 696.0 to provide protection up to the 200-year flood discharge.*

The conceptual designs and cost estimates presented in this Report assume the following for the rehabilitation of Smallwood Dam:

- Provide an updated earth and concrete structure that will have a 75+ year design service life.
- Provide temporary cofferdams and diversion structures to have the ability to safely pass base river flows plus flood flows (assumed 100-year storm event) without failing during construction.
- Rehabilitation designs to meet current industry standards of engineering practice and the design standards for high hazard dams in accordance with the State of Michigan EGLE.
- Restoring hydropower generation will not be part of the rehabilitation plans and was not included in our costs.

- Upgrade the total spillway capacity to pass at a minimum the ½ PMF in accordance with State of Michigan EGLE requirements.
- Temporary cofferdams and diversion structures to have the ability to safely pass base river flows plus flood flows (assumed 100-year storm event) without failing during construction.
- Transform the powerhouse to a gated low level outlet structure using the intake, scroll case, a fixed Francis wheel and draft tube to release 100 to 200 cfs baseflows during low flow winter months.

1.2 Project Purpose

The purposes of this Design Basis Report include providing the following:

- A descriptive narrative of the proposed spillway capacity improvements to pass the design flood (1/2 PMF);
- A description of the proposed improvements to the embankments to reduce seepage, provide protective measures against seepage-induced internal erosion, and improve slope stability;
- Document project geology, hydrology, establish hydraulic, structural concrete and earth fill embankment design for dam foundation, slope and seepage stability criteria;
- Discuss construction considerations including anticipated construction sequencing and cofferdam requirements; and
- Develop design drawings to an approximately 30% level of development and prepare an engineer's opinions of probable construction cost.

1.3 Authorization

The work was authorized by the FLTF under Task Order No. 4 dated September 19, 2020, in accordance with the Master Services Agreement dated May 29, 2020.

1.4 Project Personnel

The following GEI personnel were primarily responsible for performing the hydrology and hydraulics analyses for this report:

Project Manager:	Paul D. Drew, P.E., CFM
Staff Engineer:	Alexa Sampson, E.I.T
Staff Engineer:	Alex Michaud, E.I.T.
Project Principal:	Richard J. Anderson, P.E.
Engineer of Record:	William H. Walton, P.E. (MI), S.E.

This work was coordinated with Mr. Dave Kepler from the FLTF and Mr. Ron Hansen, P.E., P.S. from SGI.

1.5 Elevation Datum

Elevations listed herein are referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). Vertical datum conversions to the site datum and North American Vertical Datum of 1988 (NAVD88) are included in **Table 1**.

Table 1: Vertical Datum Conversions

Project	Summer Lake Level (Site Datum)[1]	Summer Lake Level (NGVD29)	Winter Lake Level (NGVD29)	VertCon[2] Conversion	Summer Lake Level (NAVD88)	Winter Lake Level (NAVD88)
Secord	745.0	**750.8**	**747.8**	-0.5	750.3	747.3
Smallwood	699.0	**704.8**	**701.8**	-0.5	704.3	701.3
Edenville	670.0	**675.8**	**672.8**	-0.6	675.2	672.2
Sanford	625.0	**630.8**	**627.8**	-0.6	630.2	627.2

1: Datum conversion Site Datum to NGVD29 = +5.8 feet.
2: National Geodetic Survey Height Conversion: https://geodesy.noaa.gov/TOOLS/Vertcon/vertcon.html

1.6 Limitation of Liability

The professional services completed in preparing this Conceptual Design Basis Report were performed in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering profession currently practicing in the same locality and under similar conditions as this project. No other representation, express or implied, is included or intended, and no warranty or guarantee is included or intended in this report, or any other instrument of service.

2. Description of Project Structures

2.1 General Project Descriptions

The Smallwood Dam is located on the Tittabawassee River, a tributary to the Saginaw River, and is approximately 35 river miles upstream of the City of Midland in Midland County, Michigan (see **Figure 1**). The facility is owned and operated by the FLTF and the FERC License is currently maintained by Boyce. Construction of the dam was completed in 1925 to provide storage and headwater level control for the purpose of hydroelectric power generation. From left to right[1], the project consists of a 1,000-foot-long left embankment, an approximately 52-foot-wide gated spillway with two Tainter gates, a 25-foot-wide powerhouse containing one turbine generating unit with a rated capacity of 1.2 MW with an operating head of 29.6 feet, and a 125-foot-wide right embankment. The normal headwater and tailwater elevations at the dam are El. 704.8 and 675.2, respectively. The Exhibit F Drawings from the FERC license, illustrating the typical plan and sections for each of the existing project structures are included in **Appendix A**. The Smallwood Hydroelectric Project is classified as having a high hazard potential based on estimated downstream impacts in the event of a failure. An aerial image illustrating the project structures is included in **Exhibit 2-1**.

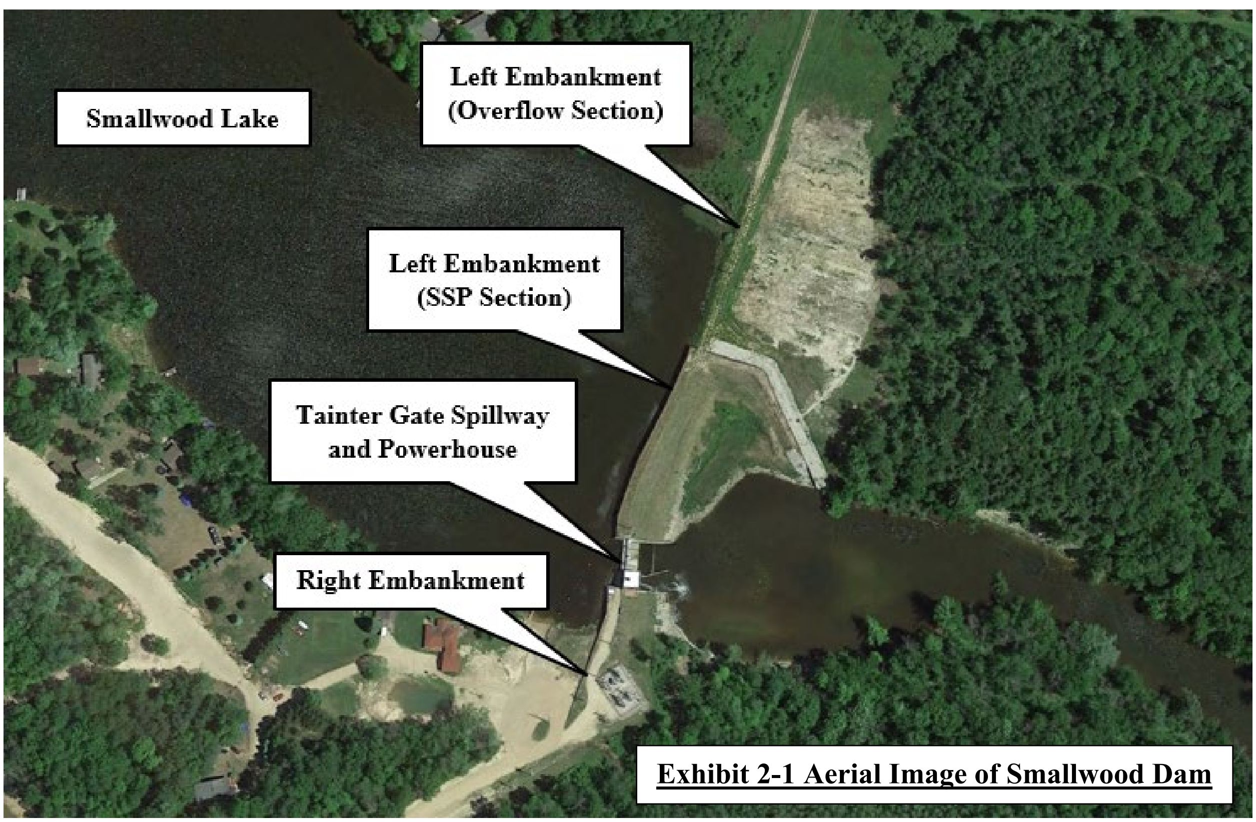

Exhibit 2-1 Aerial Image of Smallwood Dam

[1] All references to left and right herein are with respect to looking in a downstream direction.

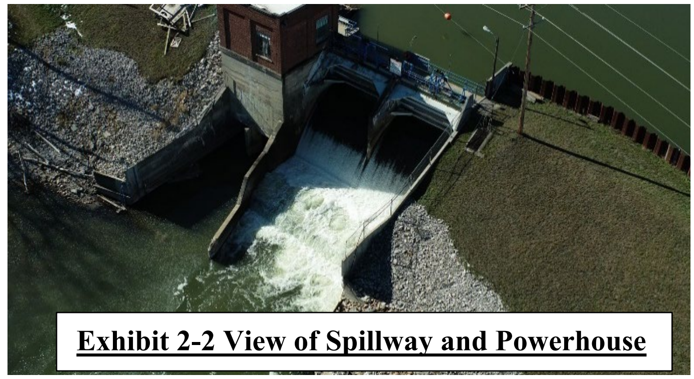

Exhibit 2-2 View of Spillway and Powerhouse

The reinforced concrete spillway is a hollow reinforced concrete barrel arch and ogee shaped rollway structure spanning to buttress piers and powerhouse wall and left spillway training wall with two Tainter gate bays. Both left and right Tainter gate is 25.4-feet-wide by 10-feet-high separated by a 1.5-foot-wide center pier. The spillway ogee crest sill is at elevation (El.) 694.8 feet [2]. The gates are operated by hydraulic hoist with the operators located directly adjacent to the hoist above each gate on an elevated platform. The hydraulic gate chain and single cable hoist and reel system was installed in 2019, replacing the original electric hoist and trolley system. The powerhouse consists of a reinforced concrete substructure and brick superstructure with one vertical Francis shaft unit. Both spillway and powerhouse structures are reportedly constructed on dense glacial till. The base slabs for both contain shear keys and an upstream concrete cutoff into the till. The powerhouse and Tainter gate spillway are illustrated in **Exhibit 2-2**.

Exhibit 2-3 View of Left Embankment Non-Overflow Section Section

The left embankment is approximately 1,000-feet long, with a maximum structural height of 38 feet near the spillway. The embankment consists of an approximately 320-foot-long non-overflow section nearest the spillway and an approximately 680-foot-long emergency overflow section. The original embankment was reportedly constructed of native silt, sand, and clay from onsite sources. The non-overflow section contains an upstream steel sheet pile (SSP) cutoff that was constructed in 1999 to El. 715.7. In 2000, the upstream SSP line was extended downstream to form a training wall between the non-overflow and emergency overflow sections. The crest of the non-overflow section was narrowed, and the downstream slope regraded and flattened in 2001 to satisfy global stability criteria. The left embankment non-overflow section and SSP are illustrated in **Exhbibit 2-3**.

The crest elevation of the 680-foot-long left embankment emergency overflow section generally ranges from El. 709.5 to 712.0 feet. This section is intended to overtop during an extreme flood event. In 1998, this area was cleared of vegetation, regraded, and flattened. In 2014,

[2] All elevations are in NGVD29, unless otherwise noted.

approximately 260 feet of this overflow section just left of the SSP training wall was raised to crest elevation 712 feet and a 20-foot-wide riprap channel was also constructed along the SSP training wall to prevent scour along the base of the wall during an extreme flood event that could overtop the embankment left of the SSP. The left embankment overflow section is illustrated in **Exhibit 2-4** looking upstream (north).

Exhibit 2-4 View of Left Embankment Overflow Section

The right embankment is 125-feet long, 38-feet tall and reportedly constructed of native silt, sand, and clay material. The right embankment also contains an upstream SSP seepage cutoff constructed in 1999 that extends approximately 250 feet beyond the end of the powerhouse abutment wall. There is no record of improvements or repairs made to the right embankment, other than installation of the SSP cutoff. Key project data for the Smallwood Dam are provided in **Table 2**.

Table 2: Key Existing Project Data

Parameter	Smallwood Project
Min. Dam Crest El. (feet)	715.7
Normal Headwater Operating Pool El. (feet)	704.8
Normal Operating Tailwater El. (feet)	675.2
Spillway Ogee Sill Gate Invert El. (feet)	694.8
# Tainter Gates	2
Gate Numbering (left to right looking downstream)	2 to 1
Gate 1 Width (feet)	25.3
Gate 1 Max Opening (feet) (as of February 2021)	10.0
Gate 2 Width (feet)	25.3
Gate 2 Max Opening (feet) (as of February 2021)	10.0
Auxiliary Spillway Type	Left Embankment Overflow
Auxiliary Spillway El. (ft) (Left Embankment Overflow)	709.5
Auxiliary Spillway Length (feet) (Left Embankment Overflow)	680
Left Embankment Length (feet) (SSP Section)	320
Left Embankment Dam Crest El. (feet) (SSP Section)	715.7
Left Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1
Right Embankment Length (feet)	125
Right Embankment Dam Crest El. (feet)	715.7
Right Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1

2.2 Reservoir Operations

The project is operated as a “run-of-river.” Per the FERC license, the reservoir is to be operated at a summer and winter elevation. The summer headwater level is maintained between elevation 704.4 and 705.1 feet with the normal summer level at elevation 704.8 feet. The winter headwater level is maintained with the normal winter level at elevation 701.8 feet so that the daily fluctuation in reservoir elevation does not exceed 0.7 foot. Currently, the Tainter gates are in the fully open position (10-feet) and Smallwood Lake is maintained approximately 1-foot above the spillway sill at El. 695.8 feet in accordance with the FERC July 2020 drawdown order.

3. Hydrology and Hydraulics

3.1 Introduction

The purpose of this report section is to establish and document the hydrology and hydraulics to upgrade the total spillway capacity to pass at a minimum the ½ PMF in accordance with State of Michigan EGLE requirements. GEI reviewed the following information to assess the hydrology and hydraulics for the Smallwood Dam project:

- Smallwood Hydropower Plant Design Drawings, 1924
- Supporting Technical Information Document (STID), 2006
- Secord Gate Test Notes, Spicer Group Inc., December 2019
- PMF Report by Ayres Associates, Inc., May 2020
- GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam, March 2021

3.2 Hydrology

GEI has reviewed the May 2020, PMF Report by Ayres Associates, Inc. (Ref. Ayres, 2020) prepared for Secord, Smallwood, Edenville and Sanford Dams. This report was prepared before the May 2020 flood and used only data available prior to that event. Following the May 2020 event, modifications were made to the analysis. These modifications are discussed below but are still under technical and regulatory review. As of this writing, no formal report on the post-May 2020 PMF updates exists. GEI has reviewed the current 2020 Ayres Report and the associated HEC-HMS model and generally agree with the methodology and results of the study.

Current modeling results by Ayres for the ½ PMF and PMF are summarized in **Table 3** and represent the results of the most recent provisional model, as revised to account for observations noted during the May 2020 flood. Note also that the "½ PMF" is not half of the PMF value. Verbal consultation with EGLE personnel clarified that "½ PMF" in the context of State of Michigan EGLE standards refers to the flood calculated to result from one-half of the Probable Maximum Precipitation (PMP).

Table 3: Smallwood Dam Flood Routing Results – Existing Conditions

Parameter or Modeling Result	½ PMF	PMF
Peak Inflow (cfs)	19,065	58,640
Peak Outflow (cfs)	18,895	58,110
Maximum Reservoir El. (feet)	713.3	718.4
Freeboard (Dam Crest El. 715.7)	2.4	-2.7

Previous studies have been performed to assess the flood hydrology and spillway hydraulics for the Secord, Smallwood, Edenville and Sanford Dams. The PMF was originally computed by

Mead and Hunt, Inc. using the 1993 EPRI Wisconsin-Michigan PMP Study. The 1994 PMF Study (Ref. Mead & Hunt, 1994) was performed as part of an evaluation of the PMF throughout the Tittabawassee River Basin. In 2011, Mill Road Engineering concluded that the 1994 model misrepresented the offset in timing between the Tittabawassee River and Tobacco River contributions to Lake Wixom. The two branches of the reservoir were re-analyzed using a HEC-RAS model, resulting in lower peak inflow at Edenville Dam. **Table 4** summarizes the results of the available PMF studies for the Secord, Smallwood, Edenville and Sanford Projects.

Table 4: Summary of Previous PMF Studies

Date	Author	Secord	Smallwood	Edenville	Sanford
1994	Mead & Hunt, Inc.	27,200	41,000	74,400	75,500
2011	Mill Road Engineering	N/A	N/A	62,000	N/A
2020	Ayres Associates (Model calibrated using 2014, 2017 floods only)	29,400	41,200	80,900	80,600
2020	Ayres Associates (Model recalibrated after May 2020 flood (provisional))	43,020	58,640	116,525	116,065
% PMF Increase since 1994 using provisional Ayers 2020 recalibrated model		*58%*	*43%*	*88%*	*54%*

As shown in **Table 4**, the 2020 PMF study, after incorporating the May 2020 flood data, significantly increased the PMF estimates at each of the FLTF projects. The 2020 studies were the first to include calibration to observations of actual flood events and associated precipitation. The May 2020 Ayres report attributes the increase primarily to the use of more conservative hydrologic loss rates derived from the calibration efforts.

Considering the significant increase in the PMF, the FLTF currently has Applied Weather Associates (AWA) under contract to compute a site-specific PMP and probability assessment of various rainfall depths for the Tittabawassee River Basin. The FLTF recognizes that PMP and PMF studies that use the most common sources of the PMP information (such as the regional HMRs or EPRI 1993), and that the generalized rainfall values are not site-specific and tend to represent the largest PMP values across a broad region. A site-specific study of the PMP and PMF can result in a lower and more appropriate estimate of the ½ PMF and PMF. The AWA will provide the updated rainfall depths and distributions to Ayres to develop site specific ½ PMF and PMF inflow hydrographs. The updated PMP and PMF study by AWA and Ayres is expected to be completed in the second quarter of 2021.

See the 2021 GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam report for more information (Ref. GEI, 2021).

3.3 Spillway Design Storm Flood Selection

In June 2020, Gladwin and Midland Counties signed a resolution to have the four projects (Secord, Smallwood, Edenville and Sanford) condemned in accordance with Part 307 of the Michigan Natural Resources and Environmental Protection Act (NREPA). The FLTF approached the Michigan bankruptcy court and worked through an agreement to have the ownership of all the projects transferred to the FLTF, while Boyce will temporarily maintain the FERC licenses. We understand that the FERC licenses at each of the FLTF project will likely be abandoned and the dams will be ultimately regulated by the State of Michigan EGLE. In accordance with Part 315 Dam Safety of the Michigan State Statues, GEI understands that the FLTF projects will be classified as high hazard dams and shall be capable of passing the ½ PMF.

Following the Edenville and Sanford Dam failures, the Michigan Dam Safety Task Force evaluated the statutory structure, budget, and program design of the Water Resources Division Dam Safety Program, the adequacy of Michigan's dam safety standards, and the level of investment needed in Michigan's dam infrastructure. Their work culminated in a report to Governor Whitmer and the state legislature dated February 25, 2021, summarizing its findings, and recommending regulatory, financial, and programmatic improvements to help ensure Michigan's dams are appropriately maintained, operated, and overseen to protect Michigan residents and aquatic resources.

We understand that the current spillway capacity requirement (1/2 PMF) will likely change as a result of the Dam Safety Task Force recommendation to follow the current Federal Emergency Management Agency (FEMA) Model Dam Safety Program (MDSP) for recommendations for design floods including FEMA P-94 – *Selecting and Accommodating Inflow Design Floods for Dams* (Ref. FEMA, P-94). According to the FEMA P-24 document, the goal of selecting the Inflow Design Flood (IDF) should be to balance the risks of a hydrologic failure of a dam with the potential downstream consequences and the benefits derived from the dam. Selection of the IDF can involve tradeoffs in trying to satisfy multiple objectives including the following:

1. Providing acceptable safety to the public,

2. Effectively applying the resources of the dam owner,

3. Maintaining the credibility of the regulator in representing the interest of the public, and

4. Assessing the desire of the public for the benefits of a dam in exchange for the inherent risks that come from living downstream of a dam.

FEMA acknowledges that no single approach to the selection of an IDF is adequate for all existing or planned dams. FEMA identifies the following approaches to defining the IDF to accommodate the wide variety of situations, resources, and conditions.

- Prescriptive approach – Evaluate the dam based on hazard potential classification of the dam. This approach is intended to be conservative to allow for efficiency of resource allocation while providing reasonable assurance of the public safety.

  This approach is similar to the current state of Michigan EGLE prescriptive requirement of the ½ PMF.

- Site Specific PMP – This approach requires a site specific Probable Maximum Precipitation (PMP) study.

  The FLTF currently has AWA under contract to calculate a site specific PMP and probability assessment of various rainfall depths for the Tittabawassee River basin. The AWA will provide the updated rainfall depths and distributions to Ayers to develop site specific ½ PMF and PMF inflow hydrographs.

- Incremental Consequence Analysis – IDF established by identifying the flood for which the downstream consequences with and without failure are not significantly different. This process is already accepted by the State of Michigan EGLE as the ½ PMF; criteria may be reduced to not less than the 200-year flood, with proper documentation evidencing a failure of a dam under ½ PMF conditions will not cause additional flood damage or loss of life.

  An incremental consequence analysis may be the preferred way to select the IDF; however, we recommend not completing an incremental consequence analysis until the site specific PMP and PMF analysis is completed by AWA and Ayres.

- Risk Informed Decision Making (RIDM) – In this method, the IDF is selected as the design flood, which assures that a given level of "tolerable risk" is not exceeded. The benefit of RIDM is providing dam owner and regulators the ability to cooperatively assess the marginal value of increasing levels of flood protection, balancing capital investment in risk reduction across multiple potential failure modes (PFM), and prioritizing risk reduction across a portfolio of dams. RIDM requires a site-specific evaluation of probability of hydrologic events and performance of the dam during those events and evaluates in detail the social, economic, and environmental consequences of failure.

  As discussed above, AWA will derive the Annual Exceedance Probability (AEP) of the rainfall up to and including the PMP. This will provide the recurrence interval of rainfall depths for critical durations and can be used for the RIDM process for dam design and selection of the IDF.

Considering the schedule of the site specific PMP and PMF study by AWA and Ayres, an interim IDF was selected for the purposes of the flood study and developing 30% design plans and budgetary costs for the FLTF projects. The current state of Michigan EGLE spillway requirement for high hazard dams is the ½ PMF; however, the project team (GEI, SGI, Essex and the FLTF) collaboratively selected a more conservative design criteria, considering the uncertainty of the state of Michigan EGLE spillway capacity requirements and the upcoming site specific PMP and PMF study. For the purposes of the 30% design phase, the selected IDF is the ½ PMF plus a 15% to 30% increase in peak inflow (i.e., 1/2 PMF + design storm). Once the site specific PMP, PMF, and AEP studies are complete; the IDF will be re-evaluated using the techniques prescribed in FEMA P-94. The selected IDF is the ½ PMF + design storm with peak inflows are summarized in **Table 5**.

Table 5: Summary of Inflow Design Flood (1/2 PMF +)

Dam	½ PMF	PMF	½ PMF +[1]	IDF Design Storm Notes	Annual Exceedance Probability (AEP)
Secord Dam	18,075	43,020	**21,150**	½ PMF + 17% Peak Inflow	1/5000 or 0.0002
Smallwood Dam	19,065	58,640	**24,550**	½ PMF + 28% Peak Inflow	1/5000 or 0.0002
Edenville Total	41,260	116,525	**52,275**	½ PMF + 26% Peak Inflow	TBD
Sanford Dam	37,695	116,065	**47,470**	½ PMF + 26% Peak Inflow	TBD

1. The current IDF for the FLTF Projects is the ½ PMF + design storm.

See the 2021 GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam report for more information (Ref. GEI, 2021).

3.4 Hydraulic Design

GEI performed hydraulic analysis to evaluate the proposed spillway upgrades at each of the FLTF projects during the ½ PMF + design storm. Based on the existing conditions of the FLTF projects, GEI has developed new conceptual spillway and dam configurations, which would allow the FLTF dams to safely pass the ½ PMF + design storm with residual freeboard. The proposed configurations consist of reconstruction or rehabilitation of earthen embankments, demolition, and replacement of the primary Tainter gate spillways with deeper hydraulic crest gates, decommissioning and selective demolition of the powerhouse and conversion of the water passages to a gated low-level outlet, and construction of a new passive overflow auxiliary spillway. The proposed dam repairs and flood capacity upgrades are described in further detail in Section 4 below.

See the 2021 GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam report for more information (Ref. GEI, 2021).

3.4.1 Hydraulic Design Criteria

GEI performed hydraulic analysis and modeling to appropriately size the proposed primary and auxiliary spillways for each of the FLTF projects. The proposed spillways were designed to achieve the following design goals:

- The reconstruction / rehabilitation of the FLTF projects will provide 75+ year design service life.
- The reconstruction / rehabilitation of the FLTF projects will be designed to meet the current industry standards of engineering practice and design standards for high hazard dams in accordance with State of Michigan EGLE.
- The proposed primary spillways when combined with the auxiliary spillways should have sufficient capacity to pass the ½ PMF + design storm without overtopping the embankments and provide sufficient freeboard below the dam crest.
- The target routed ½ PMF + design storm headwater is El. 713.0 with 2.0 feet of freeboard below the dam crest.
- Pass the ½ PMF + design storm without overtopping the left embankment overflow section at El. 709.5. Raise the overflow section of the left embankment to El. 715.0.
- The structural integrity of the earthen dam and its foundation should not be jeopardized by auxiliary spillway operations.
- Operation of the crest control gates will be the primary means for regulated releases to the Tittabawassee River under both normal and flood conditions.
- Auxiliary spillways will have an un-gated free overflow crest with fusible stanchions (pins) supporting timber flashboards to assist in safely passing the ½ PMF + design storm without human intervention. The steel pipe fold over when reservoir rise to water level hydraulic loads exceed the ultimate strength of the pipes. These passive systems have been used for more than 100 years to pass flow when needed.
- The proposed auxiliary spillway and stilling basin should fit within the footprint of the existing embankments to minimize the impact to downstream wetlands.
- The impoundments will be drawn down 3 feet in winter in accordance with the current lake operating level standards (see **Table 1** in Section 1.4) to minimize static ice loading on the auxiliary spillway. The winter drawdown will keep ice off the passive steel (pipe) pin-flashboards.

3.5 Empirical Equations Analysis

Prior to developing the hydraulic computer models, GEI evaluated proposed crest gates and auxiliary spillways using traditional empirically based equations. This provides an initial evaluation of the hydraulic performance of the proposed spillways structures for each of the FLTF projects up to the ½ PMF + design storm. Conceptual-level proposed spillway rating curves were developed using the methods prescribed in the United States Bureau of Reclamation Design of Small Dams (Ref. USBR, 1987).

3.5.1 Crest Gate Spillways

In accordance with the *Design of Small Dams* (Ref. USBR, 1987), the crest gate spillway calculations were computed using the weir equation: $\mathbf{Q = CLH_e^{3/2}}$, where:

Q = discharge, cfs
C = discharge coefficient
L = effective crest length, feet
H_e = energy head on crest, feet

We adopted a standard Steel-Fab, Inc. (Steel-Fab) hydraulically operated crest gate profile, which closely approximates that of the lower nappe of sharp crested weir discharging at the design head of the crest gate. This ideal shape has been modified to provide positive pressure at all heads up to the design head. According to Steel-Fab (crest gate manufacturer in Fitchburg, MA), the discharge coefficient of the standard Steel-Fab crest gate at design head is estimated to be a minimum of 3.5 when the crest gate is fully down, and the water level is at the design head equal to height of the gate. At water levels less than the design head, the discharge coefficient decreases. At water levels greater than the design head, the discharge coefficient increases.

The effective length **L** of a spillway crest used in spillway discharge computations is expressed by the equation: $\mathbf{L = L' - 2(NK_p + K_a)\, H_e}$, where:

L = effective length, ft
L' = net length of crest, ft
N= number of piers
K_p = pier contraction coefficient
K_a = abutment contraction coefficient
H_e = energy head on crest, ft

3.5.2 Auxiliary Overflow Spillways

In accordance with the *Design of Small Dams* (Ref. USBR, 1987), the pin flashboard spillway calculations were computed using the weir equation: $\mathbf{Q = CLH_e^{3/2}}$, where:

Q = discharge, cfs
C = discharge coefficient
L = effective crest length, ft
H_e = energy head on crest, ft

The discharge coefficient was computed using the nomographs provided in Chapter A5 of the USGS *Measurement of Peak Discharge at Dams by Indirect Method (*USGS 1968) assuming an upstream slope of 2.5H:1V and downstream slope equal to 2.5H:1V. The supporting rating curve calculations are provided in **Appendix B**.

3.6 Proposed Conditions HEC-RAS Model

Once the initial evaluation of the hydraulic performance of the proposed spillways structures for each of the FLTF projects were completed, GEI developed a more detailed hydraulic model using the United States Army Corps of Engineers (USACE) HEC-RAS, Version 5.0.7. computer model (Ref. USACE, 2019) to further evaluate the proposed spillway capacity of the FLTF crest gates and auxiliary spillways. The HEC-RAS model and flood inundation mapping extended from Secord Lake to approximately 2-miles downstream of Sanford Dam. The HEC-RAS computer model can perform one-dimensional (1D) and two-dimensional (2D) unsteady flow modeling. The 2D unsteady flow modeling capabilities are useful for the relatively flat downstream topographic features. The 2D hydraulic calculations were performed in the HEC-RAS model using unsteady flow simulations with a variable time step based on the courant number calculated for cells within the computation mesh. This allows for longer time steps during intervals of lower velocities and shorter time steps during intervals with higher velocities. This is ideal for spillway flood studies as it allows for the time step to decrease as flow rates and velocities through the spillway increase. HEC-RAS 2D can solve full momentum equations or a simplified version of the equations (known as the diffusion wave equations). The full momentum equations were used in the 2D model calculations.

See the 2021 GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam report for more information (Ref. GEI, 2021).

3.7 Smallwood Dam Flood Routing Results

The proposed spillway rating curves developed using the 2D HEC-RAS model were input into the HEC-HMS model as the primary spillway to determine the final routing results. Based on the proposed spillway configuration for the Smallwood Dam, the ½ PMF + design storm results in a peak inflow of 24,550 cfs, a maximum reservoir water surface at El. 713.1, a peak discharge of 24,100 cfs, and a minimum of 1.9-feet of dam crest freeboard. The Smallwood Dam ½ PMF + design storm inflow, outflow, and stage hydrographs are shown on **Figure 2**. Based on the configuration described above, the proposed Smallwood Dam spillway configuration would have sufficient discharge capacity to safely pass the ½ PMF + design storm with over 1.9 feet of freeboard.

The proposed Smallwood Dam spillway discharge rating curves calculated by the 2D model are compared to the empirical equation-based rating curves in **Figure 3**. In general, the empirical rating curves align well with the rating curves calculated by the 2D model up to the ½ PMF + design storm headwater level of El. 713.1, meaning that downstream submergence has little impact on the discharge capacity of the spillway. During the ½ PMF + design storm, the downstream tailwater rises to El. 699.6, which is approximately 10.1 feet higher than the spillway crest El. 688.8. In general, tailwater submergence begins to reduce spillway capacity when the tailwater depth divided by the headwater energy depth above the spillway is greater than 0.67; therefore, the tailwater submergence ratio of 0.41 is not high enough to cause an increase in the upstream headwater elevation during the ½ PMF + design storm. Output data from the HEC-HMS model are summarized in **Table 6**.

Table 6: Smallwood Dam Flood Routing Results – Proposed Conditions

Parameter or Modeling Result	½ PMF + design storm
Initial Water Surface El. (feet)	704.8
Peak Inflow (cfs)	24,550
Peak Outflow (cfs)	24,100
Maximum Reservoir El. (feet)	713.1
Freeboard (Dam Crest El. 715.0)	1.9

See the 2021 GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam report for more information (Ref. GEI, 2021).

4. Summary of Dam Repairs and Flood Capacity Upgrades

4.1 Primary Spillway Modifications

The existing Tainter gate spillway will be partially demolished and the two (2) Tainter gates will be replaced with hydraulically operated crest gates at sill El. 688.8 to increase the spillway capacity. The left crest gate (Bay No. 2) and the right gate (Bay No. 1) will be 22.6-feet-wide by 16-feet-high. The automated crest gates would be designed to open and close with minimal human intervention during normal operation or during flood events. The hydraulic gate operators will be supported on a new, reinforced concrete center pier. The upstream portions of the barrel arches below El. 688.8 will remain and the crest gates and their anchorage embedments will be founded on new mass concrete. A reinforced concrete stepped chute will convey water that discharges over the crest gates down to a new reinforced concrete stilling basin. Both the left and right spillway walls will be extended downstream and raised to provide adequate flow clearance and accommodate flattening of the flanking embankments. The proposed design drawings for the spillway improvements are provided in **Appendix C**.

4.2 Auxiliary Spillway

A new 150-foot-wide ungated pin flashboard overflow spillway will be constructed across the of the left embankment adjacent (east) to the steel sheet pile section of the left embankment at El. 706.0 with steel pipe pins embedded in concrete holding timber flashboards that extend up to El. 710.0. The pin-flashboards will be designed to fail when overflow greater than 1.5 feet of water head over the top of the flashboards reaches El. 711.5. This release will provide additional spillway capacity during the ½ PMF + design storm. Beneath the concrete auxiliary spillway will be a new hot rolled SSP wall with interlock sealants that will extend another 100 feet left of auxiliary to reduce under seepage and allow construction of the spillway with reduced seepage inflow. The overflow spillway will discharge into a 150-foot wide USBR Type III stilling basin to dissipate energy and to reduce scour and erosion in the discharge channel. Downstream of the stilling basin, the ½ PMF + design storm will be routed approximately 350 feet downstream to the confluence with the Tittabawassee River in a rock-lined spillway discharge channel. The discharge channel includes a trapezoidal cross section with a floodplain shelf and berm to protect from overtopping. The proposed design drawings are provided in **Appendix C.**

4.3 Powerhouse Modifications to Provide a Low-Level Outlet

As highlighted by the ongoing ice issues experienced at the upstream Secord Dam during the winter of 2020 / 2021, it is crucial to develop a reliable low-level outlet design to pass base flows in the winter at Smallwood Dam to minimize active daily ice management. For the long-term reconstruction, we are proposing to retrofit the existing powerhouse to pass base flows

(100-200 cfs) through the powerhouse in accordance with the 95% exceedance base flows estimated by the State of Michigan Department of Environmental Quality (DEQ) Flood discharge database. This will be accomplished by removing the existing generator, turbine shaft, wicket gates and ancillary mechanical and electrical equipment, installing a bulkhead over the runner pit and fixing the runner into place. A new vertical slide gate will be installed upstream of the existing head gate to control flow into the runner and draft bay. The low-level outlet conceptual design was developed by GEI, Essex and SGI. The proposed low-level outlet design consists of the following elements.

- The total impoundment drawdown potential is from El. 704.8 to El. 686.0 ±.
- Backfill the abandoned sluice bay below the intake with mass concrete.
- Construct a new vertical slide gate with integrated bulkhead slots upstream of the existing head gate.
- Remove the generator, turbine shaft and wicket gates.
- Keep the existing trash racks.
- Construct a new bulkhead over the top of the runner pit in the powerhouse floor slab.
- Remove the existing timber headgates.
- Leave the runner in place and affix (weld) to the new bulkhead to provide horizontal to vertical flow energy dissipation.
- The upstream slide gates will be used to throttle base flows to pass approximately 100 to 200 cfs of flow.
- The upstream bulkhead and head gate will allow for full de-watering for maintenance and inspections of the downstream water passages.

The conceptual design for the powerhouse modifications is illustrated on Drawing C-12 included in **Appendix C**.

4.4 Embankment Modifications

The upstream and downstream embankment slopes will be flattened, and crest widened to at least 15 feet to provide adequate stability in accordance with EGLE requirements under normal and flood pool loading criteria. The overflow section of the left embankment will be raised to El. 715.0 and extended approximately 700 feet to the east to "tie-in" to high ground at the El. 715.0 topographic contour. A portion of the left embankment the existing 2009 SPP will have new SSP seepage control cutoff wall under the dam crest and it will be extended under the new auxiliary spillway and 100 feet left (east) of the new spillway. General site plans and cross section for the Smallwood Dam rehabilitation are provided in **Appendix C**.

4.4.1 Embankment Fill

New embankment fill will be used to reconstruct the downstream slope of the embankment sections left of the 1999 steel sheet pile walls and in between the new auxiliary spillway. The embankment fill will consist of material either salvaged from on-site excavation or imported from approved off-site sources, as required. All cobbles greater than 4 inches in diameter will be screened out. New embankment fill will be comprised of semi-pervious granular material (Unified Soil Classification System soil types: SP-SM, SM, and SC-SM) and will be compatible with the remaining, existing embankment fill in terms of filter criteria. Embankment fill will be placed in loose horizontal lifts not exceeding 12 inches and compacted in a controlled manner to a minimum of 95 percent of maximum dry density determined by the standard Proctor (ASTM D698) with appropriate moisture control measures.

4.4.2 Reverse Filter and Toe Drain

A reverse filter toe drain consisting of filter sand and drainage stone will be constructed at downstream slope and toe of the left and right embankments to mitigate against seepage and internal erosion of the embankment and foundation soils. The reverse filter and drain will generally consist of 18 inches of fine filter (MDOT 2NS natural sand) and 24 inches of coarse filter (MDOT 29A stone).

4.4.3 Riprap and Bedding

Riprap placed on the upstream side of the auxiliary spillway approach apron, and upstream and downstream embankment slopes will consist of a hard, durable, non-weathered, angular stone in accordance with Michigan Department of Transportation (MDOT) standard specifications. Riprap placed downstream of the stilling basin and in the auxiliary spillway discharge channel will consist of MDOT heavy riprap. Bedding material will consist of imported granular material in accordance with MDOT Specifications placed over MDOT 29A crushed stone. The 29A stone should be placed on natural 2NS sand placed over native soil subgrades. For accessible riprap and bedding subgrades, the bedding material can be placed on non-woven geotextile.

5. Structural Design Criteria

5.1 General

The existing and proposed concrete spillways, water retaining structures and conveyance channels described in this Report are the primary gated spillway (comprised of side walls, center piers, rollway, stilling basin and crest gates), powerhouse (side walls, intake, scroll case, draft bay, stilling basin) and auxiliary spillway (side walls, base slab, chute stilling basin, flashboard and stanchions). The structural design criteria applicable to these structures are described in the following sections.

Geotechnical explorations, standard penetration test sampling and pressuremeter testing and soil-structure analyses will be performed at Secord Dam to quantify bearing capacity, subgrade moduli and estimate settlement of glacial till foundation settlement under new dam loads to assess dam performance when the hollow sections of the existing spillway and powerhouse dam are filled in with concrete and steel crest gate and operators are installed. Based on Fisher measurements at lowered Tobacco Spillway weir, the 15.5 feet of new mass concrete cause the two piers and training walls to settlement 0.3 inches with no observed distress to the wall and piers. Our design approach will be model new normal or lightweight concrete on the existing spillway mat with and without grouted 100 to 200 ton battered drilled and grouted steel micro-piles under the heavily loaded piers and gate operators. We will run finite element stress and deformations using pressuremeter data to compute settlement with and without underpinning piles.

Special attention will be made to work with the existing counterfort walls to ensure the walls remain stable as the rollway, barrel arches and cross lot struts are removed and replaced with mass concrete that support the gates and buttress the walls. Partial backfilling of the powerhouse tailrace and installation of supplemental temporary and higher bracing and steel or concrete struts may be required to brace the right (no counterforts on the right side of the powerhouse downstream training wall) and left spillway training wall (due to a buried fish passage structure that has truncated counterfort walls). Concrete wall overlays counterfort extension and use of lightweight fill may be required on the right and left downstream embankment sides of the existing walls to reduce lateral earth pressures. Counterforts are missing on the right downstream side of the power tailrace wall, that may require partial concrete filling of the powerhouse tailrace to allow wall stability and pass 100 to 200 cfs flow.

5.1.1 Stability Analyses

Stability analyses of the spillway training wall, spillway overflow section, piers and powerhouse concrete structures will be based on FERC Dam Safety Guidelines Chapter 3 *Gravity Dams* and

Chapter 10 *Other Dams* and USACE EM-1110-2-2100 – *Stability Analysis of Concrete Structures* (Ref. USACE, 2005).

5.1.2 Reinforced Concrete Design

Reinforced concrete design is in accordance with applicable provisions of Building Code Requirements for Structural Concrete (ACI 318-11) and USACE EM-1110-2-2104 – *Strength Design for Reinforced-Concrete Hydraulic Structures* (Ref. USACE, 2016). For design of hydraulic structures, ACI 318-14 will be supplemented by the provisions of the American Society of Civil Engineer's *Strength Design of Reinforced-Concrete Hydraulic Structures* (Ref. ASCE, 1993). Concrete cover, temperature and shrinkage steel will meet USACE requirements.

5.2 Material Properties

The following material properties will be used to calculate the compression and flexural design strength and shear capacity for new and retrofitted reinforced concrete structures.

Compressive Strength:

- For Exterior Exposed Structural Concrete components: Specified 28-day compressive strength of concrete cylinders of f`c = 4,000 psi. Air entrainment in normal concrete should be 5 to 7 percent. Water to cement ratio for normal weight concrete should be no higher than 0.4. Concrete should meet ACI 318-14 and the latest MDOT standards.
- For Interior Mass Lightweight Concrete (flowable, self-leveling): Specified 28 day compressive strength of concrete cylinders of f`c = 3,000 psi. Air entrainment in normal concrete should be 5 to 7 percent. Water to cement ratio for normal weight concrete should be no higher than 0.45. Concrete should meet ACI 318-14 standards.

Unit Weight: normal weight reinforced concrete was selected with a unit weight of 140 to 150 pounds per cubic foot (pcf). Lightweight concrete shall have a unit weight of 90 to 115 pcf.

Steel Reinforcing: ASTM A615, Grade 60 reinforcing steel, uncoated, with yield strength fy = 60,000 psi.

5.2.1 Load Cases and Required Factors of Safety Against Sliding

The stability of the primary and auxiliary spillway and outlet works will be analyzed as a rigid 2-dimensional block using the shear friction factor (SFF) of safety method; conducted in accordance with Chapters 3 and 10 of the current FERC Guidelines. The FERC Guidelines require that stability versus sliding be computed for the following load cases and corresponding recommended factors of safety presented in **Table 7**:

Table 7: Applicable Loading Conditions and FERC Recommended Minimum Factors of Safety

FERC Required Loading Condition	FS with Cohesion (High or Significant Hazard)	FS without Cohesion
Case I (Usual Loading Combination) – Normal Operating Condition	3.0	1.5
Case II (Unusual Loading Combination) – Flood Discharge Loading	2.0	1.5 [(1)]
Case IIA (Unusual Loading Combination) – Normal Operating Condition plus Ice Loading	2.0	1.5

Notes: (1) Can be reduced to 1.3 flood load case if flood is equal to PMF.
(2) Stability under seismic loading (Case III) is not anticipated as a requirement as Central Michigan USGS defined earthquake having a 2% probability in 50-year event (2,500-year return period) has a reported Peak Ground Acceleration (PGA) of 0.05g.

5.2.2 Limits on Resultant Force Location

In accordance with USACE EM 1110-2-2100 (Ref. USACE, 2005), limits on the location of the resultant of applied forces acting on the base of the structure are specified for each load condition category. We will use existing piezometers to assess hydrostatic uplift under the gravity spillway dam. The existing mat has an effective upstream concrete seepage cutoff wall in hardpan glacial till. The location of the resultant can be determined by static analysis. The rotational behavior of the structure must comply with the limits given in **Table 8**.

Table 8: Requirements for Loading of Resultant – All Structures

Site Information Category	Load Condition Categories		
	Usual	Unusual	Extreme
All Categories	100% of Base in Compression	75% of Base in Compression	Resultant Within Base

5.2.3 Factors of Safety versus Floatation

The required factors of safety for uplift (flotation) stability (FERC Load Case IA) in accordance with FERC Dam Safety Guidelines Chapter 10 are shown in **Table 9**.

Table 9: Required Factors of Safety for Low-Level (Retrofitted Powerhouse) Flotation

Site Information Category	Load Condition Categories		
	Normal	Scheduled Maintenance	Construction
All Categories	1.5	1.3	1.1

6. Embankment Design Criteria

6.1 Existing Subsurface Information

In 1924 there were test borings and a well performed at the site and a drawing top of hardpan clay. Ten (10) soil borings were performed by PSI (Ref. PSI, 1998) as part of the 1998 stability improvements. Boring B-1 was performed on the right embankment and borings B-2 through B-9 on the left embankment. Boring locations are shown on attached Drawing A8721-02 from the 1998 design drawings and Drawing 0.1.00 from the 2016 as-built drawings for PFM No. 8 modifications. There is no record of prior borings and no record of new or additional borings since 1998. The results of the borings were used to support the 1998 Mead & Hunt design of the embankment repairs and 2000 record stability analysis by Barr Engineering.

Boring B-1 was completed on the right embankment crest near the powerhouse. The fill consisted of loose to very loose sand to 9 feet, firm to very soft clay fill to 23 feet and layers of soft clay and loose sand fill to 34 feet. The driller reported 6 inches of concrete at 34 feet with a mix of wood and clay fill to 36 feet. The native hard clayey sand glacial till (hardpan) was below the fill to the termination depth of 40 feet. Boring B-1 was completed through the powerhouse wall backfill and may not be representative of the right embankment material.

Borings B-2, B-3, B-4, B-5.1, B-7, B-8 and B-9 were completed from the left embankment crest and advanced to the underlying hard sandy clay till (hardpan). The following generalized subsurface description was included in Mead & Hunt’s 1998 Bai and used to develop the interpreted subsurface profile shown on Drawing A8721-02.

> *“In general, the fill material containing poorly graded sand to silty sand was found in boring B-1 to B-4. The height of the fill material varied from about 35 feet at boring B-2 to 27 feet at boring B-4. The SPT blow counts generally ranged from 2 to 14. A loose-to-very-loose layer was also encountered between the fill and hardpan layer. The thickness of the layer varied between 3 and 8 feet. The hardpan layer ranged from 27 to 40 feet below the embankment crest. Borings B-5 to B-9 were taken from the north end of the embankment. The fill material contained 10 feet of poorly graded sand to silty sand. A layer of stiff clay was encountered below the loose sandy fill, and a hardpan layer was found below the still clay. Undisturbed soil samples could not be collected from hardpan layer because of its stiffness.”*

Further review of the individual boring logs by PSI indicates the following:

1. The conditions encountered at boring B-2 appear consistent with the previous interpretation. Embankment fill consisted of very loose to loose silty sand and sand material with traces of organics to a depth of 36 feet. Traces of organics were noted within the sand layer from 27.5 to 32.5 feet. Native medium dense to dense clayey sand and sand were present below the fill to 42 feet where native hard clayey sand till (hardpan) was encountered.

2. At borings B-3 and B-4, loose to medium dense sand and clayey sand fill were encountered to depths of 29.5 and 23 feet, respectively. However, a mix of black organic peat/very soft sandy clay was encountered from 29.5 to 31 feet at boring B-3 and a layer of very soft (SPT N=0 blows per foot) sandy clay was encountered from 23 to 25 feet at boring B-4. These layers were not specifically identified in the 1998 design or the 2000 stability analysis. These very soft peat and marl may be organic layers within the native sand, remnant layers that were not stripped prior to original embankment construction, or organics buried within the granular embankment fill during construction.

3. Below the peat and marl, native loose clayey sand with traces of peat and vegetation extended below the peat to the native hard sandy clay till (hardpan) encountered at a depth of 39.5 feet in boring B-3 and 27 feet in boring B-4.

4. The boring logs for B-5.1, B-5.2, B-6, B-7 and B-8 are also consistent with the generalize profile except for black organic layers were also noted around 5 feet below grade on the boring logs for B-7 and B-9. These layers are likely buried topsoil from original dam construction.

The results of the borings were used to develop the interpreted subsurface profile included in **Appendix D**.

6.2 Existing Stability Analyses

In 1998, Mead & Hunt performed stability analyses as part of their design. The results indicated that a stability berm along the toe of both right and left embankments was required to satisfy FERC stability requirements. The toe berm crest was 16-feet-wide at elevation 696 feet. The downstream slope is shown as 2.25H:1V and the toe is protected with riprap. However, the 1998 stability analysis conservatively did not consider the effects of the upstream SSP cutoff and the toe berm was not constructed as designed.

Upon construction of the SSP cutoff in 1999, embankment seepage at the toe was noted to have been dramatically reduced or eliminated. Two driven well points (MW#1 and MW#2) in the left embankment confirmed the SSP cutoff was effective at lowering the phreatic surface from what Mead & Hunt assumed in their design. Therefore, Barr updated the stability analysis of the left embankment considering the lower phreatic surface. The results confirmed improvements at the left embankment were still required to satisfy stability. Therefore, Barr recommended narrowing the embankment crest and flattening of the upper slope as an alternative to the toe berm to satisfy FERC stability requirements. The revised slope geometry satisfied the FERC minimum required factors of safety for the loading conditions analyzed. These repairs were completed in 2001 in accordance with Barr's recommendations.

The analysis performed by Barr in 2000 is considered the current record stability analysis for the project. Barr utilized the computer program SLOPE/W to evaluate stability of circular failure surfaces using Spencer's method of analysis, which satisfies force and moment equilibrium. The following loading conditions were evaluated in accordance with the FERC guidelines:

1. Normal Pool
2. Earthquake
3. Maximum Pool
4. Rapid Drawdown

Barr's analysis evaluated one section on the left embankment near boring B-3 (Sta. 1+00). Barr considered the left embankment section to be representative of the most critical section. However, there is no record analysis for the right embankment. Table 10 below provides a summary of factor of safety for the loading conditions listed above. The analyses show factors of safety summarized in **Table 10**.

Table 10: Summary of Embankment Stability

Loading Condition	Computed FS	FERC Required FS
Downstream Normal Pool	1.52	1.5
Downstream Earthquake at Normal Pool	1.31	1.0
Downstream Maximum Pool	1.45	1.5
Upstream Rapid Drawdown	1.32	1.2

Material properties used in the stability analysis were reportedly developed from correlations with SPT N-values and laboratory strength testing from borings B-2, B-3 and B-4. The embankment cross section geometry and subsurface stratigraphy appear to be interpreted from boring B-3 and the generalized profile. However, the organic peat and marl layers shown in borings B-3 and B-4 are not specifically modeled. Further, a block-type failure surface along this soft layer was not evaluated. The phreatic surface was reportedly estimated from the driven well point (MW#1 and MW#2) measurements taken after construction of the upstream SSP wall.

6.3 Review of Existing Subsurface Information and Stability Analyses

The subsurface profile of the left embankment included in the 1998 design drawings is a reasonable interpretation of the conditions below the left embankment, but there is no information to define the upstream to downstream stratigraphy. There is also limited and no representative subsurface information for the right embankment. Additional subsurface information is required to adequately analyze the embankment stability. Therefore, we recommend additional soil borings on both the left and right embankments to further define these conditions.

Well points MW#1 and MW#2 are currently used to monitor the phreatic surface in the embankments. The exact date these well points were installed is unknown, but reportedly prior to 2009. While effective for short-term monitoring, driven well points are not typically used for long-term measurements of the phreatic surface. Well points are prone to clogging and deterioration and have a limited life span. New Casagrande-type observation wells should be constructed within the additional recommended borings.

Additional subsurface information is needed to inform the designs for the new auxiliary spillway and left embankment crest raising presented in the GEI 30% design drawings. Improvements to the existing spillway are also planned that include adding mass concrete inside the existing barrel arches. The additional concrete will increase loads on the underlying till foundation soil. To evaluate the bearing capacity and settlement from this additional load, we recommend performing in-situ pressuremeter tests (PMT) in the hardpan glacial till foundation soils below elevation 660 feet. The PMT can be performed within the additional recommended soil borings.

The material properties and methods used in Barr's 2000 record stability analysis are generally considered appropriate to evaluate the stability of the left embankment. However, the model did not specifically include the very low strength peat and marl layers shown in borings B-3 and B-4. It is not known whether these soft layers are continuous from upstream to downstream below the embankment. Continuous soft and low strength layers along the base of embankments are typically evaluated using both circular and block failure surfaces. The additional recommended soil borings would further define the limits of this layer. Upon completion of the additional borings, we recommend the record stability analysis be updated to reflect this new subsurface information and evaluate both circular and block failure surfaces.

Since there is no record analysis for the right embankment, we recommend that a record stability analysis for the right embankment be completed using the results of the additional recommended soil borings. For both right and left embankments, the updated stability analyses should consider the current slope geometry and the proposed new slope geometry presented in the GEI conceptual drawings. Additional subsurface investigations at Smallwood Dam are currently planned for Spring 2021.

See the GEI Subsurface Exploration Work Plan, February 2021 for more information (Ref, GEI 2021b).

6.4 Proposed Embankment Seepage and Stability Analyses Approach

Upstream and downstream embankment and foundation stability analyses will be performed in accordance with the current Chapter 4 of the FERC Engineering Guidelines using the SLOPE/W and SEEP/W modules of the GeoStudio software package (ref. GEOSLOPE International Ltd). Section geometry will be based on survey data. Section lithology will be based on subsurface exploration results. Phreatic surface will be based on the observed subsurface conditions or the SEEP/W parent model results. For each section analyzed for stability, a critical surface search routine will be performed using the Slope/W program. As appropriate, GEI will use SEEP/W to predict piezometric pressures distribution for use as input in the SLOPE/W slope stability model. Surfaces considered critical may vary by structure, but in general are required to either breach the embankment crest, or intercept the phreatic surface in a manner that would lead to breaching of the embankment crest by progressive slope failure. Shallow failure surfaces, which do not meet the critical criteria are not typically considered. Factors of safety in SLOPE/W will be computed by using Spencer and the Morgenstern-Price method applied to a method of slices, limit equilibrium approach. Circular or block failure surfaces will be considered in the analyses, as considered appropriate, based on the geotechnical characteristics of the section analyzed.

6.5 Loading Conditions

The following FERC-required loading conditions will be evaluated:

- Steady Seepage with Maximum Storage Pool – Upstream and Downstream Slopes
- Steady Seepage, End of Construction Conditions – Upstream and Downstream Slopes
- Rapid Drawdown – Upstream Slope
- Steady Seepage with Surcharge Pool – Downstream slope

Because the dam is located in an area of low seismic activity and the peak ground acceleration at the dam site is less than 0.05 g for a 2,500 year period of return (Ref. USGS, 2014), evaluation of liquefaction potential, post-earthquake seismic stability, and seismic-induced permanent deformation are not required per the FERC Engineering Guidelines.

6.6 Material Properties

Unit weights and shear strengths for the foundation and embankment fill will be developed from the subsurface explorations and laboratory testing of recovered samples, available information from previous work on the project, and published correlations based on SPT blow counts for similar materials.

6.7 Phreatic Surface Assumptions

The steady-state phreatic surface used in the stability model will be computed using the integrated SEEP/W file results or informed by the subsurface exploration program results.

6.8 Results

To be completed as part of final design scheduled for late 2021 to early 2022.

7. Construction Considerations

7.1 Erosion Control

All construction work on site will be completed in accordance with the State of Michigan EGLE construction activity permit and the Stormwater Pollution Prevention Plan (SWPPP) that will be prepared for this project. All other federal, state, and local permit requirements should be adhered to during construction. Work should be planned to minimize soil erosion from the construction area. Soil erosion and sediment control measures should be in place prior to any earthwork operation and will be used to prevent construction related degradation of the natural water quality. Erosion and sediment control best management practices (BMPs) should be used for all site erosion and sediment control.

To minimize soil erosion, all work should be planned, conducted, and controlled to reduce the areas disturbed by the new construction. Precipitation runoff should be directed to retention basins and infiltration areas. Disturbed areas should be promptly stabilized. Effective use and maintenance of erosion and sediment control measures such as silt fences, seeding and erosion control blankets for soil slopes should be used throughout the construction period and maintained until the permanent drainage and erosion control measures are installed.

To protect the water quality in natural water bodies, set-back criteria should be established for equipment traffic. Siltation of the water should be prevented by dispersing any flows to infiltration areas and retention basins. Gravel pads should be used to prevent spillage or tracking soils or other construction material on roads used for site access. Exposed soil slopes should be seeded and covered with erosion control blankets. For long slopes, earth berms and ditches should be constructed across the slopes to intercept and convey surface water to stable outlets at non-erosive velocities.

7.2 Upstream and Downstream Cofferdams

The proposed upstream and downstream cofferdam design consists of internally braced, hot rolled steel sheet pile (SSP) with interlock sealants. The cofferdam cells can be constructed in three (III) phases at the powerhouse and each bay. Phase I is constructed at the powerhouse to allow construction of the low-level outlet while the Tainter gate spillway bays remain open to pass base river flow. Phase I requires an upstream cofferdam only. Phase II requires both an upstream and downstream cofferdam and would occur at Spillway Bay No. 2 while the newly constructed low-level outlet and Spillway Bay No. 1 pass base river flow. Phase II construction includes the Spillway Bay No. 2 demolition of the concrete barrel arch and downstream rollway, concrete repairs, construction of the new concrete rollway and left crest gate. Finally, Phase III would occur at Spillway Bay No. 1 like Phase II, while Spillway Bay No. 2 and the low-level outlet would remain open to pass base river flow. The upstream cofferdams will consist of steel sheet piles braced internally with three levels of walers and struts. The Phase II and III upstream cofferdams will require three levels of internal waler, cross-lot and corner bracing will be installed prior to dewatering, which will require some underwater diver assisted installation. The Phase II and III downstream cofferdams will need two levels of bracing. Sheet piles running upstream and downstream will be cut within the barrel arch and require a closure connection using divers between the steel sheet pile and concrete barrel arch to create a “watertight” seal. The internal bracing will react against the end walls, the powerhouse, or the internal pier. The conceptual design is illustrated in **Exhibits 7-1** through **7-3** and included in **Appendix E**.

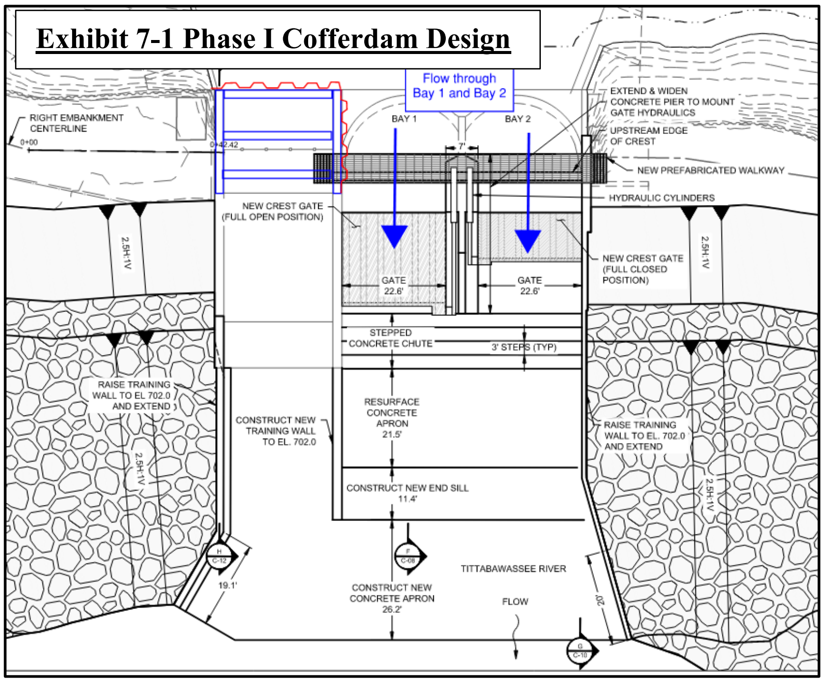

Exhibit 7-1 Phase I Cofferdam Design

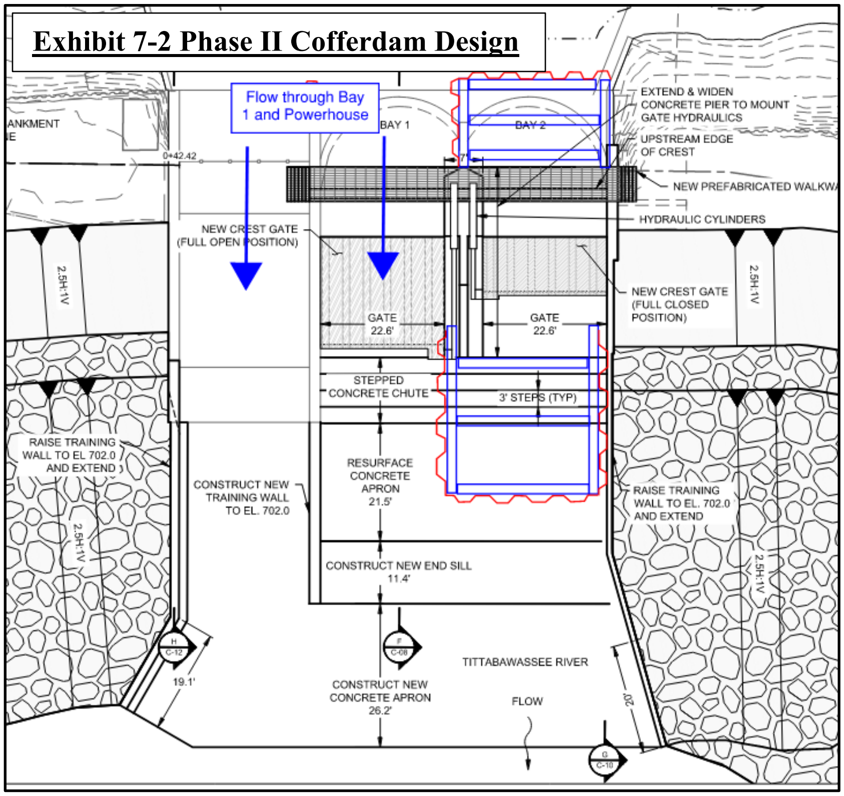
Exhibit 7-2 Phase II Cofferdam Design
Flow through Bay 1 and Powerhouse
BAY 1
BAY 2
EXTEND & WIDEN CONCRETE PIER TO MOUNT GATE HYDRAULICS
UPSTREAM EDGE OF CREST
NEW PREFABRICATED WALKWA
HYDRAULIC CYLINDERS
NEW CREST GATE (FULL OPEN POSITION)
NEW CREST GATE (FULL CLOSED POSITION)
GATE 22.6'
GATE 22.6'
STEPPED CONCRETE CHUTE
3' STEPS (TYP)
RAISE TRAINING WALL TO EL 702.0 AND EXTEND
CONSTRUCT NEW TRAINING WALL TO EL. 702.0
RESURFACE CONCRETE APRON 21.5'
RAISE TRAINING WALL TO EL. 702.0 AND EXTEND
CONSTRUCT NEW END SILL 11.4'
TITTABAWASSEE RIVER
CONSTRUCT NEW CONCRETE APRON 26.2'
FLOW
19.1'
2.5H:1V
0+42.42

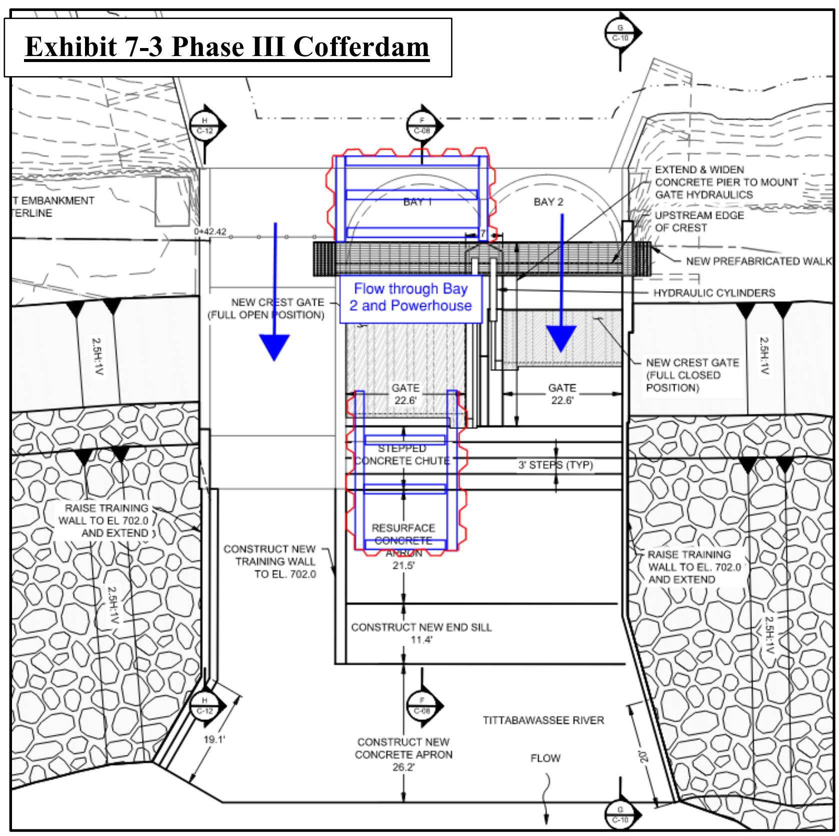
Exhibit 7-3 Phase III Cofferdam
Flow through Bay 2 and Powerhouse
BAY 1
BAY 2
EXTEND & WIDEN CONCRETE PIER TO MOUNT GATE HYDRAULICS
UPSTREAM EDGE OF CREST
NEW PREFABRICATED WALK
HYDRAULIC CYLINDERS
NEW CREST GATE (FULL OPEN POSITION)
NEW CREST GATE (FULL CLOSED POSITION)
GATE 22.6'
GATE 22.6'
STEPPED CONCRETE CHUTE
3' STEPS (TYP)
RAISE TRAINING WALL TO EL 702.0 AND EXTEND
CONSTRUCT NEW TRAINING WALL TO EL. 702.0
RESURFACE CONCRETE APRON 21.5'
RAISE TRAINING WALL TO EL. 702.0 AND EXTEND
CONSTRUCT NEW END SILL 11.4'
TITTABAWASSEE RIVER
CONSTRUCT NEW CONCRETE APRON 26.2'
FLOW
19.1'
2.5H:1V
0+42.42

7.3 Reservoir Operations During Construction

The reservoir is currently drawn down to approximately El. 695.8 +/- or within one foot above the spillway crest (El. 694.8) with the Tainter gates fully open (10-feet) and dogged off. The reservoir will remain drawn down during construction and the headwater will fluctuate based on seasonal Tittabawassee River flow.

7.4 Dewatering and Diversion Needs

The Tittabawassee River will be conveyed through the new low-level outlet constructed within the existing powerhouse and through the current Tainter gate spillway bays in the following three phases:

- Phase I – Pass base river flow through open Tainter Gate Spillway Bays No. 1 and No. 2 while constructing the low-level outlet in the powerhouse.
- Phase II – Pass base river flow through the low-level outlet and Tainter Gate Spillway Gate Bay No. 1 while demolishing Tainter Gate Bay No. 2 and constructing the new left crest gate and concrete rollway.
- Phase III – Pass base river flow through the low-level outlet and Tainter Gate Bay No. 2 while demolishing Tainter Gate Bay No. 1 and constructing the new right crest gate and concrete rollway.

Additional flow during extreme flood events will be passed through the new auxiliary spillway constructed in the left embankment.

7.5 Anticipated Construction Sequence

The anticipated construction sequence for the Smallwood Dam rehabilitation is as follows:

1. Contractor mobilization and develop crane pads, material laydown and work areas.
2. Remove the angled divider between Spillway Bay 1 and the Powerhouse tailrace.
3. Install a temporary braced cofferdam upstream of the powerhouse intake and downstream in the powerhouse tailrace area. Remove the turbine shaft, generator set and associated appurtenant mechanical and electrical equipment from within the powerhouse. Install a bulkhead over the runner pit and fix the runner into place.
4. Fill the hollow portion of the powerhouse structure upstream of the draft bay with mass concrete.

5. Construct a new slide frame, slide gate and steel hoist frame structure upstream of the powerhouse intake and trash racks. Construct repairs to the powerhouse intake and outlet walls, penstock inlet, and draft tube outlet concrete, as needed. Raise and extend the left outlet works retaining wall.

6. Test and commission the new low-level outlet gate at the powerhouse. Remove the upstream and downstream cofferdams from the powerhouse intake and outlet areas.

7. Drive additional steel sheeting left of the existing sheet piles under and east of the new auxiliary spillway alignment.

8. Construct the new flashboard auxiliary spillway over new steel sheet piling, stilling basin, and discharge channel. Do not yet install the flashboards.

9. Concurrent with Step 6, construct rehabilitation repairs to the left and right embankments, including installation of filter sand, drainage stone, and additional embankment fill. Excavation from the overflow spillway and outlet channel can be used as embankment fill, if suitable.

10. Install the braced upstream and downstream cofferdams to isolate the left Spillway Bay No. 2, rollway and center pier.

11. Remove the left Tainter gate and hoist. Cut down and demolish the upstream barrel arch concrete to El. 688.8 feet and demolish the rollway ogee crest, downstream rollway and cross struts as designated on the drawings down to the stilling basin within the left Spillway Bay No. 2.

12. Fill the barrel arch bay with mass concrete, and install the new hydraulic crest gate steel anchor embedment. Construct the reinforced concrete stepped chute, ogee crest, stilling basin overlay and new downstream stilling basin end sill. Install reinforcement and construct the widened center pier. Raise and extend the left spillway wall. Install the left crest gate, hydraulic operator, and controls.

13. Excavate embankment fill against the right downstream powerhouse and left downstream spillway training walls.

14. Buttress the right downstream training wall with concrete in the powerhouse tailrace area.

15. Raise and reinforce the right downstream training wall and then place select lightweight backfill against the higher walls.

16. Raise the counterforts above the old fish ladder slab and then place select lightweight backfill against the higher left training wall.

17. Test and commission the left gate.

18. Remove the upstream and downstream cofferdams from the left spillway bay and relocate to the right spillway bay. Repeat steps 9 and 10 and test and commission the new crest gate in the right Spillway Bay No. 1. Remove the upstream and downstream cofferdams.

19. Install the new pre-engineered spillway operator's deck.

20. Install the auxiliary spillway stanchions and timber flashboards.

21. Install site instrumentation (piezometers, settlement monitoring points, etc.).

22. Site restoration and contractor demobilization.

23. Refill Smallwood Lake and monitor performance and record instrumentation and deformation point performance on a routine baseline.

8. Opinions of Probable Construction Cost

8.1 30% Design Cost Analysis

An engineer's opinions of probable construction cost (OPCC) was developed for the Smallwood Dam to pass the ½ PMF + design storm based on the proposed project facilities and construction approaches presented in this Report. The level of detail for this type of estimate is assumed to provide construction costs typically within a range of ± 25% at the 30% design level. The OPCC includes 25% contingency for all construction items and includes an allowance for site investigations, engineering design, permitting and construction engineering / management costs. The total OPCC for the Smallwood Dam to pass the ½ PMF + design storm is approximately **$17.9 million**. A summary of the ½ PMF + design storm OPPC for the Smallwood project is summarized in **Table 11** and cost estimate worksheets are provided as **Attachment F**.

Table 11: Summary of Opinion of Probable Construction Costs

Item	Description	Estimated Cost
0.00	General Conditions	$ 867,000
1.00	Site Preparation and Cofferdams	$ 1,470,000
2.00	Site Demolition (Spillway and Powerhouse)	$ 560,000
3.00	Left Embankment Repair and Stabilization	$ 1,222,000
4.00	Right Embankment Repair and Stabilization	$ 201,000
5.00	New Crest Gate Spillway and Outlet Works	$ 3,817,000
6.00	Powerhouse Rehabilitation	$ 1,500,000
7.00	Auxiliary Spillway Structure	$ 1,262,000
8.00	Discharge Channel	$ 2,060,000
9.00	Site Restoration	$ 150,000
	Subtotal	$ 13,109,000
	Contingency (25%)	$ 3,280,000
	Construction Subtotal	$ 16,389,000
	Site Investigations, Engineering, Permitting and Construction Management	$ 1,550,000
	Total Estimated Cost	**$ 17,939,000**

8.2 Closing

Our opinions of probable design and construction costs should be considered rough budgetary estimates based on conceptual level designs, costs for similar projects and engineering judgment. Detailed designs and quantities have not yet been prepared. 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.

9. References

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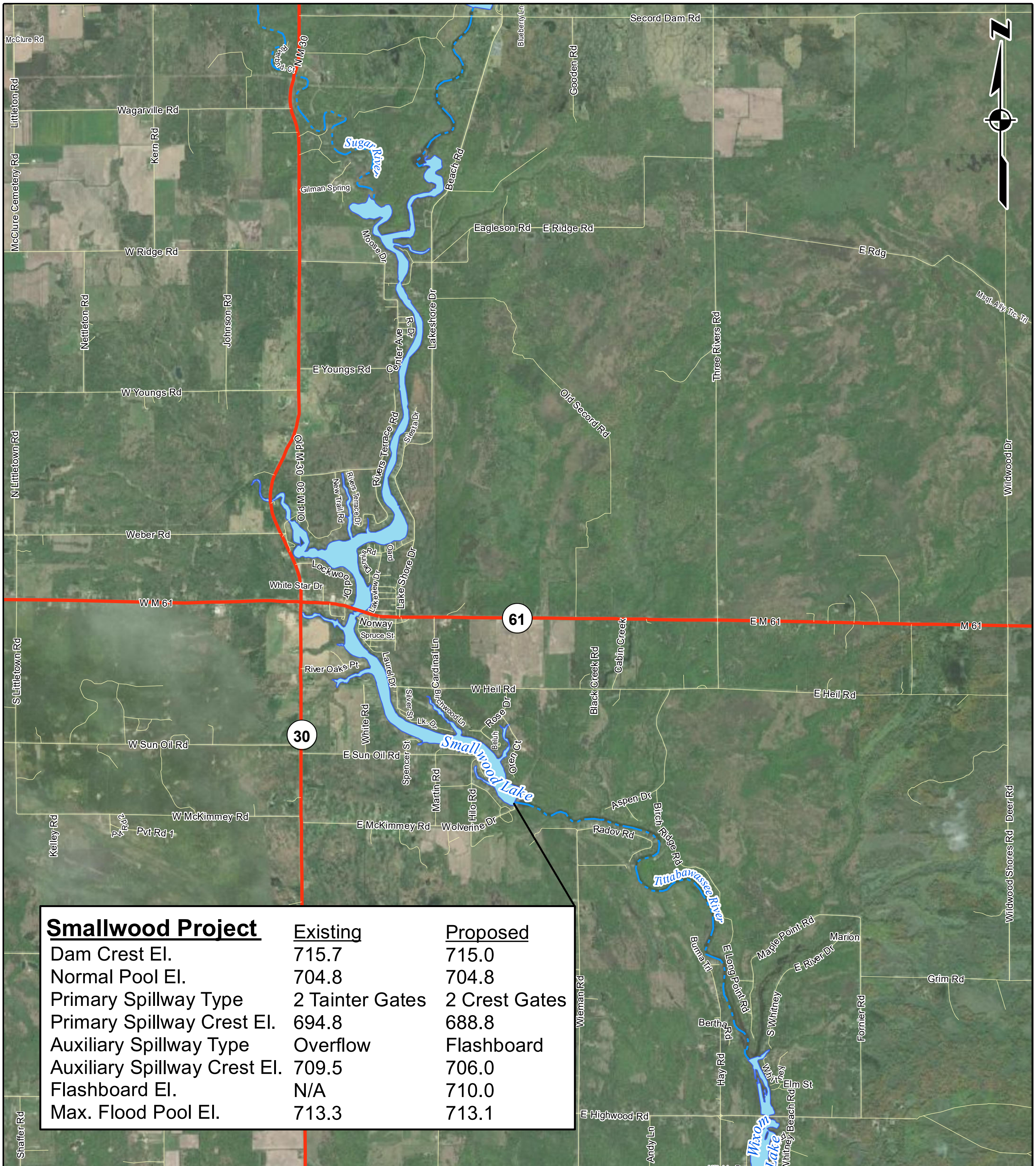
Figures



Smallwood Project	Existing	Proposed
Dam Crest El.	715.7	715.0
Normal Pool El.	704.8	704.8
Primary Spillway Type	2 Tainter Gates	2 Crest Gates
Primary Spillway Crest El.	694.8	688.8
Auxiliary Spillway Type	Overflow	Flashboard
Auxiliary Spillway Crest El.	709.5	706.0
Flashboard El.	N/A	710.0
Max. Flood Pool El.	713.3	713.1

0 1 2

Scale, Miles

Note: All elevations referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). The acronym "El." represents Elevation.

Conceptual Design Basis Report
Smallwood Dam

Four Lakes Task Force
Gladwin and Midland County, Michigan

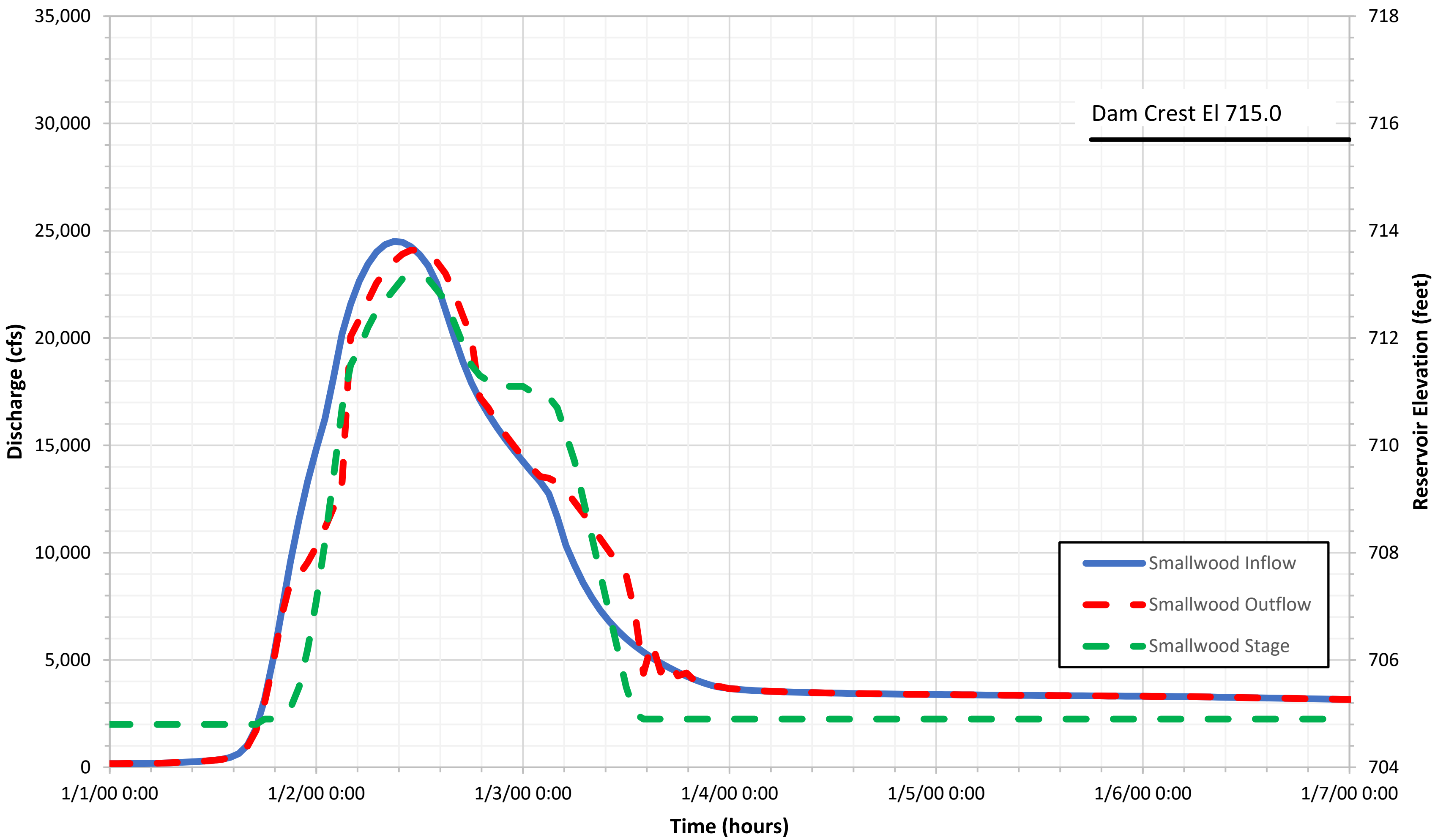
GEI Consultants

Project 2002879

SMALLWOOD DAM
SITE LOCATION MAP

March 2021

Figure 1



Smallwood Dam
Client: Four Lakes Task Force
Location: Gladwin County, Michigan

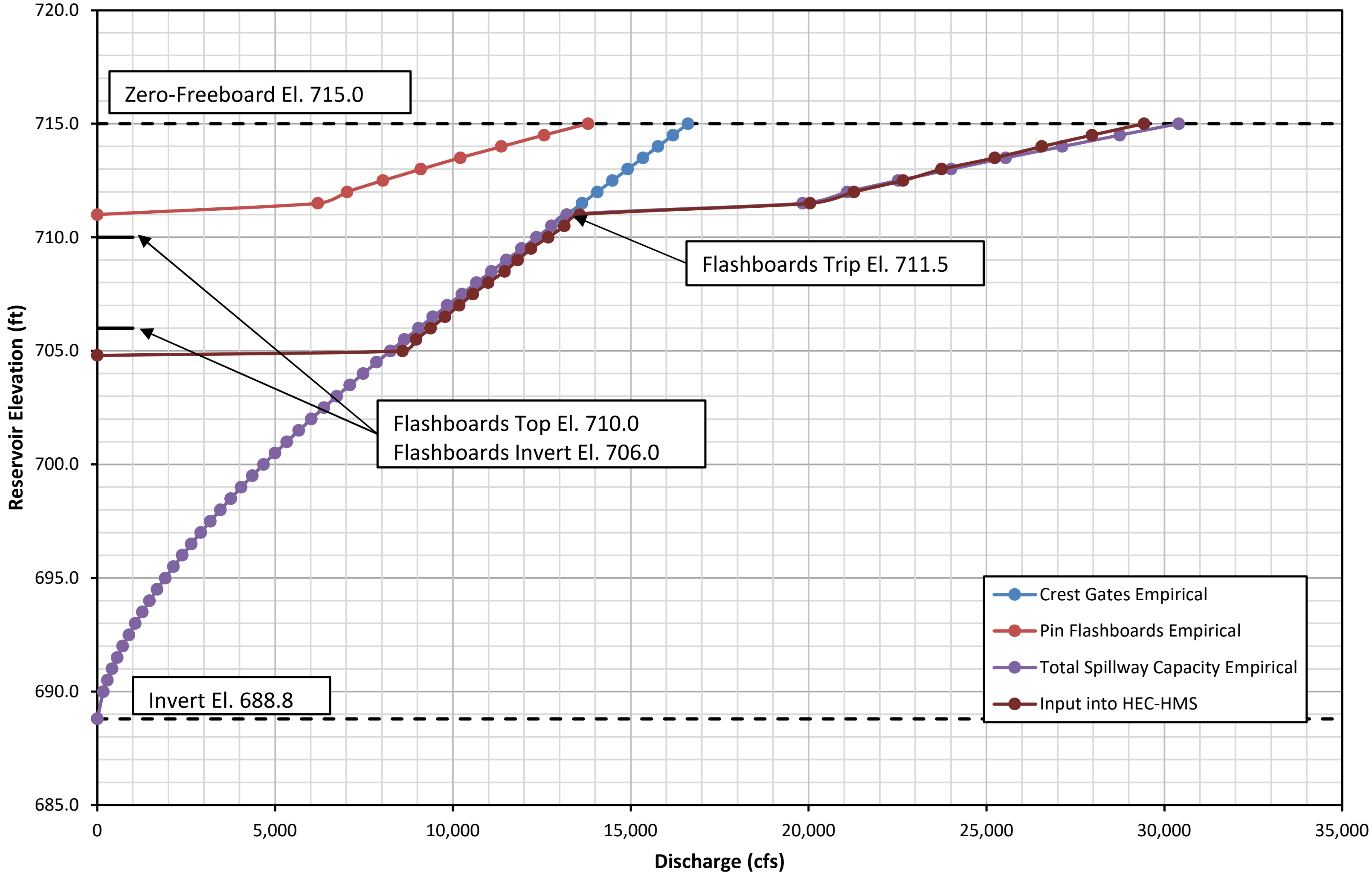
GEI Consultants

Proposed Conditions 1/2 PMF + Flood Routing Results

Project 2002879

March 2021

Figure 2



Smallwood Dam
Client: Four Lakes Task Force
Location: Gladwin County, Michigan

GEI Consultants

Smallwood Dam 1/2 PMF + Spillway Rating Curves

Project 2002879

March 2021

Figure 3

Appendix A

Exhibit F Drawings

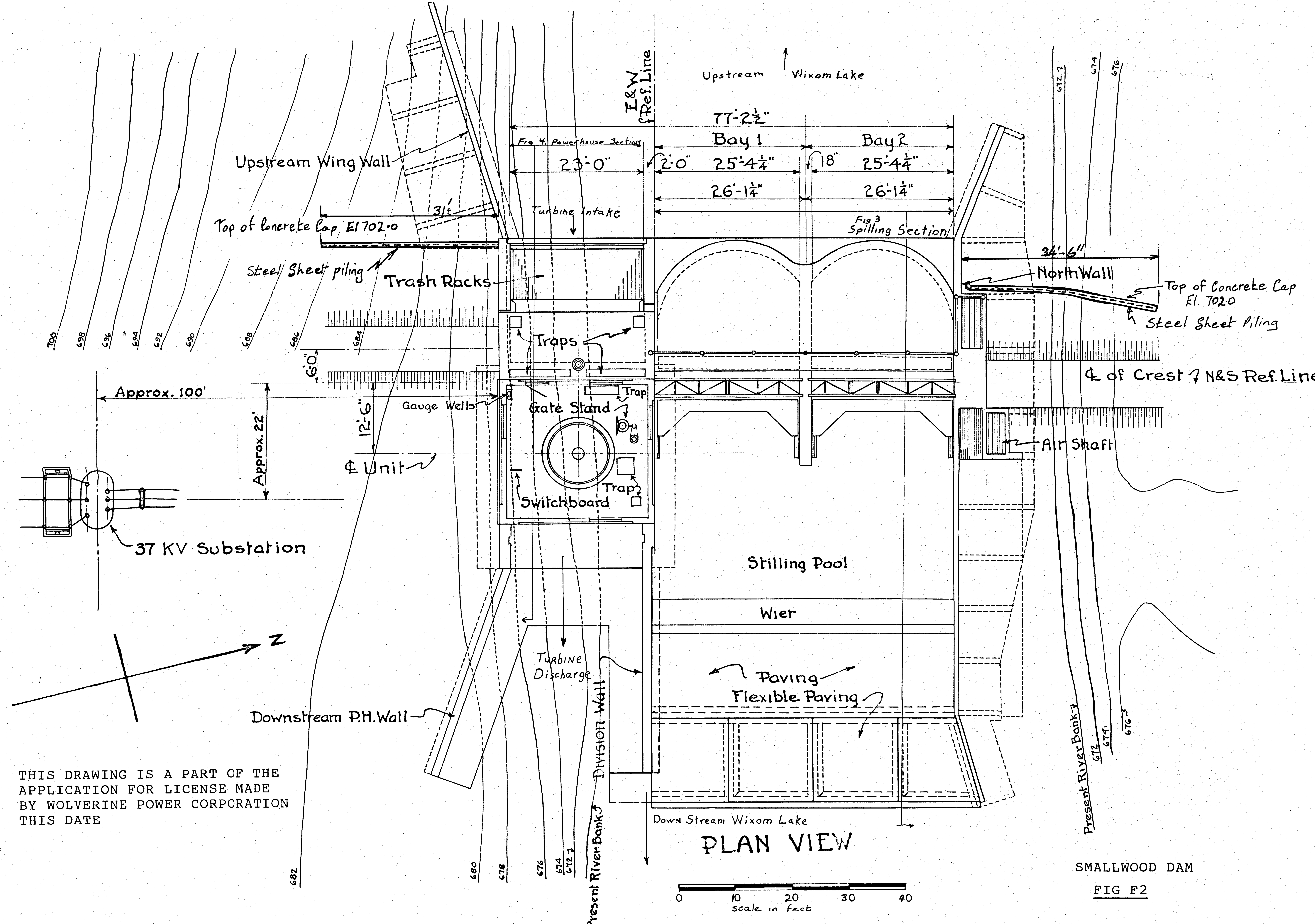
WOLVERINE POWER CORP

SMALLWOOD DAM

SURVEY PLAN

Scale 1" : 50'

FIG F1

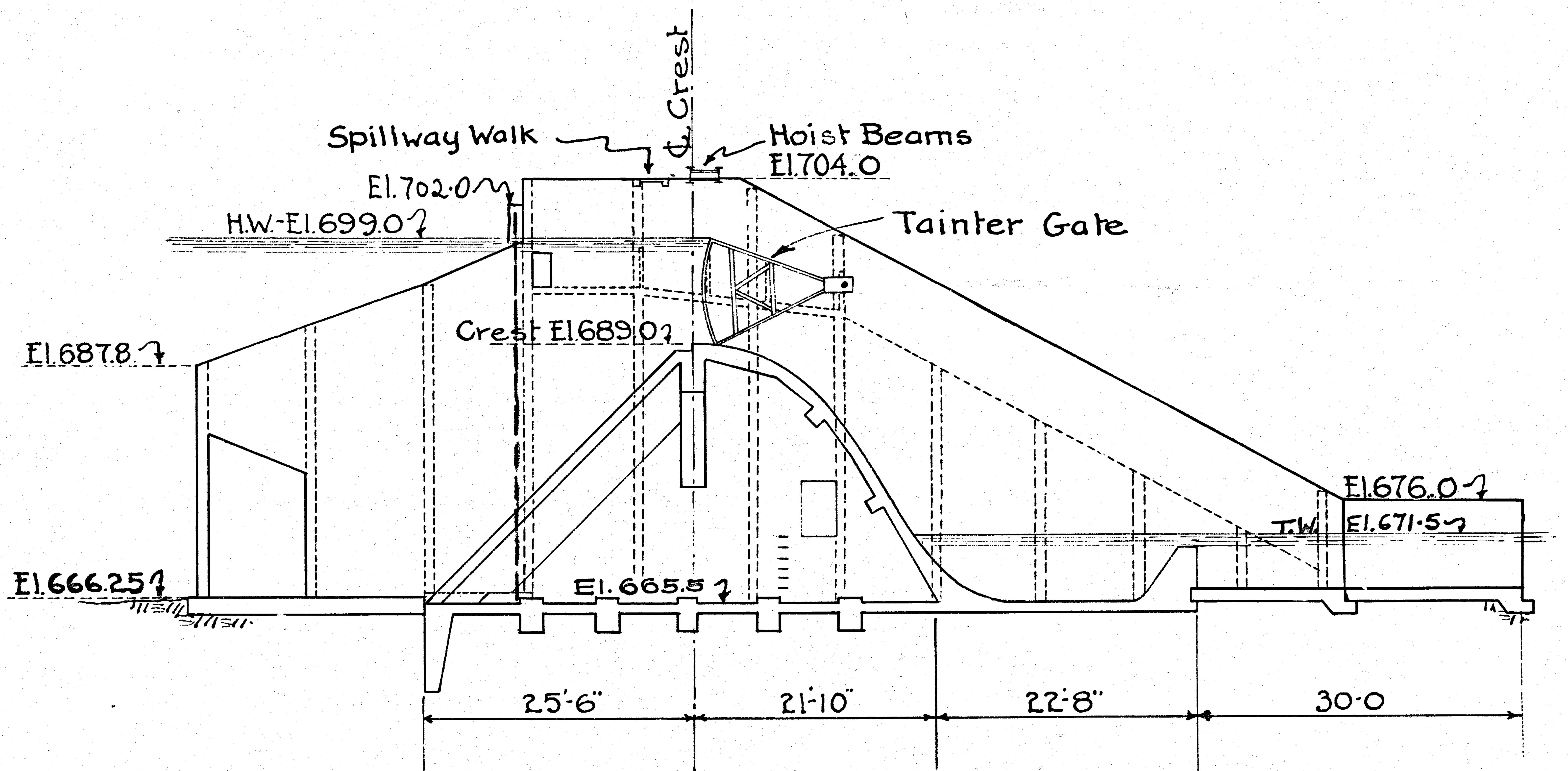


PLAN VIEW

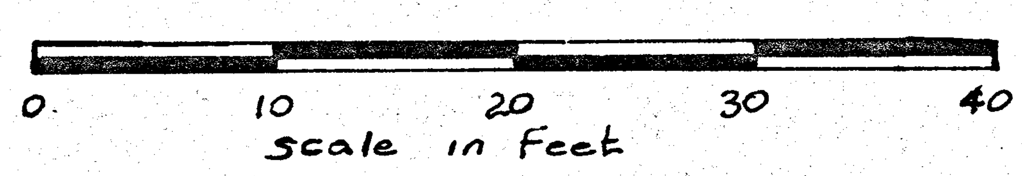
THIS DRAWING IS A PART OF THE
APPLICATION FOR LICENSE MADE
BY WOLVERINE POWER CORPORATION
THIS DATE

SMALLWOOD DAM

FIG F2



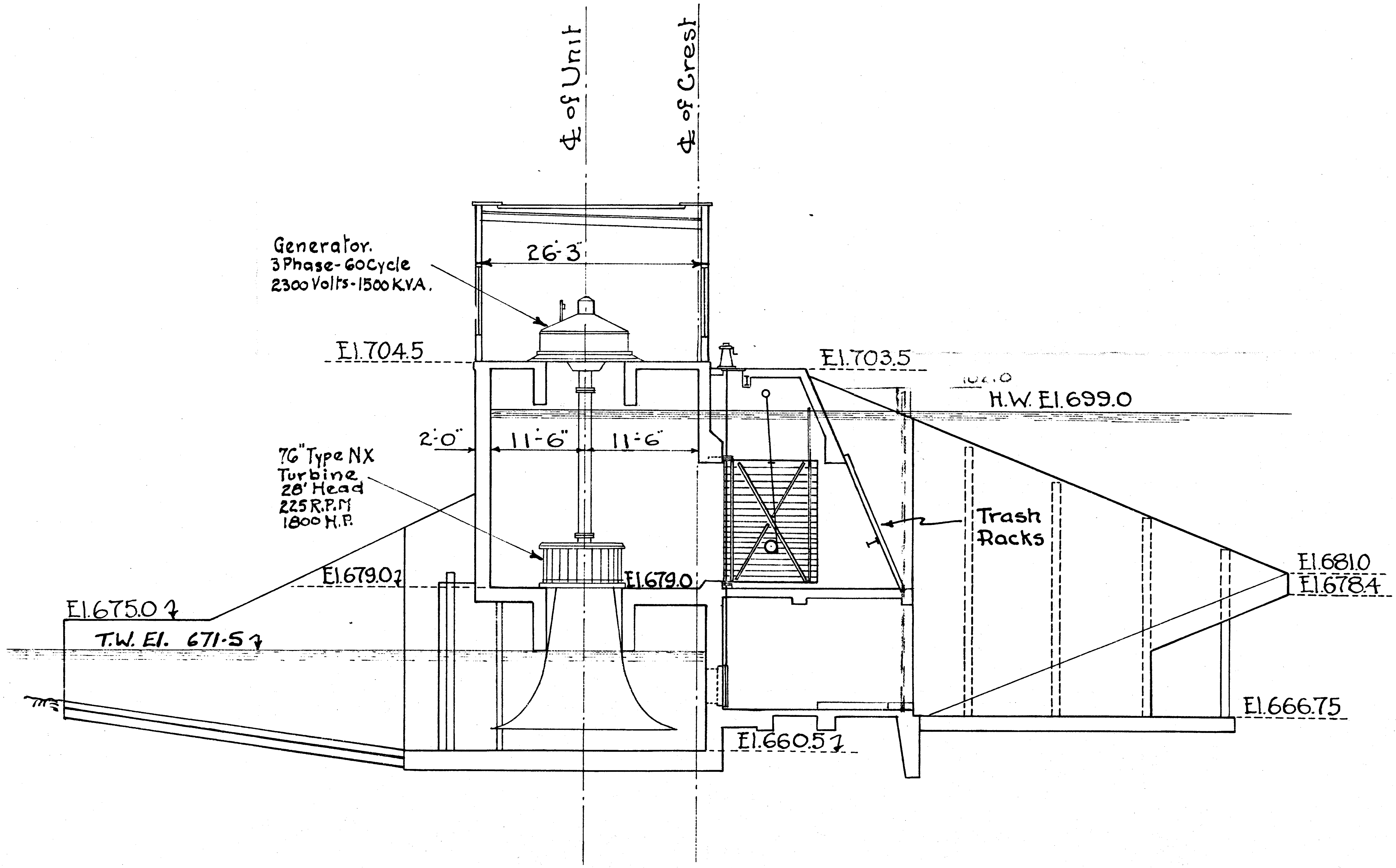
SECTION THRU BAY 2
(Looking North)



THIS DRAWING IS A PART OF THE
APPLICATION FOR LICENSE MADE
BY WOLVERINE POWER CORPORATION
THIS DATE

SMALLWOOD DAM

FIG F3



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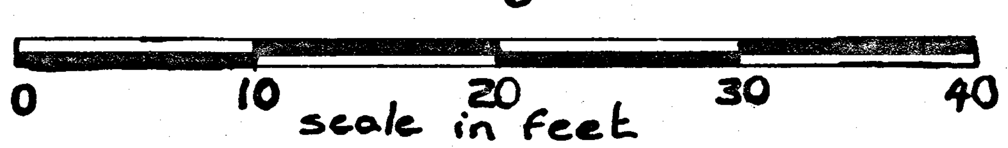
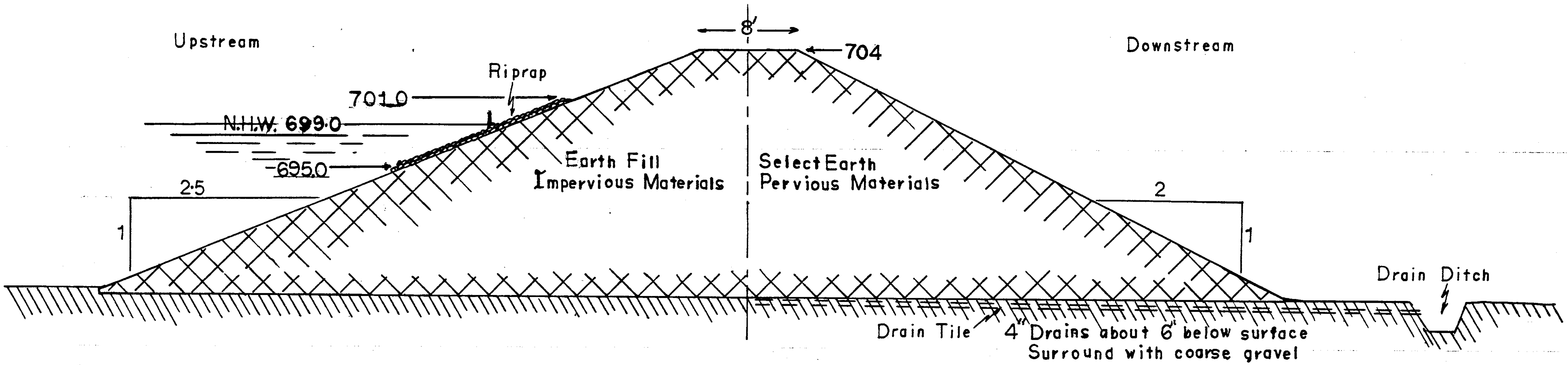
THIS DATE

SECTION THRU POWER HOUSE
(Looking South)

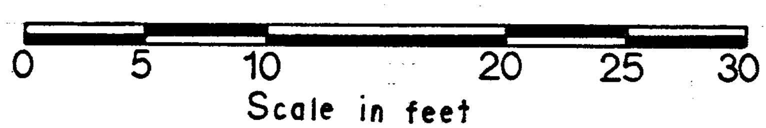


SMALLWOOD DAM

FIG F4



P.C. 10/86



Embankment Section
Smallwood Dam
Fig E5

Appendix B

Spillway Rating Curve Calculations

GEI Consultants

CLIENT:	Four Lakes Task Force		
PROJECT:	Smallwood Dam	Project: 2002879	Pages:
SUBJECT:	1/2 PMF + Spillway Design (Crest Gates)	Date: 11/12/2020	By: P. Drew
		Checked:	By:
		Approved:	By:

Purpose: Develop a spillway discharge rating curve for the proposed spillway

Procedure: Follow design steps presented in *Discharge Characterisitics of Broad-Crested Weirs*

References:
USBR (1987). Design of Small Dams
USGS (1957). Geological Survey Circular 397 Discharge Characteristics of Broad-Crested Weirs, J.H. Tracy
USGS (1968). Measurement of Peak Discharge at Dams by Indirect Method, Harry Hulsing

Input Variables:

Weir Crest El.	688.8	ft	L, Width Along Dam Axis	16.00	ft
Gate Weir Crest Width, b	22.6	ft	Number of Piers, N	1.0	-
Upstream Slope	1H:1V	Hor:Ver	Pier Contraction Coeff., Kp	0.01	-
Upstream Slope factor, Kr	Varies	-	Abutment Shape	45 Degree	-
Downstream Slope	1H:1V	Hor:Ver	Contraction Coeff., Ka	0.1	-
Downstream Slope Factor	Varies	-			
Number of Gates	2				

Step 1: Develop Spillway Discharge Rating Curve

Eq. (1-1) $Q=CbH^{3/2}$ USBR (1987) - Equation 3 pg. 365 (Discharge over uncontrolled crest)

where:

Q = Flow Rate (cfs)

C = Discharge Coefficient (USGS 1957), Figure 11 -- Discharge Coefficieints for broad-crested weirs with upstream face slope of 1:1

b = L' - 2(NKp + Ka)H (width of weir normal to flow)

H= Total Energy Head

Reservoir El. (ft)	Head, H (ft)	H/L	Weir Coeff.,C	D/S Slope Adjust[1].	Adjusted Weir Coeff.,C[2]	Effective Length (1 Gate) (ft), L'	Discharge (1 Gate) (cfs)	Discharge (Total) (cfs)	Comments
688.8	0.0	0.0	2.88	1.00	2.88	22.6	0	0	Spillway Invert
690.0	1.2	0.1	2.86	1.00	2.86	22.3	84	168	
690.5	1.7	0.1	2.86	1.00	2.86	22.2	141	282	
691.0	2.2	0.1	2.85	1.00	2.85	22.1	206	412	
691.5	2.7	0.2	2.85	1.00	2.85	22.0	279	558	
692.0	3.2	0.2	2.86	1.00	2.86	21.9	359	717	
692.5	3.7	0.2	2.86	1.00	2.86	21.8	444	889	
693.0	4.2	0.3	2.87	1.00	2.87	21.7	536	1,072	
693.5	4.7	0.3	2.87	1.00	2.87	21.6	633	1,266	
694.0	5.2	0.3	2.88	1.00	2.88	21.5	735	1,471	
694.5	5.7	0.4	2.89	1.00	2.89	21.4	843	1,686	
695.0	6.2	0.4	2.91	1.00	2.91	21.3	955	1,911	
695.5	6.7	0.4	2.92	1.00	2.92	21.2	1,073	2,145	
696.0	7.2	0.5	2.93	1.00	2.93	21.1	1,195	2,390	
696.5	7.7	0.5	2.95	1.00	2.95	21.0	1,322	2,644	
697.0	8.2	0.5	2.96	1.00	2.96	20.9	1,453	2,907	
697.5	8.7	0.5	2.98	1.00	2.98	20.8	1,589	3,179	
698.0	9.2	0.6	3.00	1.00	3.00	20.7	1,730	3,460	
698.5	9.7	0.6	3.02	1.00	3.02	20.6	1,875	3,750	
699.0	10.2	0.6	3.04	1.00	3.04	20.5	2,025	4,049	
699.5	10.7	0.7	3.06	1.00	3.06	20.4	2,178	4,356	
700.0	11.2	0.7	3.08	1.00	3.08	20.2	2,336	4,672	
700.5	11.7	0.7	3.10	1.00	3.10	20.1	2,498	4,996	
701.0	12.2	0.8	3.12	1.00	3.12	20.0	2,664	5,328	
701.5	12.7	0.8	3.14	1.00	3.14	19.9	2,834	5,668	
702.0	13.2	0.8	3.16	1.00	3.16	19.8	3,007	6,015	
702.5	13.7	0.9	3.18	1.00	3.18	19.7	3,185	6,369	
703.0	14.2	0.9	3.21	1.00	3.21	19.6	3,366	6,731	
703.5	14.7	0.9	3.23	1.00	3.23	19.5	3,550	7,099	
704.0	15.2	1.0	3.25	1.00	3.25	19.4	3,737	7,474	
704.5	15.7	1.0	3.27	1.00	3.27	19.3	3,927	7,855	
705.0	16.2	1.0	3.29	1.00	3.29	19.2	4,121	8,242	Normal Pool
705.5	16.7	1.0	3.31	1.00	3.31	19.1	4,317	8,634	
706.0	17.2	1.1	3.33	1.00	3.33	19.0	4,516	9,031	Auxiliary Spillway
706.5	17.7	1.1	3.35	1.00	3.35	18.9	4,717	9,433	
707.0	18.2	1.1	3.37	1.00	3.37	18.8	4,920	9,840	
707.5	18.7	1.2	3.39	1.00	3.39	18.7	5,125	10,250	
708.0	19.2	1.2	3.41	1.00	3.41	18.6	5,332	10,664	
708.5	19.7	1.2	3.43	1.00	3.43	18.5	5,541	11,081	
709.0	20.2	1.3	3.45	1.00	3.45	18.4	5,751	11,501	
709.5	20.7	1.3	3.47	1.00	3.47	18.3	5,962	11,924	
710.0	21.2	1.3	3.49	1.00	3.49	18.1	6,174	12,348	
710.5	21.7	1.4	3.50	1.00	3.50	18.0	6,387	12,774	
711.0	22.2	1.4	3.52	1.00	3.52	17.9	6,601	13,201	
711.5	22.7	1.4	3.53	1.00	3.53	17.8	6,814	13,629	
712.0	23.2	1.5	3.55	1.00	3.55	17.7	7,028	14,057	
712.5	23.7	1.5	3.56	1.00	3.56	17.6	7,242	14,485	
713.0	24.2	1.5	3.58	1.00	3.58	17.5	7,456	14,912	
713.5	24.7	1.5	3.59	1.00	3.59	17.4	7,669	15,338	
714.0	25.2	1.6	3.60	1.00	3.60	17.3	7,882	15,763	
714.5	25.7	1.6	3.61	1.00	3.61	17.2	8,093	16,187	
715.0	26.2	1.6	3.62	1.00	3.62	17.1	8,304	16,608	Zero Freeboard

GEI Consultants

CLIENT:	Four Lakes Task Force		
PROJECT:	Smallwood Dam	Project: 2002879	Pages:
SUBJECT:	1/2 PMF + Spillway Design (Auxiliary Flashboards)	Date: 11/12/2020	By: P. Drew
		Checked:	By:
		Approved:	By:

Purpose: Develop a spillway discharge rating curve for the proposed spillway

Procedure: Follow design steps presented in *Discharge Characterisitics of Broad-Crested Weirs*

References: USBR (1987). Design of Small Dams
USGS (1957). Geological Survey Circular 397 Discharge Characteristics of Broad-Crested Weirs, J.H. Tracy
USGS (1968). Measurement of Peak Discharge at Dams by Indirect Method, Harry Hulsing

Input Variables:

Weir Crest El.	706.0	ft	L, Width Along Dam Axis	6.00	ft
Weir Crest Width, b	150.0	ft	Number of Piers, N	1.0	-
Upstream Slope	2H:1V	Hor:Ver	Pier Contraction Coeff., Kp	0.0	-
Upstream Slope factor, Kr	Varies	-	Abutment Shape	45 Degree	-
Downstream Slope	2H:1V	Hor:Ver	Contraction Coeff., Ka	0.1	-
Downstream Slope Factor	Varies	-			

Step 1: Develop Spillway Discharge Rating Curve

Eq. (1-1) $Q=CbH^{3/2}$ USBR (1987) - Equation 3 pg. 365 (Discharge over uncontrolled crest)

where:

Q = Flow Rate (cfs)

C = Discharge Coefficient (USGS 1957), Figure 11 -- Discharge Coefficieints for broad-crested weirs with upstream face slope of 2:1

b = L' - 2(NKp + Ka)H (width of weir normal to flow)

H= Total Energy Head

Reservoir El. (ft)	Head, H (ft)	H/L	Weir Coeff.,C	D/S Slope Adjust[1].	Adjusted Weir Coeff.,C[2]	Effective Length (Gate 1) (ft), L'	Discharge (cfs)	Comments
706.0	0.0	0.0	2.89	1.00	2.89	150.0	0	Spillway Invert
706.5	0.5	0.1	2.89	1.00	2.89	149.9	0	
707.0	1.0	0.2	2.90	1.00	2.90	149.8	0	
707.5	1.5	0.3	2.92	1.00	2.92	149.7	0	
708.0	2.0	0.3	2.95	1.00	2.95	149.6	0	
708.5	2.5	0.4	2.99	1.00	2.99	149.5	0	
709.0	3.0	0.5	3.04	0.98	2.97	149.4	0	
709.5	3.5	0.6	3.08	0.98	3.02	149.3	0	
710.0	4.0	0.7	3.13	0.98	3.07	149.2	0	
710.5	4.5	0.8	3.19	0.98	3.12	149.1	0	
711.0	5.0	0.8	3.24	0.98	3.18	149.0	0	
711.5	5.5	0.9	3.29	0.98	3.23	148.9	6,198	Flasboards Trip
712.0	6.0	1.0	3.34	0.96	3.21	148.8	7,022	
712.5	6.5	1.1	3.39	0.96	3.26	148.7	8,030	
713.0	7.0	1.2	3.44	0.96	3.30	148.6	9,092	
713.5	7.5	1.3	3.48	0.96	3.35	148.5	10,204	
714.0	8.0	1.3	3.52	0.96	3.38	148.4	11,363	
714.5	8.5	1.4	3.56	0.96	3.42	148.3	12,562	
715.0	9.0	1.5	3.59	0.96	3.45	148.2	13,798	Zero Freeboard

GEI Consultants

CLIENT:	Four Lakes Task Force		
PROJECT:	Smallwood Dam	Project: 2002879	Pages:
SUBJECT:	1/2 PMF + Spillway Design (Total)	Date: 11/12/2020	By: P. Drew
		Checked:	By:
		Approved:	By:

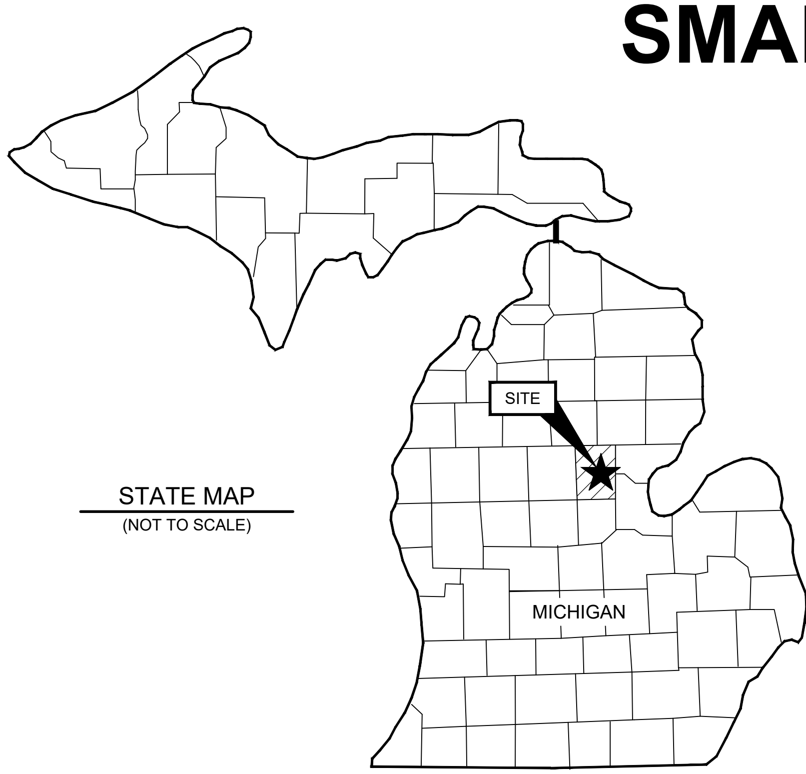
Reservoir El. (ft)	Gated Spillway (cfs)	Auxiliary Spillway (cfs)	Total Spillway Capacity (cfs)	Comments
688.8	0	0	0	Primary Gated Spillway
690.0	168	0	168	
690.5	282	0	282	
691.0	412	0	412	
691.5	558	0	558	
692.0	717	0	717	
692.5	889	0	889	
693.0	1,072	0	1,072	
693.5	1,266	0	1,266	
694.0	1,471	0	1,471	
694.5	1,686	0	1,686	
695.0	1,911	0	1,911	
695.5	2,145	0	2,145	
696.0	2,390	0	2,390	
696.5	2,644	0	2,644	
697.0	2,907	0	2,907	
697.5	3,179	0	3,179	
698.0	3,460	0	3,460	
698.5	3,750	0	3,750	
699.0	4,049	0	4,049	
699.5	4,356	0	4,356	
700.0	4,672	0	4,672	
700.5	4,996	0	4,996	
701.0	5,328	0	5,328	
701.5	5,668	0	5,668	
702.0	6,015	0	6,015	
702.5	6,369	0	6,369	
703.0	6,731	0	6,731	
703.5	7,099	0	7,099	
704.0	7,474	0	7,474	
704.5	7,855	0	7,855	
705.0	8,242	0	8,242	
705.5	8,634	0	8,634	
706.0	9,031	0	9,031	Auxiliary Spillway
706.5	9,433	0	9,433	
707.0	9,840	0	9,840	
707.5	10,250	0	10,250	
708.0	10,664	0	10,664	
708.5	11,081	0	11,081	
709.0	11,501	0	11,501	
709.5	11,924	0	11,924	
710.0	12,348	0	12,348	
710.5	12,774	0	12,774	
711.0	13,201	0	13,201	
711.5	13,629	6,198	19,827	Flasboards Trip
712.0	14,057	7,022	21,079	
712.5	14,485	8,030	22,515	
713.0	14,912	9,092	24,004	
713.5	15,338	10,204	25,543	
714.0	15,763	11,363	27,126	
714.5	16,187	12,562	28,749	
715.0	16,608	13,798	30,406	Zero-Freeboard

Appendix C

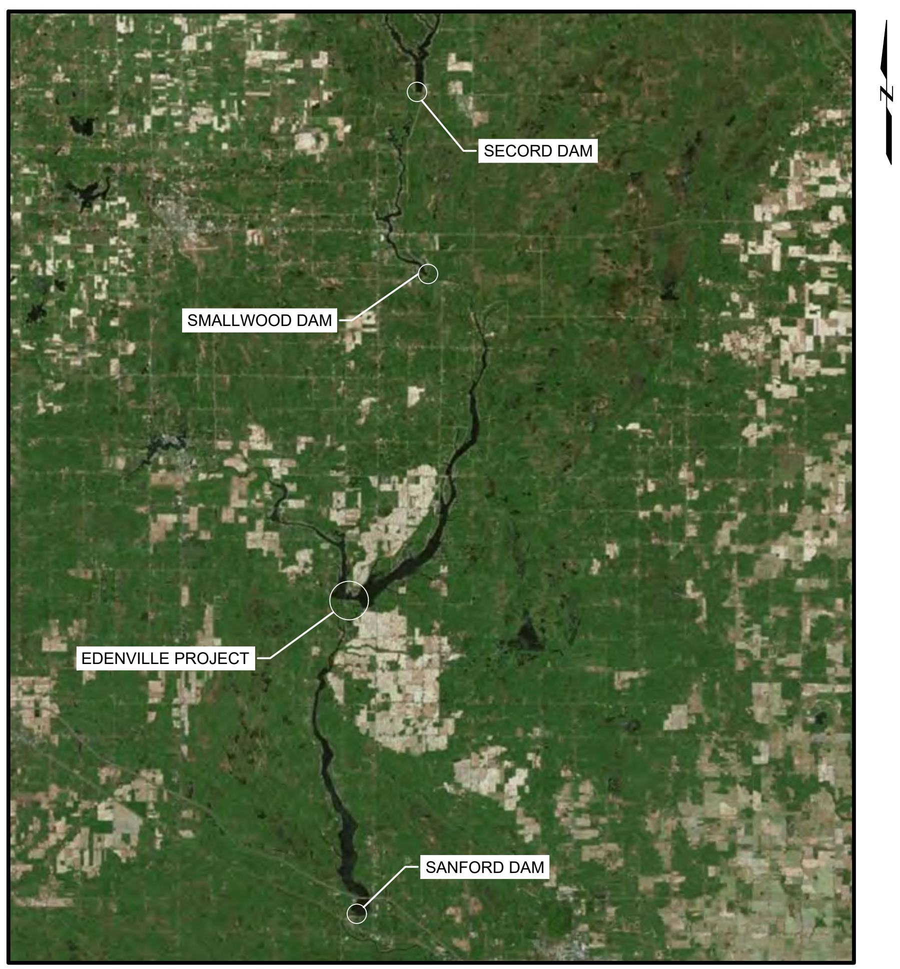
Smallwood Dam Conceptual Design Drawings

SMALLWOOD DAM CONCEPTUAL DESIGN

GLADWIN COUNTY, MICHIGAN
FOUR LAKES TASK FORCE
FERC PROJECT NO. 10810

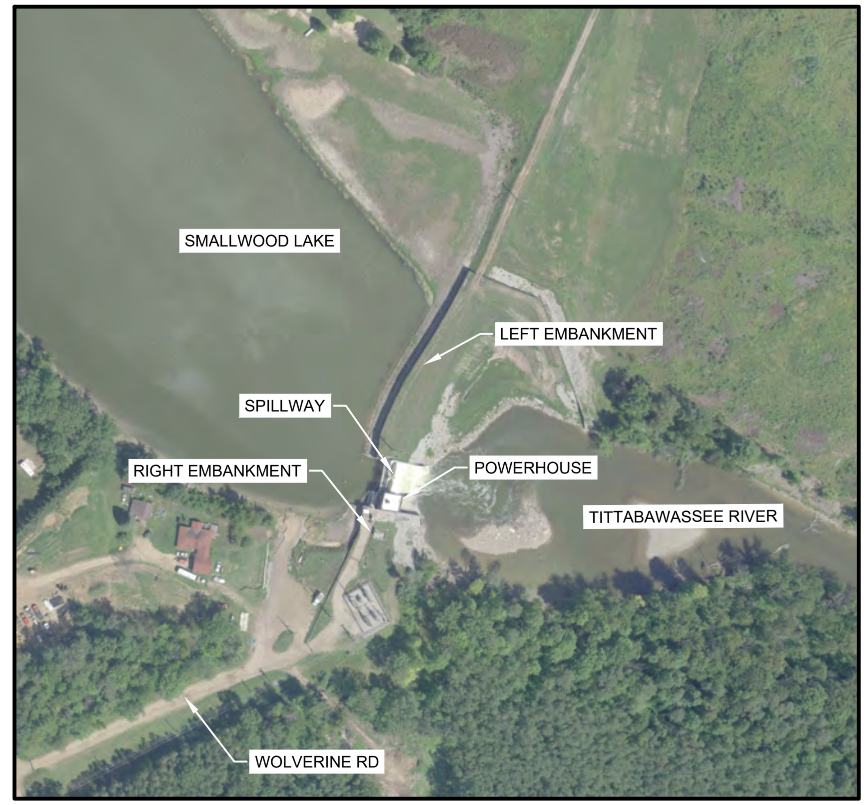


STATE MAP
(NOT TO SCALE)



SOURCE:
AERIAL IMAGE TAKEN FROM GOOGLE EARTH

SITE LOCATION
(NOT TO SCALE)



SITE AERIAL
(NOT TO SCALE)

SHEET INDEX

SHEET NO.	DRAWING NO.	TITLE
1	G-01	COVER SHEET AND SITE LOCATION
2	G-02	GENERAL NOTES AND LEGEND
3	C-01	SITE PLAN - EXISTING CONDITIONS
4	C-02	OUTLET WORKS - EXISTING CONDITIONS PLAN
5	C-03	OUTLET WORKS - TEMPORARY COFFERDAMS PLAN
6	S	OUTLET WORKS - DEMOLITION PLAN
7	C-05	OUTLET WORKS - DEMOLITION SECTION
8	C-06	SITE PLAN - PROPOSED MODIFICATIONS
9	C-07	OUTLET WORKS - MODIFICATION PLAN VIEW
10	C-08	PRIMARY SPILLWAY - MODIFICATIONS SECTION
11	C-09	PRIMARY SPILLWAY - CREST GATE DETAILS
12	C-10	NORTH TRAINING WALL - MODIFICATIONS SECTION
13	C-11	NORTH TRAINING WALL - MODIFICATIONS DETAILS
14	C-12	POWERHOUSE - MODIFICATIONS SECTION
15	C-13	EMBANKMENTS - MODIFICATIONS SECTIONS (SHEET 1 OF 2)
16	C-14	EMBANKMENTS - MODIFICATIONS SECTIONS (SHEET 2 OF 2)
17	C-15	AUXILIARY SPILLWAY - PROPOSED PLAN VIEW
18	C-16	AUXILIARY SPILLWAY - PROPOSED SPILLWAY & CHANNEL CROSS SECTIONS, SPILLWAY DETAILS

PREPARED FOR:

FOUR LAKES TASK FORCE
233 E. LARKIN
MIDLAND, MI 48640

PREPARED BY:

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GEI PROJECT NO. 2002879

NO.	DATE	ISSUE/REVISION	APP
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DRAFT

DWG. NO. G-01

SHEET NO. 1

1. GENERAL

SPACIAL DATUM INFORMATION

- VERTICAL: NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29).
- HORIZONTAL: NORTH AMERICAN DATUM OF 1983 (NAD83), MICHIGAN STATE PLANE, CENTRAL ZONE.
- A CONVERSION OF +5.8' IS REQUIRED WHEN CONVERTING VERTICAL DAM DATUM TO NGVD29 (E.G., HEADWATER ELEVATION AT DAM DATUM IS 699.0' AND AT NGVD29 DATUM IS 704.8').
- A CONVERSION OF -0.541' IS REQUIRED WHEN CONVERTING VERTICAL NGVD29 DATUM TO NAVD88 DATUM.
- CONTROL MONUMENTS ON-SITE SHALL BE REFERRED TO CONFIRM HORIZONTAL AND VERTICAL MEASUREMENTS.

BASEMAP DATA

- SITE TOPOGRAPHY AND AERIAL IMAGE OBTAINED DRONE FLIGHT PERFORMED BY SPICER GROUP IN 2020.
- COVER SHEET AERIAL IMAGES OBTAINED FROM GOOGLE EARTH REPRESENT CONDITIONS IN JUNE, 2018.
- OBTAINED FROM BOYCE HYDRO:
  - ORIGINAL CONSTRUCTION DRAWINGS
  - EXHIBIT F LICENSE DRAWINGS

DESIGN PARAMETERS

- NORMAL RESERVOIR ELEVATION 704.8' (+0.3' / -0.4')
- WINTER RESERVOIR OPERATIONS: MINIMUM 701.8'
- ORDINARY HIGH WATER MARK ELEVATION 675.2'

DESIGN REFERENCE STANDARDS

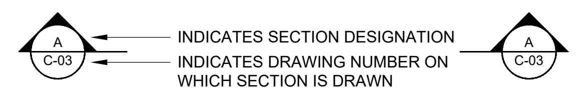
- (USBR, 1987) UNITED STATES DEPARTMENT OF THE INTERIORER, BUREAU OF RECLAMATION, "DESIGN OF SMALL DAMS", 1987.
- (USACE, 1995) UNITED STATES ARMY CORPS OF ENGINEERS, ENGINEERING AND DESIGN, "CONSTRUCTION CONTROL FOR EARTH AND ROCK-FILL DAMS", EM 1110-2-1911, 1995.
- (ACI, 2001) AMERICAN CONCRETE INSTITUTE, "CONTROL OF CRACKING IN CONCRETE STRUCTURES" (ACI 224), 2001.
- (USACE, 2004) UNITED STATES ARMY CORPS OF ENGINEERS, ENGINEERING AND DESIGN, "GENERAL DESIGN AND CONSTRUCTION CONSIDERATIONS FOR EARTH AND ROCK-FILL DAMS", EM 1110-2-2300, 2004.
- (ACI, 2006) AMERICAN CONCRETE INSTITUTE, "CODE REQUIREMENTS FOR ENVIRONMENTAL ENGINEERING CONCRETE STRUCTURES" (ACI 350), 2006.
- (ACI, 2011) AMERICAN CONCRETE INSTITUTE, "BUILDING CODE REQUIREMENTS FOR STRUCTURAL CONCRETE" (ACI 318), 2011.
- (FERC, 2016) FEDERAL ENERGY REGULATORY COMMISSION, ENGINEERING GUIDELINES FOR EVALUATION OF HYDROPOWER PROJECTS (MOST RECENT VERSIONS)

ABBREVIATIONS

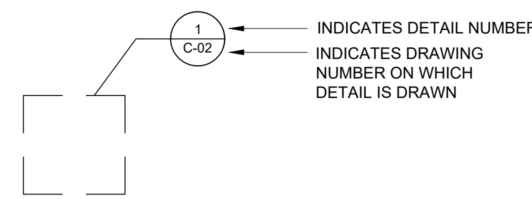
BO = BOTTOM OF
C = CENTER LINE
MM = MOVEMENT MONUMENT
CLSM = CONTROLLED LOW-STRENGTH MATERIAL
CONC = CONCRETE
CONT = CONTINUOUS
CTRD = CENTERED
D/S = DOWNSTREAM
EO = EDGE OF
EX = EXISTING
EF = EACH FACE
EL = ELEVATION (FEET)
HW = HEADWATER
MAX = MAXIMUM
OC = ON CENTER
OCEW = ON CENTER EACH WAY
OHWM = ORDINARY HIGH WATER MARK
PL = PLATE
PMF = PROBABLE MAXIMUM FLOOD
SDF = SPILLWAY DESIGN FLOOD
SSP = STEEL SHEET PILE
STD = STANDARD
STIFF = STIFFENER
TBD = TO BE DETERMINED
TO = TOP OF
TW = TAILWATER
TYP = TYPICAL
UON = UNLESS OTHERWISE NOTED
U/S = UPSTREAM
VIF = VERIFY IN FIELD
WL = WETLAND
W/ = WITH

SECTION AND DETAIL LEGEND

SECTION



DETAIL



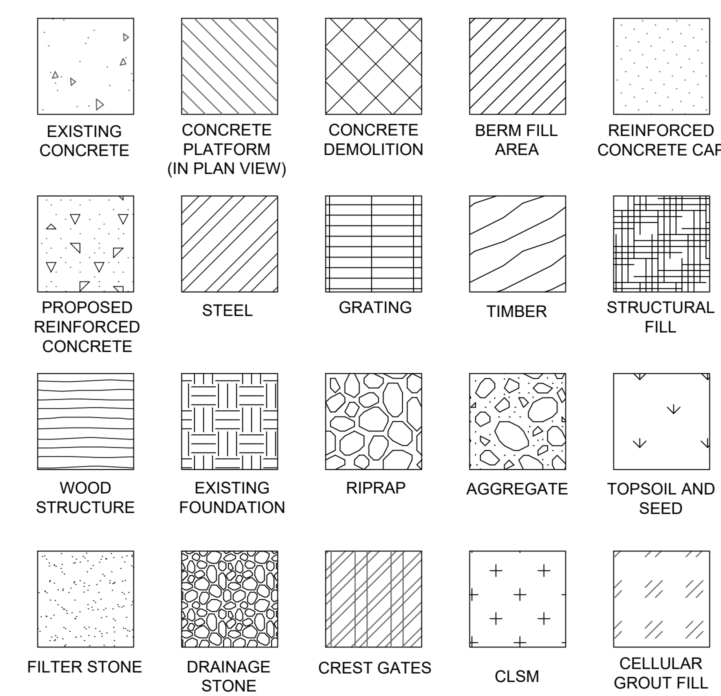
LINETYPE LEGEND

- CENTERLINE
- WATER ELEVATION
- O/E — OVERHEAD ELECTRIC LINES
- X — FENCE LINE (STEEL)
- FENCE LINE (WOOD)
- CATV — UNDERGROUND CABLE
- GAS — GAS LINE
- EDGE OF ROADWAY (UNPAVED)
- ROADWAY CENTERLINE
- BURIED PIPING
- SILT FENCE
- 750 — EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- 750 — DESIGN MAJOR CONTOURS
- DESIGN MINOR CONTOURS
- SHEETPILE

SYMBOLS LEGEND

- WATER ELEVATION
- FLOW DIRECTION
- 1H:1V — CUT SLOPE
- 1H:1V — FILL SLOPE
- POWER POLE
- SB-1 — SOIL BORING COMPLETED BY PROFESSIONAL SERVICE INDUSTRIES, 1997
- BM #200 — SURVEY REFERENCE MONUMENT (CONTORL POINT / BENCHMARK)

HATCH LEGEND



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0 1" If this scale bar does not measure 1" then drawing is not original scale.	0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Checked:	P. DREW
Drawn:	A. SAMPSON
Approved By:	B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

GENERAL NOTES AND LEGEND

DWG. NO. G-02

SHEET NO. 2

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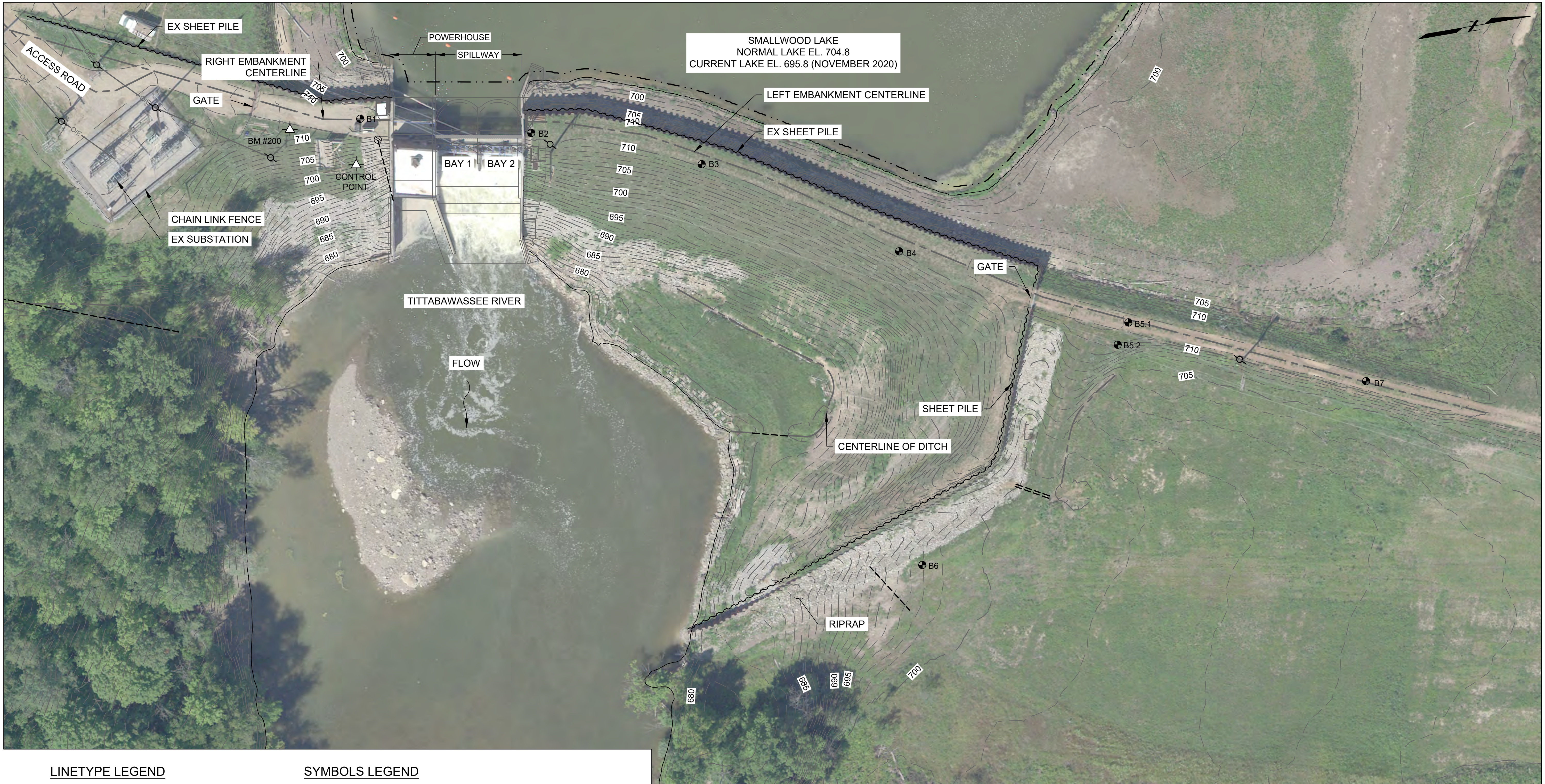

LINETYPE LEGEND

CENTERLINE	
WATER ELEVATION	
OVERHEAD ELECTRIC LINES	O/E
FENCE LINE (STEEL)	X
FENCE LINE (WOOD)	
EDGE OF ROADWAY (UNPAVED)	
BURIED PIPING	
EXISTING MAJOR CONTOURS	750
EXISTING MINOR CONTOURS	
SHEETPILE	

SYMBOLS LEGEND

SB-3	SOIL BORING COMPLETED BY PROFESSIONAL SERVICE INDUSTRIES, 1997
	FLOW DIRECTION
BM #200	SURVEY REFERENCE MONUMENT
	POWER POLE

EXISTING CONDITIONS SITE PLAN

0 30' 60'
SCALE, FT

SURVEY CONTROL MONUMENT LOCATIONS

ID	ELEVATION	NORTHING	EASTING
BM #200	710.61	234,396.048	19,693,143.919
CONTROL POINT	702.36	234,431.875	19,693,171.675

NOTES:
1. VERTICAL DATUM: NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29)
2. SPATIAL DATUM: NORTH AMERICAN DATUM OF 1983 (NAD83), MICHIGAN STATE PLANE, CENTRAL ZONE

Attention:
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Four Lakes Task Force
FERC Project No. 10810
GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

SITE PLAN - EXISTING CONDITIONS

DWG. NO.
C-01

SHEET NO.
3

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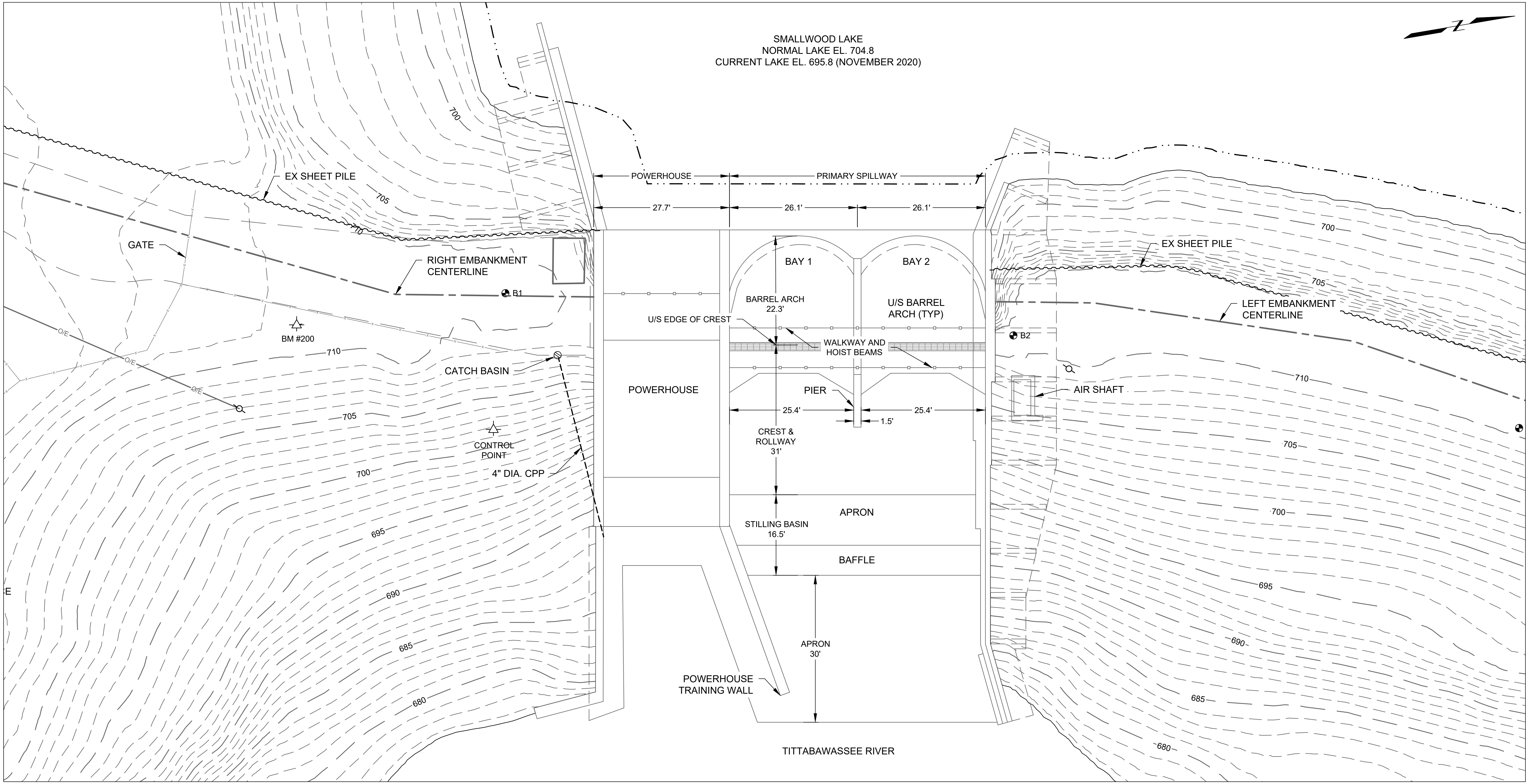

LINETYPE LEGEND

CENTERLINE
WATER ELEVATION
OVERHEAD ELECTRIC LINES
FENCE LINE (STEEL)
FENCE LINE (WOOD)
EDGE OF ROADWAY (UNPAVED)
BURIED PIPING
EXISTING MAJOR CONTOURS
EXISTING MINOR CONTOURS
SHEETPILE

SYMBOLS LEGEND

SB-3 SOIL BORING COMPLETED BY PROFESSIONAL SERVICE INDUSTRIES, 1997
FLOW DIRECTION
BM #200 SURVEY REFERENCE MONUMENT
POWER POLE

OUTLET WORKS - EXISTING PLAN VIEW

0 10' 20'
SCALE, FT

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

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Approved By: B. WALTON

Four Lakes Task Force
FERC Project No. 10810
GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

OUTLET WORKS - EXISTING CONDITIONS PLAN

DWG. NO. C-02
SHEET NO. 4

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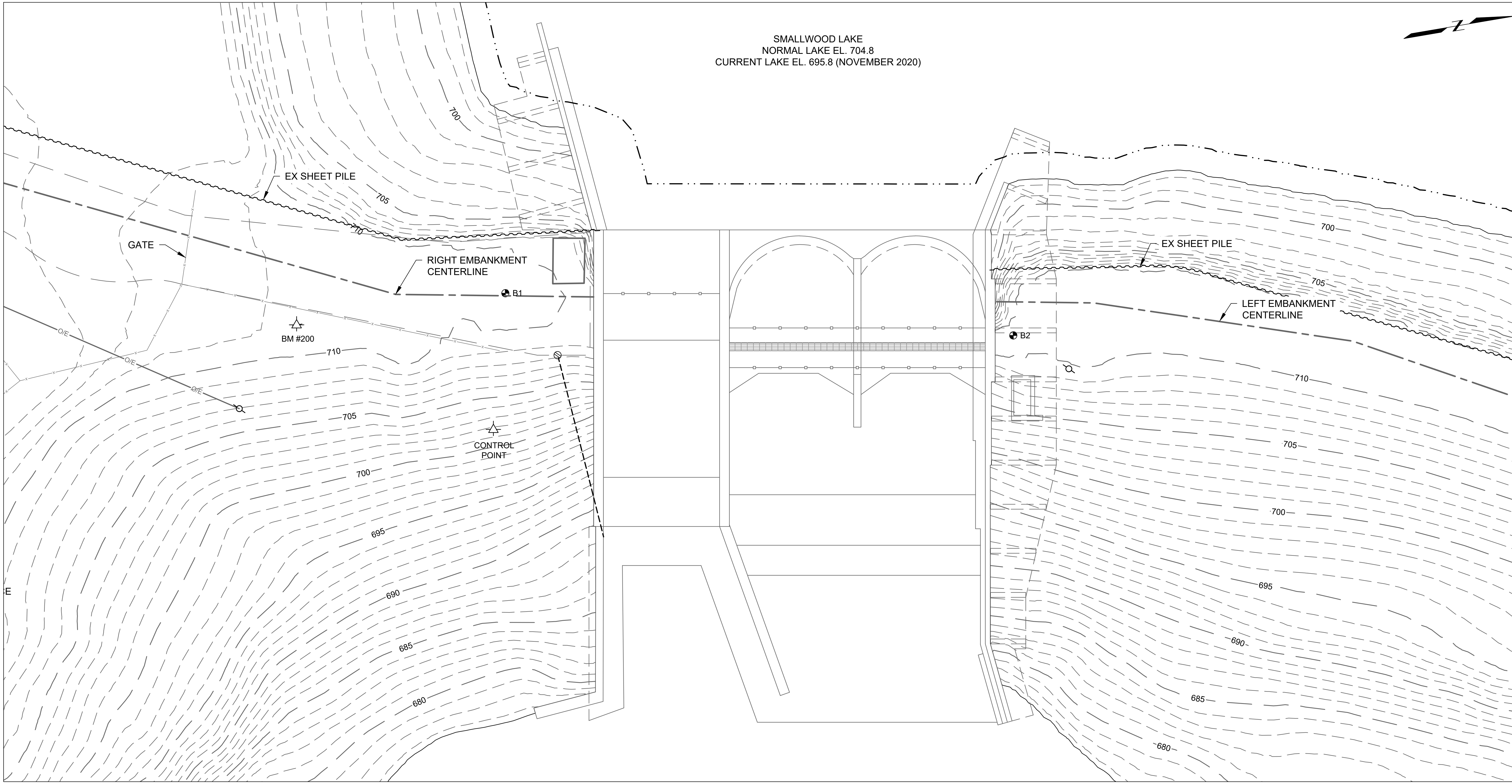

OUTLET WORKS - PLAN VIEW

0 10' 20'
SCALE, FT

LINETYPE LEGEND

- CENTERLINE
- WATER ELEVATION
- O/E OVERHEAD ELECTRIC LINES
- X FENCE LINE (STEEL)
- FENCE LINE (WOOD)
- EDGE OF ROADWAY (UNPAVED)
- BURIED PIPING
- 750 EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- SHEETPILE

SYMBOLS LEGEND

- SB-3 SOIL BORING COMPLETED BY PROFESSIONAL SERVICE INDUSTRIES, 1997
- FLOW DIRECTION
- BM #200 SURVEY REFERENCE MONUMENT
- POWER POLE

Attention:

0 1"

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NO.	DATE	ISSUE/REVISION	APP
0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Checked:	P. DREW
Drawn:	A. SAMPSON
Approved By:	B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

OUTLET WORKS - TEMPORARY COFFERDAMS PLAN

DWG. NO. C-03

SHEET NO. 5

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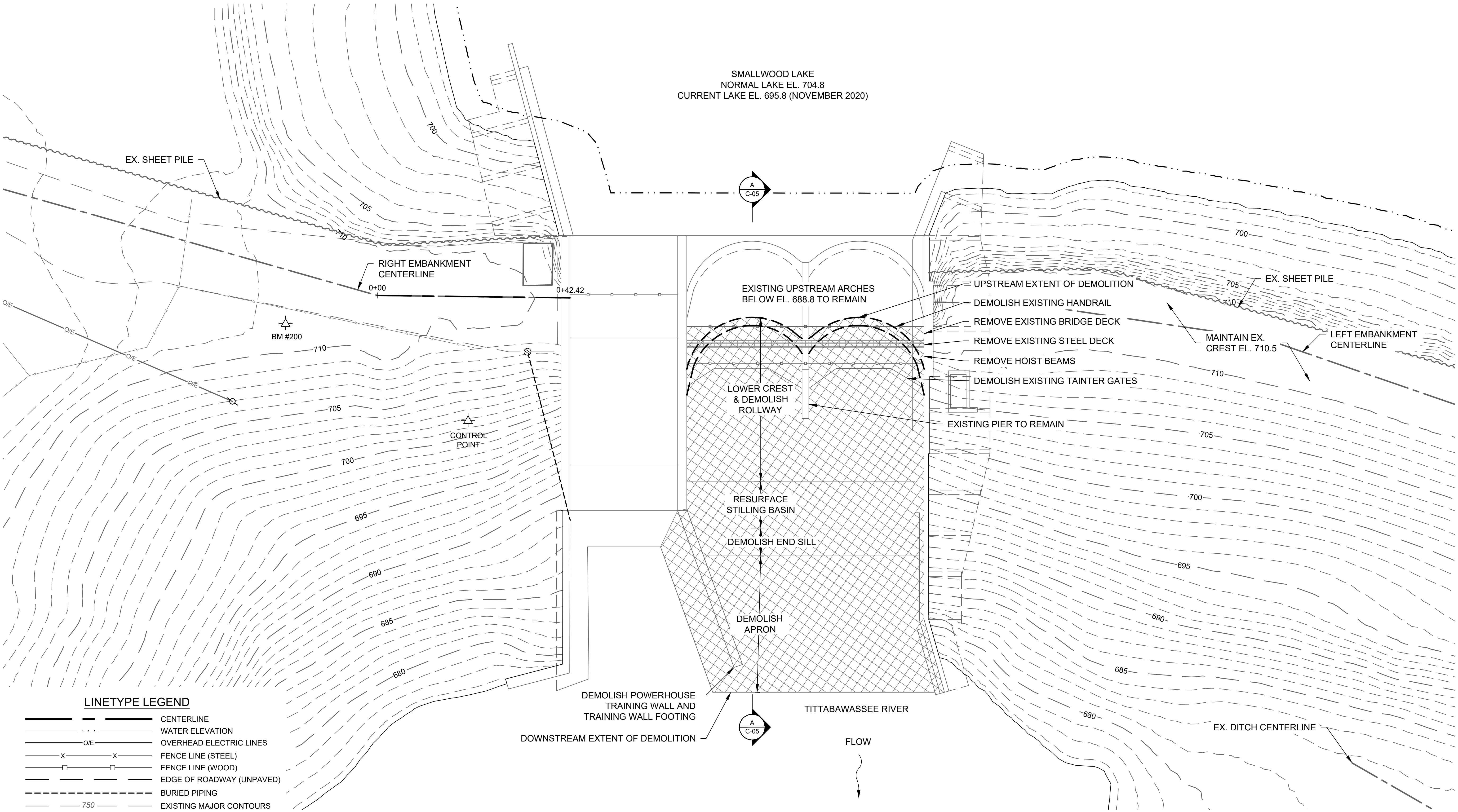

LINETYPE LEGEND

- CENTERLINE
- WATER ELEVATION
- OVERHEAD ELECTRIC LINES (O/E)
- FENCE LINE (STEEL)
- FENCE LINE (WOOD)
- EDGE OF ROADWAY (UNPAVED)
- BURIED PIPING
- EXISTING MAJOR CONTOURS (750)
- EXISTING MINOR CONTOURS

HATCH LEGEND

- CONCRETE DEMOLITION
- GRATING

SYMBOLS LEGEND

- FLOW DIRECTION

OUTLET WORKS - DEMOLITION PLAN VIEW

SCALE, FT: 0 10 20

Attention: 0 1" — If this scale bar does not measure 1" then drawing is not original scale.

NO.	DATE	ISSUE/REVISION	APP
0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Checked:	P. DREW
Drawn:	A. SAMPSON
Approved By:	B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

OUTLET WORKS - DEMOLITION PLAN

DWG. NO. C-04

SHEET NO. 6

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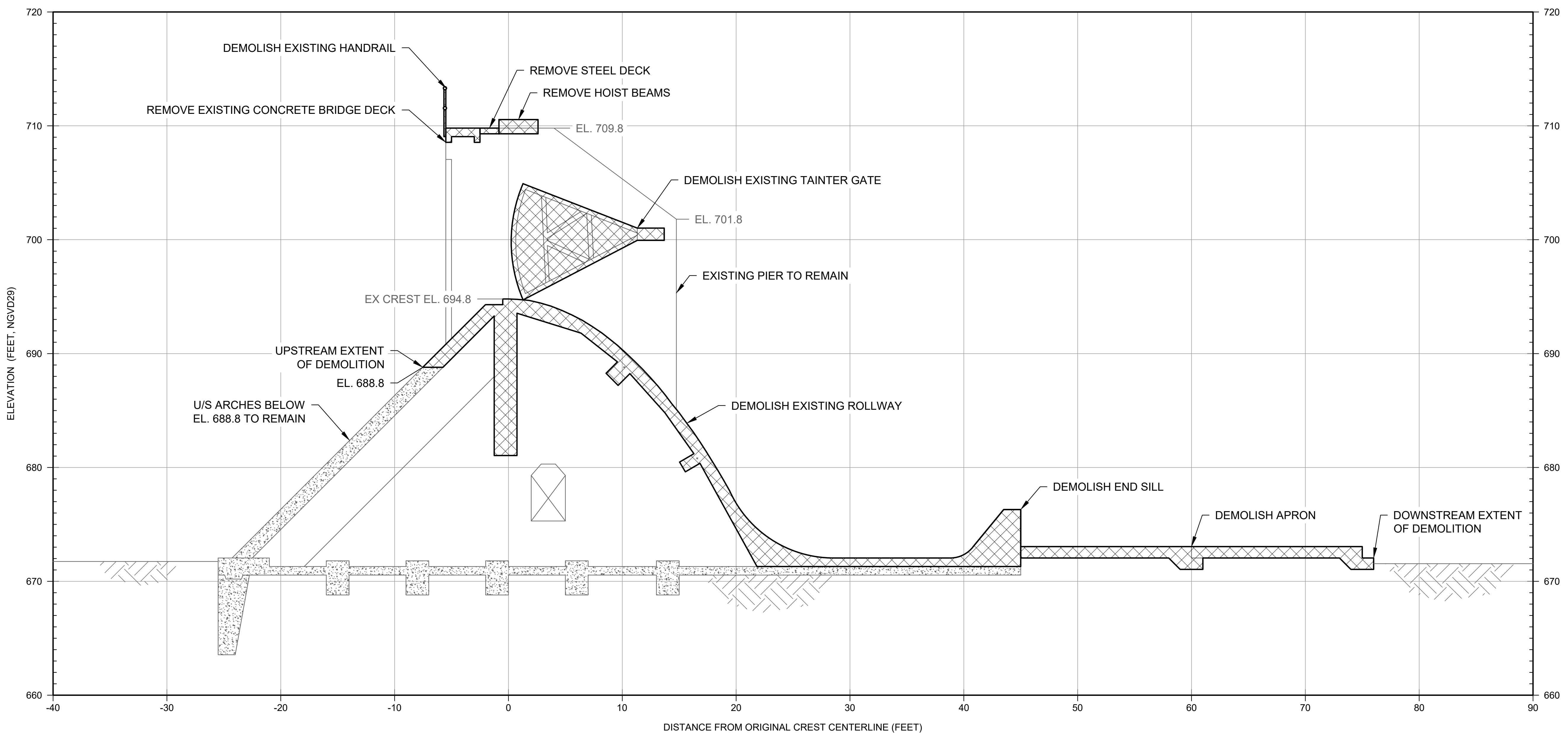

A
C-04
SECTION
SPILLWAY DEMOLITION

0 5 10
SCALE, FT

LINETYPE LEGEND

- WATER ELEVATION
- EXISTING FEATURE
- PROPOSED FEATURE

HATCH LEGEND

- CONCRETE DEMOLITION
- EXISTING CONCRETE
- EXISTING FOUNDATION

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

NO.	DATE	ISSUE/REVISION	APP
0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Drawn:	A. SAMPSON
Approved By:	B. WALTON

Four Lakes Task Force
FERC Project No. 10810
GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

OUTLET WORKS - DEMOLITION SECTION

DWG. NO. C-05
SHEET NO. 7

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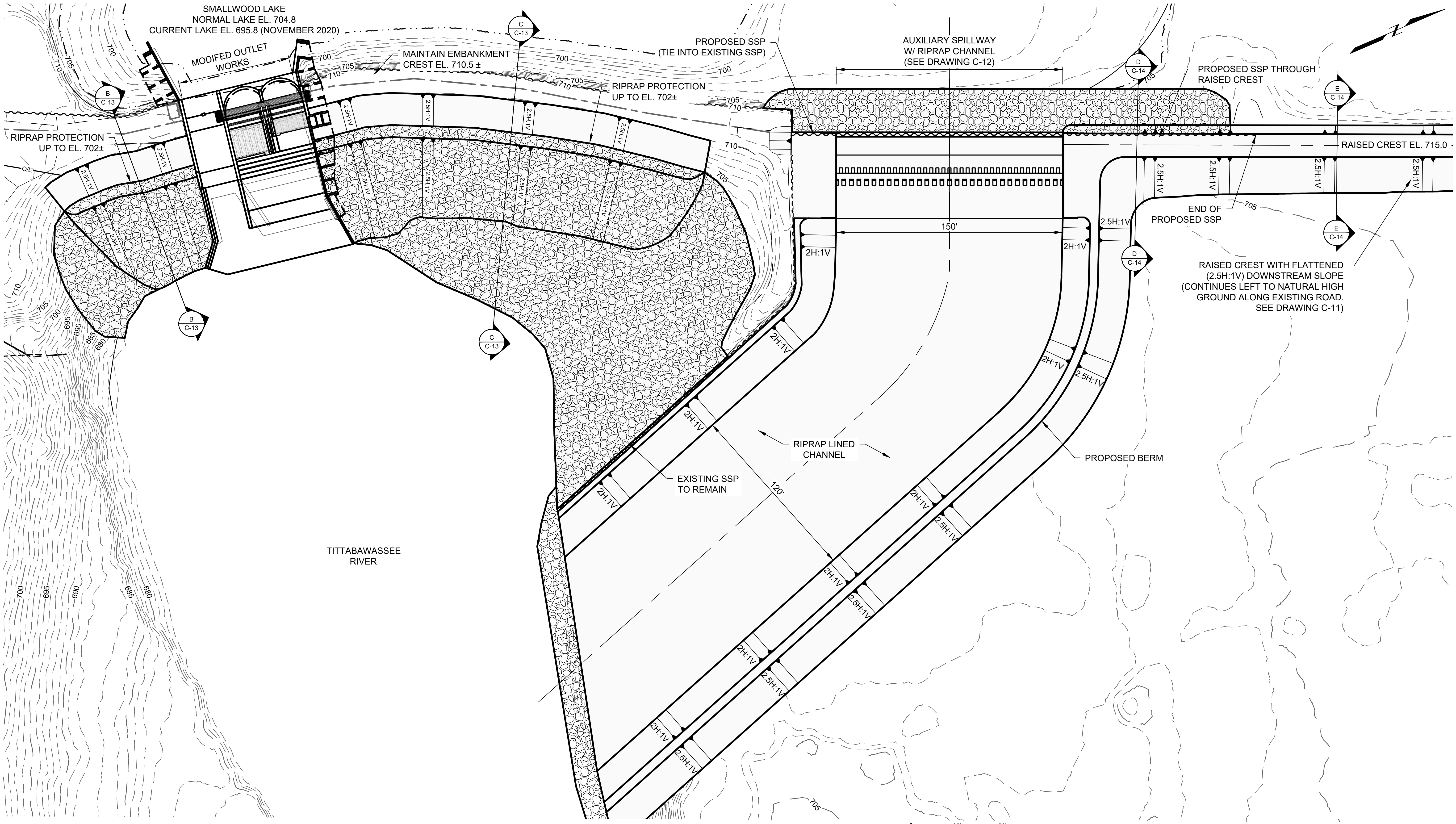

SITE PLAN - PROPOSED MODIFICATIONS

0 30' 60'
SCALE, FEET

0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-
NO.	DATE	ISSUE/REVISION	APP

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Gladwin County, Michigan

SITE PLAN - PROPOSED MODIFICATIONS

DWG. NO. C-06

SHEET NO. 8

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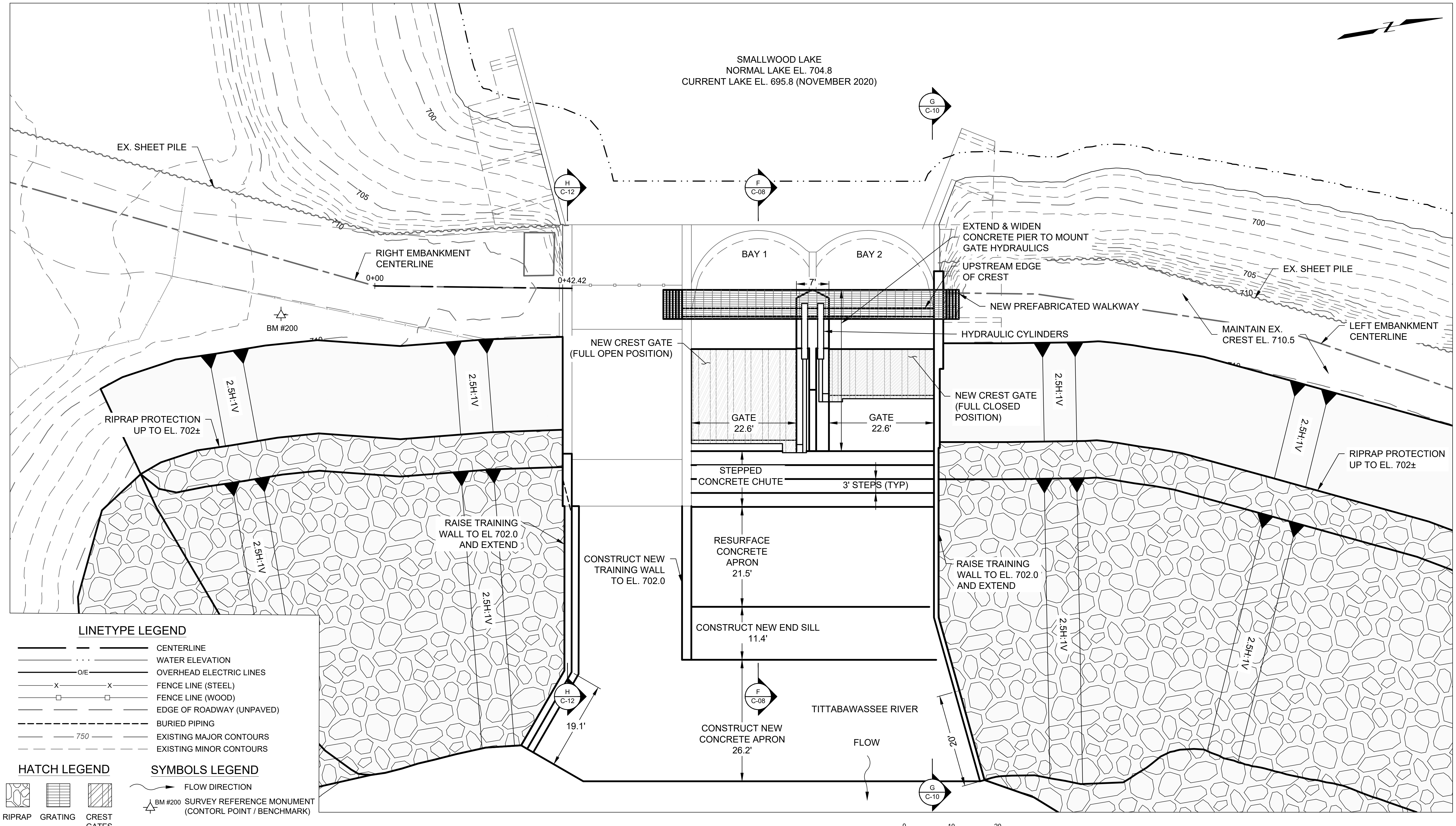

OUTLET WORKS - MODIFICATIONS PLAN VIEW

NO.	DATE	ISSUE/REVISION	APP
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Gladwin County, Michigan

OUTLET WORKS - MODIFICATIONS PLAN VIEW

DWG. NO. C-07
SHEET NO. 9

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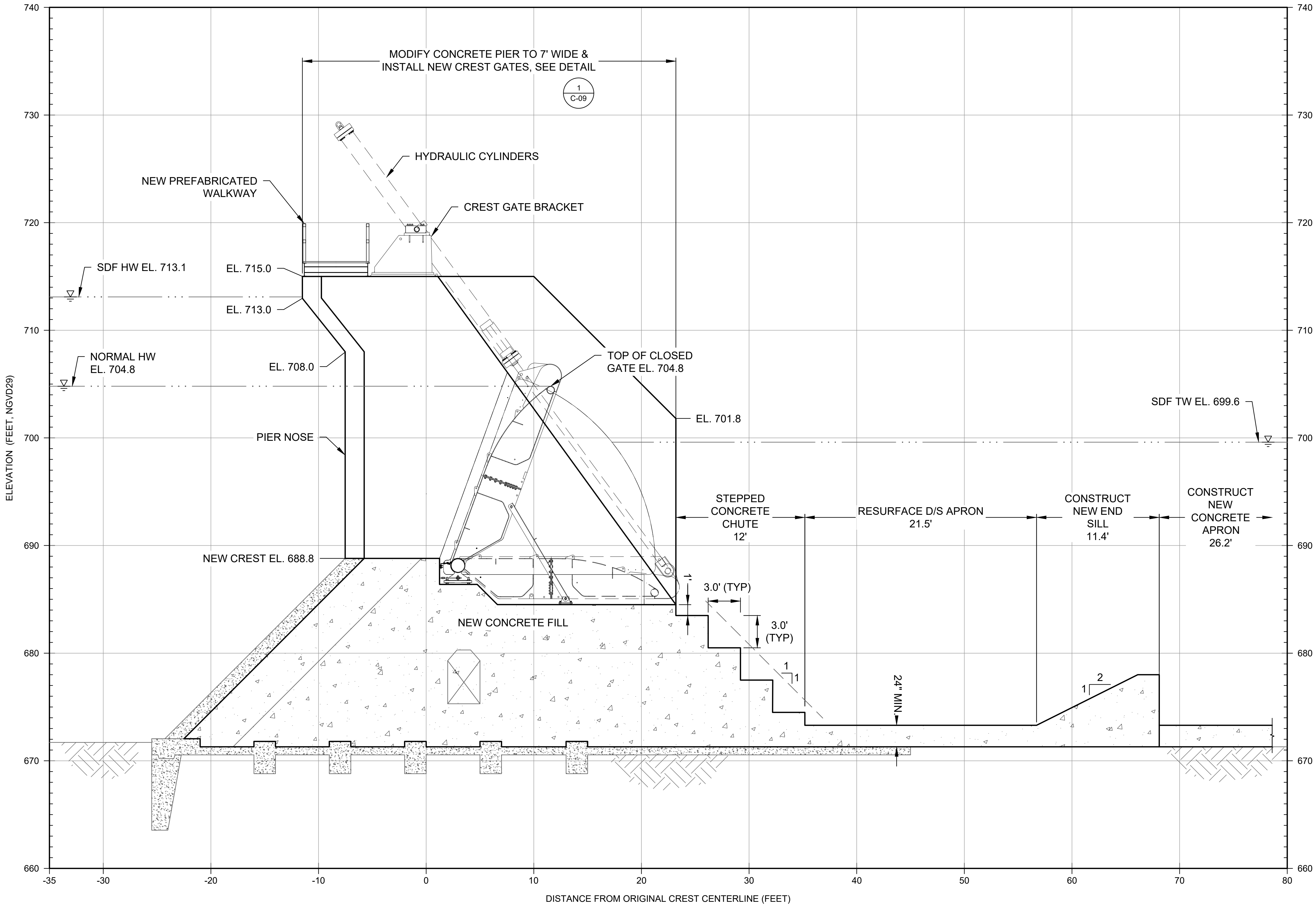

SECTION

F / C-07 — SPILLWAY BAY 1

0 5 10

LINETYPE LEGEND

- WATER ELEVATION
- EXISTING FEATURE
- PROPOSED FEATURE

HATCH LEGEND

- PROPOSED REINFORCED CONCRETE
- EXISTING CONCRETE
- EXISTING FOUNDATION

Attention:	NO.	DATE	ISSUE/REVISION	APP
0 1" If this scale bar does not measure 1" then drawing is not original scale.	0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Smallwood Dam
Gladwin County, Michigan

PRIMARY SPILLWAY - MODIFICATIONS SECTION

DWG. NO. C-08

SHEET NO. 10

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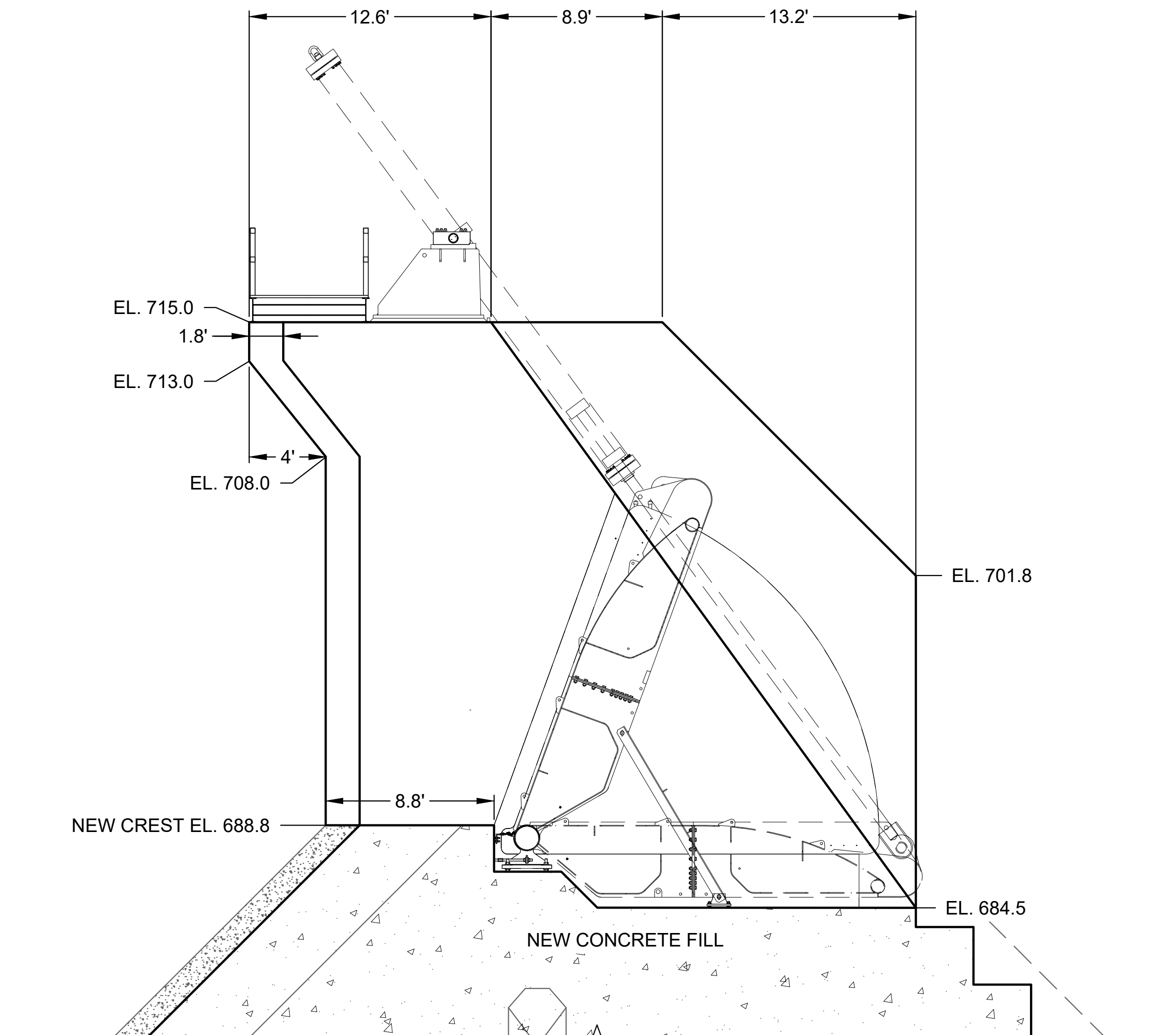
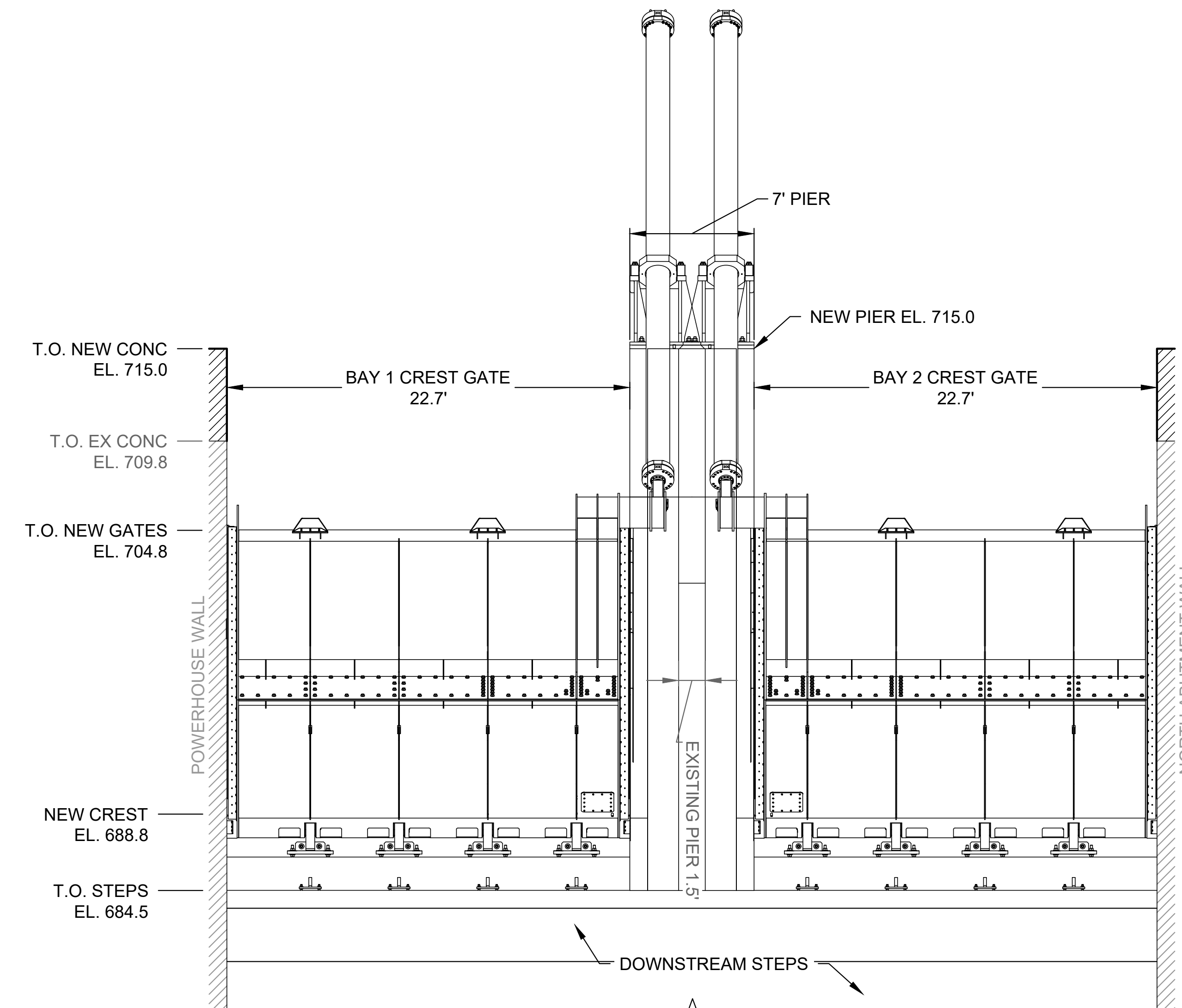


SECTION



DOWNSTREAM ELEVATION
(LOOKING UPSTREAM)

1 / C-08 DETAIL
PIER-MOUNTED CREST GATE

0 5 10

Attention:
0 1"
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Gladwin County, Michigan

PRIMARY SPILLWAY - CREST GATE DETAILS

DWG. NO. C-09

SHEET NO. 11

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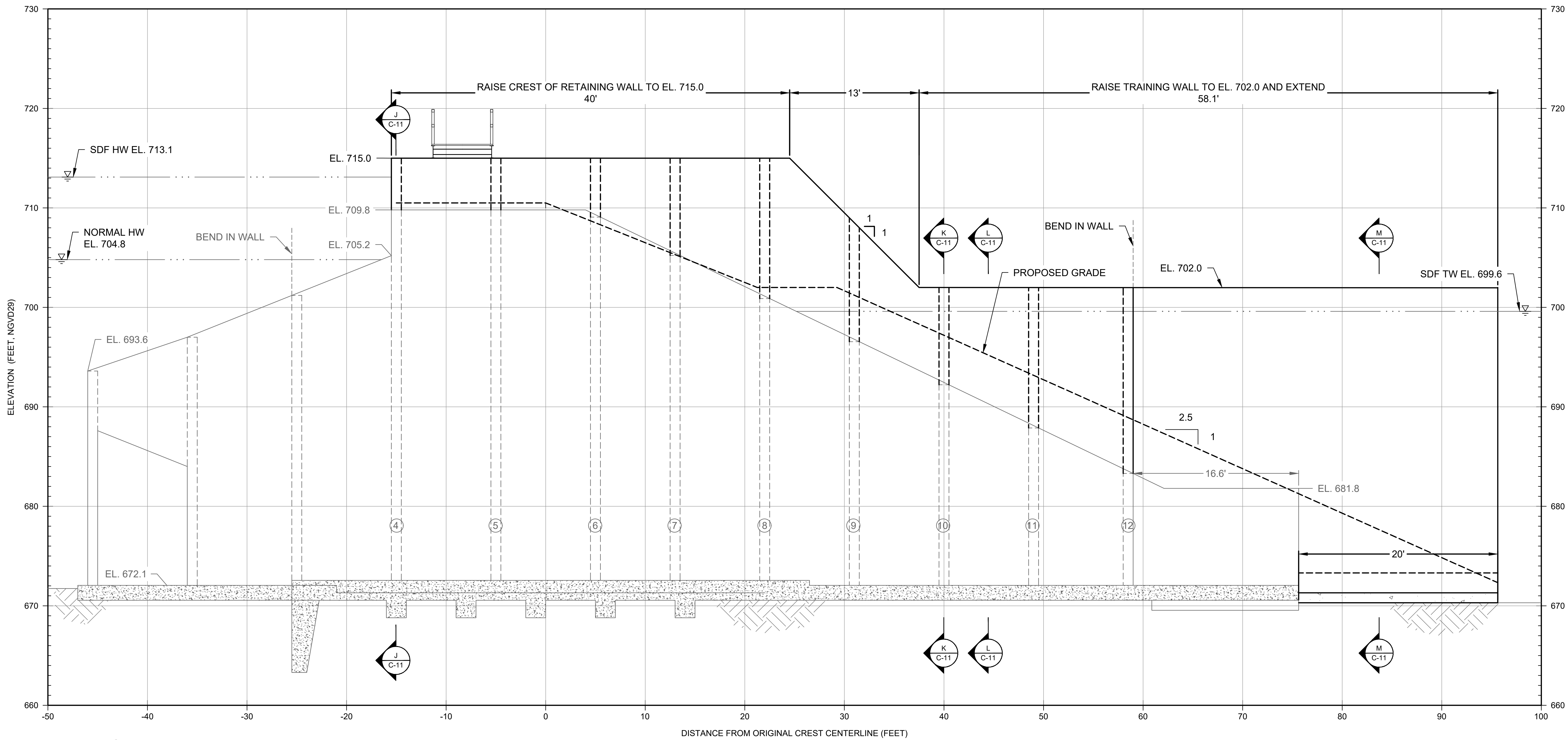

G
C-07
SECTION
NORTH TRAINING WALL

0 5 10

LINETYPE LEGEND

WATER ELEVATION
EXISTING FEATURE
PROPOSED FEATURE

HATCH LEGEND

EXISTING CONCRETE
EXISTING FOUNDATION

SYMBOL LEGEND

(1) BUTTRESS NUMBER

Attention:
0 1"
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Smallwood Dam
Gladwin County, Michigan

NORTH TRAINING WALL - MODIFICATIONS SECTION

DWG. NO. C-10
SHEET NO. 12

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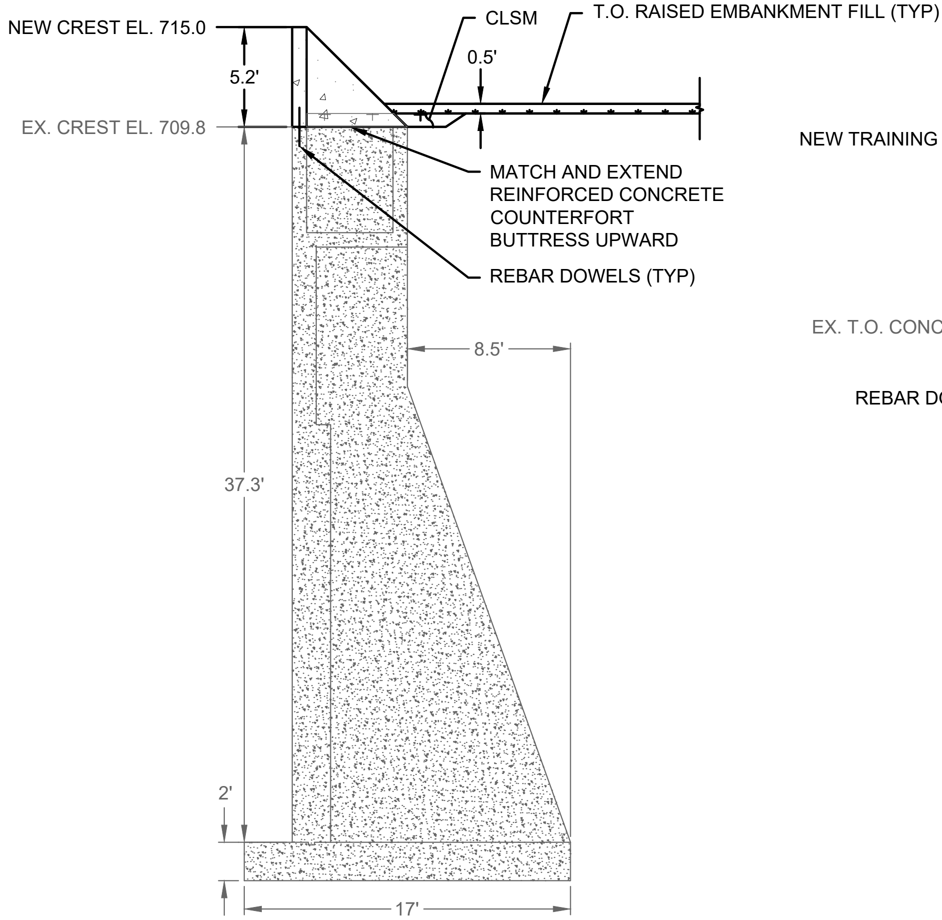
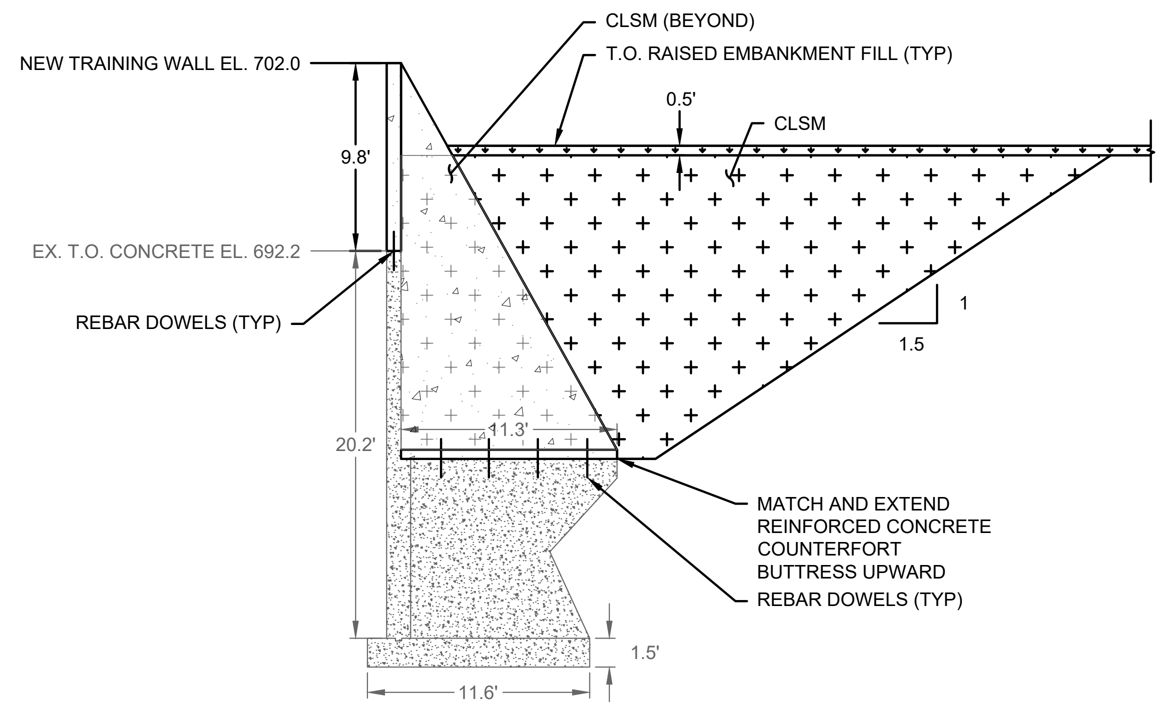


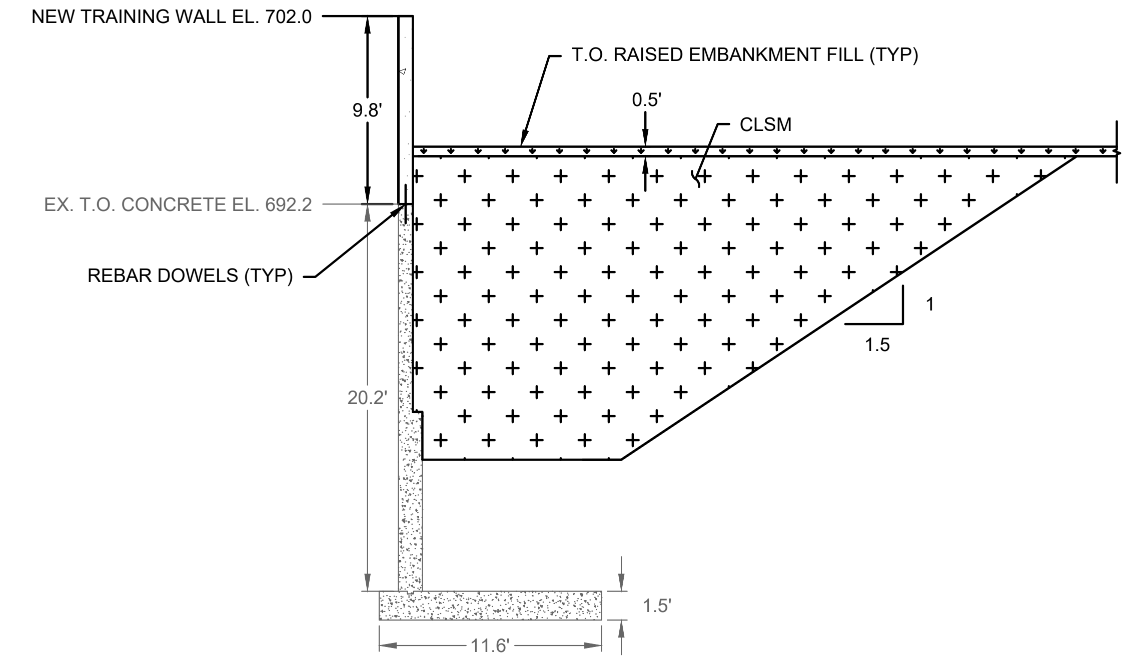
J
C-10
SECTION
BUTTRESS 4

0 5 10



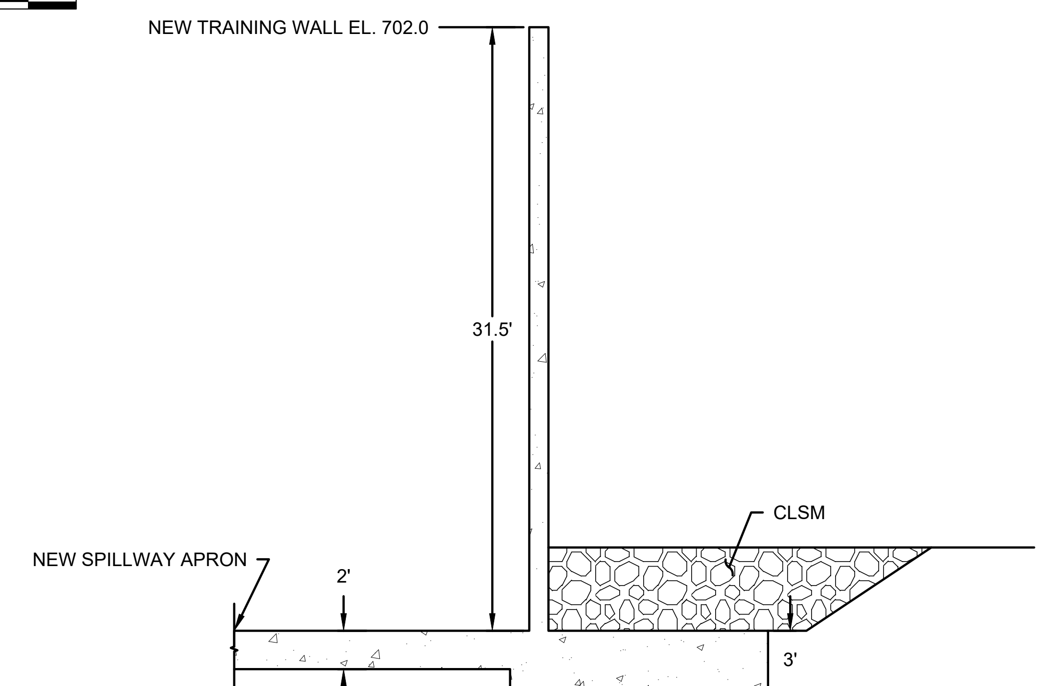
K
C-10
SECTION
BUTTRESS 10

0 5 10



L
C-10
SECTION
BETWEEN BUTTRESSES 10 & 11

0 5 10



M
C-11
SECTION
NEW WALL EXTENSION

0 5 10

LINETYPE LEGEND

EXISTING FEATURE
PROPOSED FEATURE

HATCH LEGEND

PROPOSED REINFORCED CONCRETE
EXISTING CONCRETE
RIPRAP
CLSM
GRASS

Attention:
0 1"
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Drawn: A. SAMPSON
Approved By: B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

NORTH TRAINING WALL - MODIFICATIONS DETAILS

DWG. NO.
C-11

SHEET NO.
13

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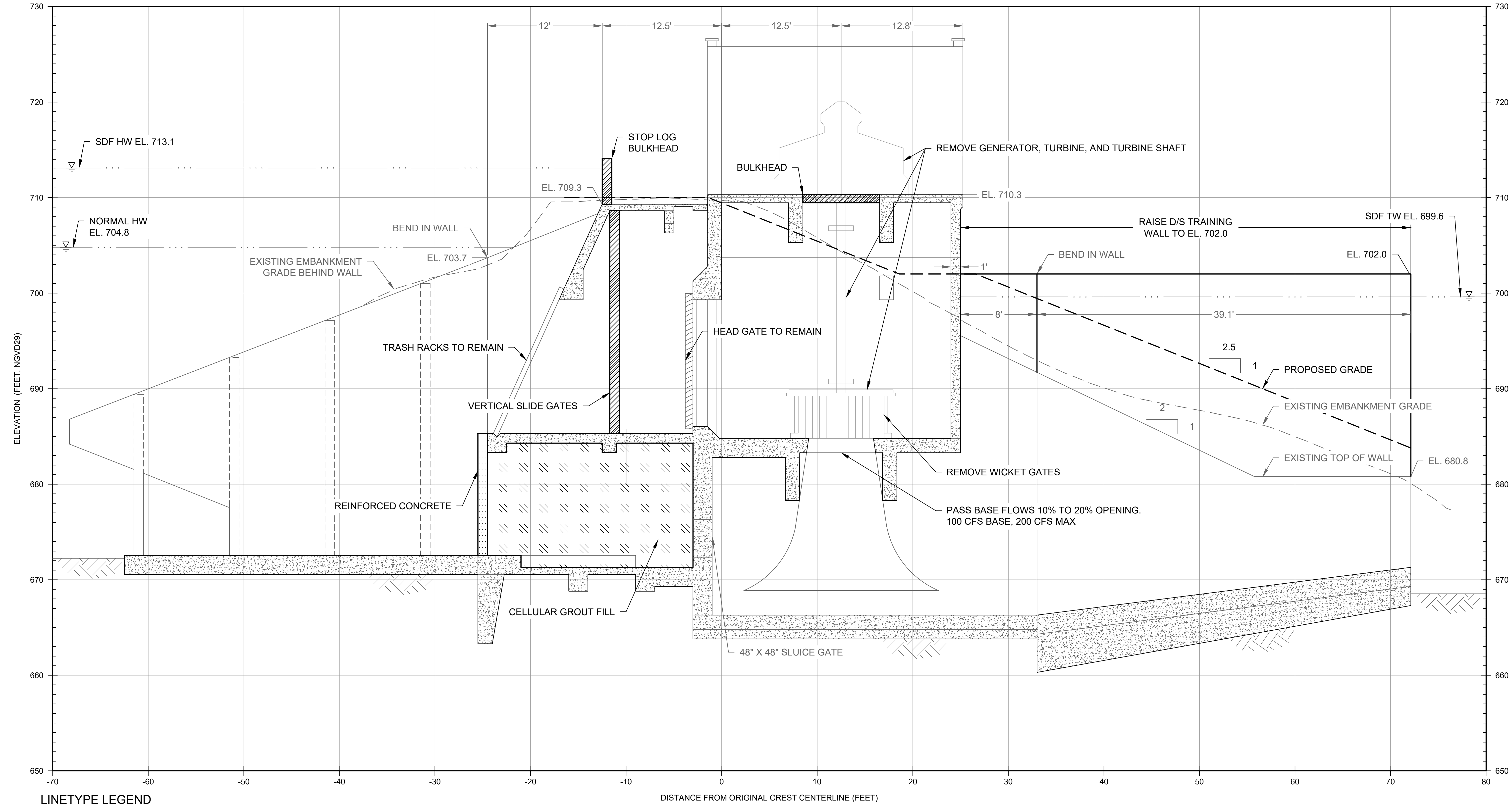

LINETYPE LEGEND

- WATER ELEVATION
- EXISTING FEATURE
- PROPOSED FEATURE

H / C-07 SECTION
POWERHOUSE

0 5 10

HATCH LEGEND

EXISTING CONCRETE | EXISTING FOUNDATION | REINFORCED CONCRETE CAP | CELLULAR GROUT FILL | TIMBER

Attention:
0 1"
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0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Smallwood Dam
Gladwin County, Michigan

POWERHOUSE - MODIFICATIONS SECTION

DWG. NO. C-12

SHEET NO. 14

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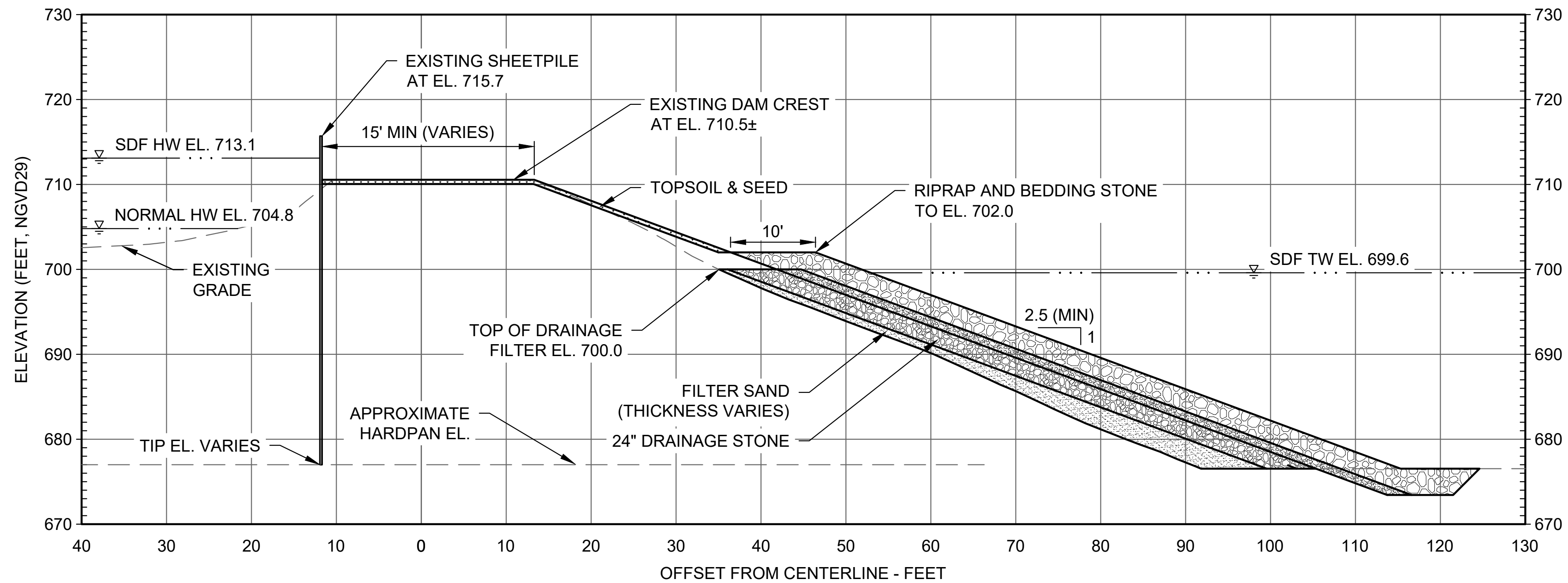
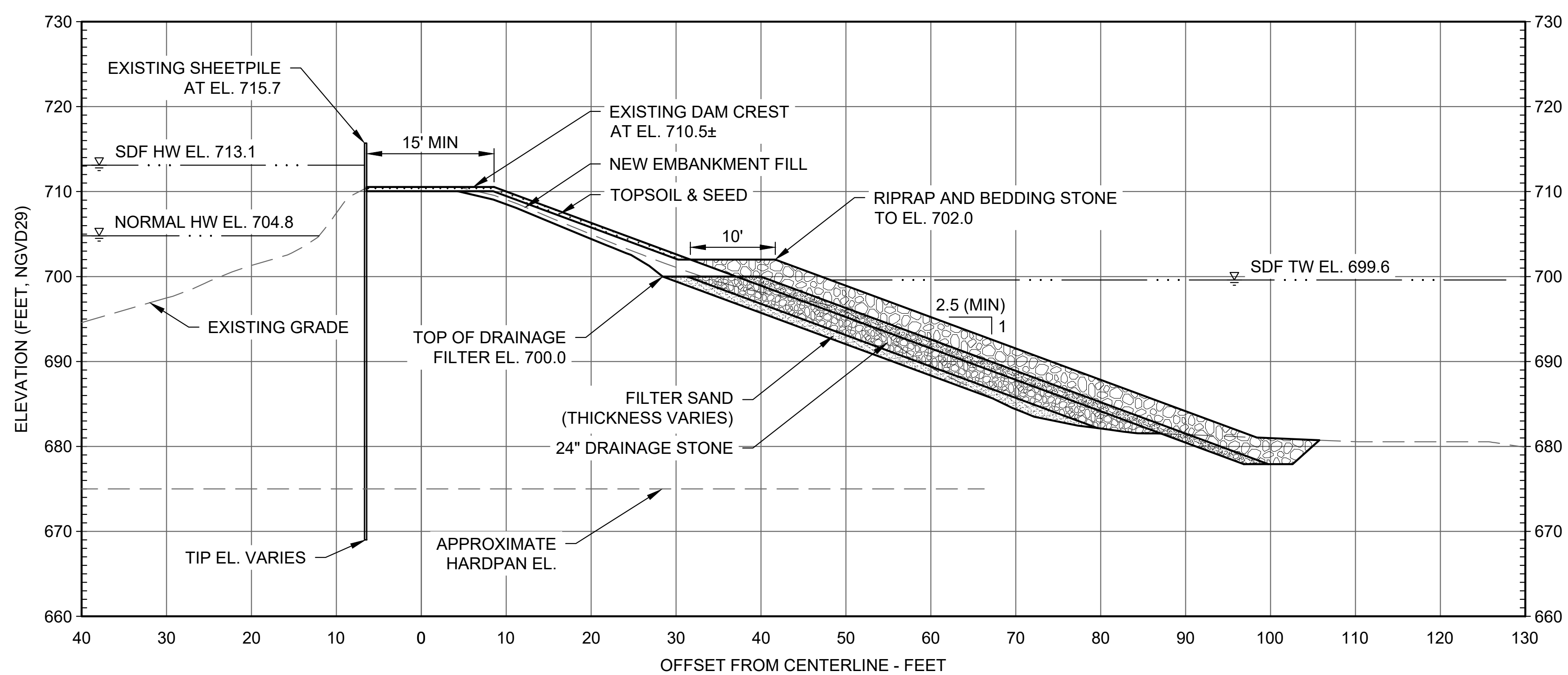


B SECTION
C-06 RIGHT EMBANKMENT

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION



C SECTION
C-06 LEFT EMBANKMENT

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION

Attention:
0 1"
If this scale bar does not measure 1" then drawing is not original scale.

NO.	DATE	ISSUE/REVISION	APP
0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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Smallwood Dam
Gladwin County, Michigan

EMBANKMENTS - MODIFICATIONS
SECTIONS (SHEET 1 OF 2)

DWG. NO. C-13

SHEET NO. 15

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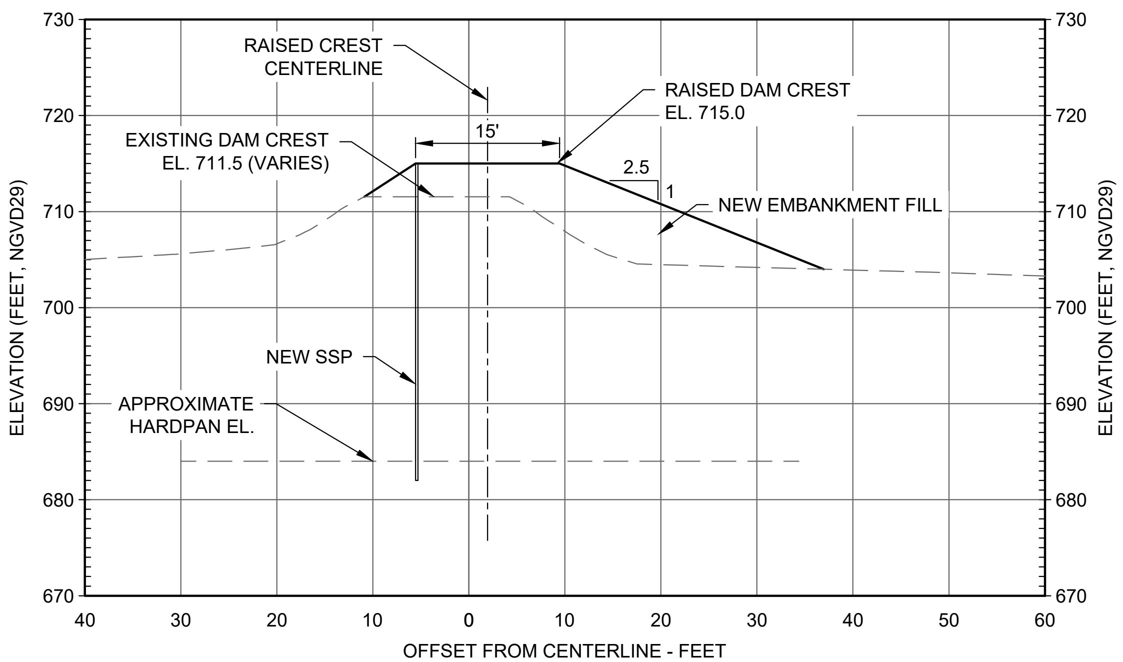
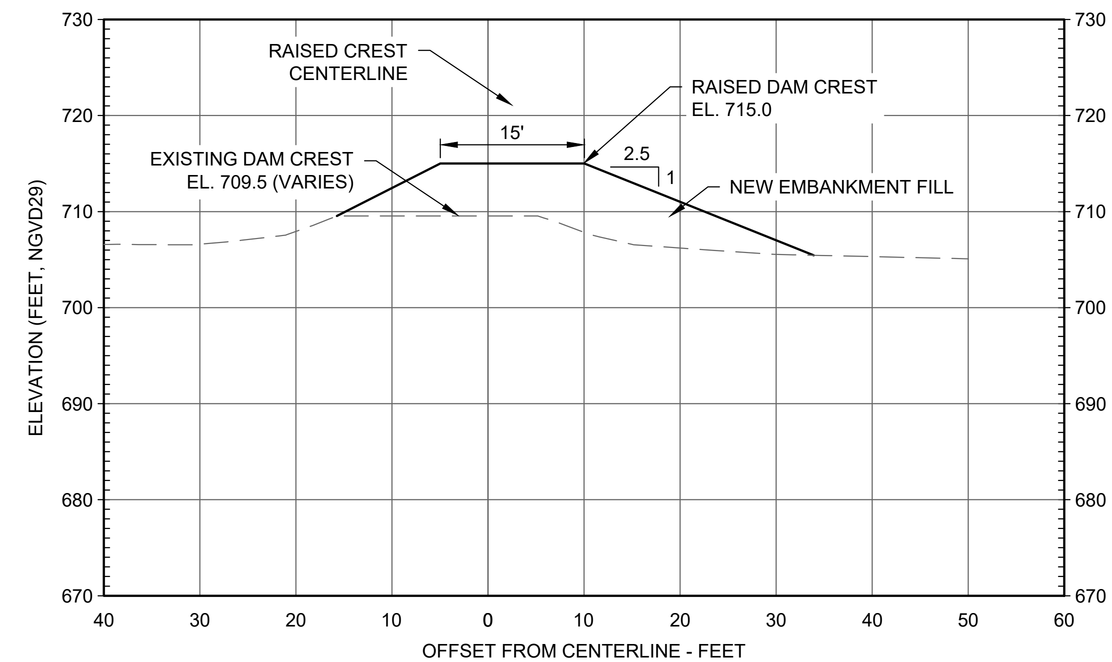


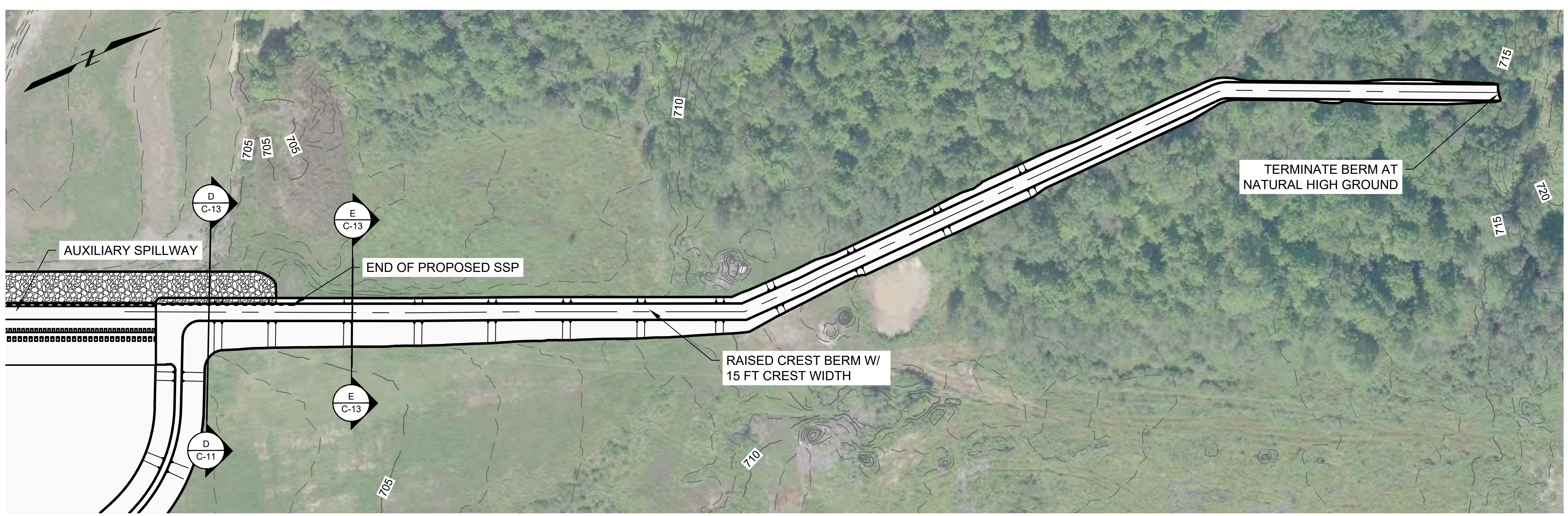
D SECTION
C-06 C-14 LEFT EMBANKMENT W/ SSP CUTOFF

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION



E SECTION
C-06 C-14 LEFT EMBANKMENT BERM DETAIL

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION



LEFT EMBANKMENT PLAN

0 60' 120'
SCALE, FEET

Attention:	NO.	DATE	ISSUE/REVISION	APP
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Smallwood Dam
Gladwin County, Michigan

EMBANKMENTS - MODIFICATIONS
SECTIONS (SHEET 2 OF 2)

DWG. NO. C-14

SHEET NO. 16

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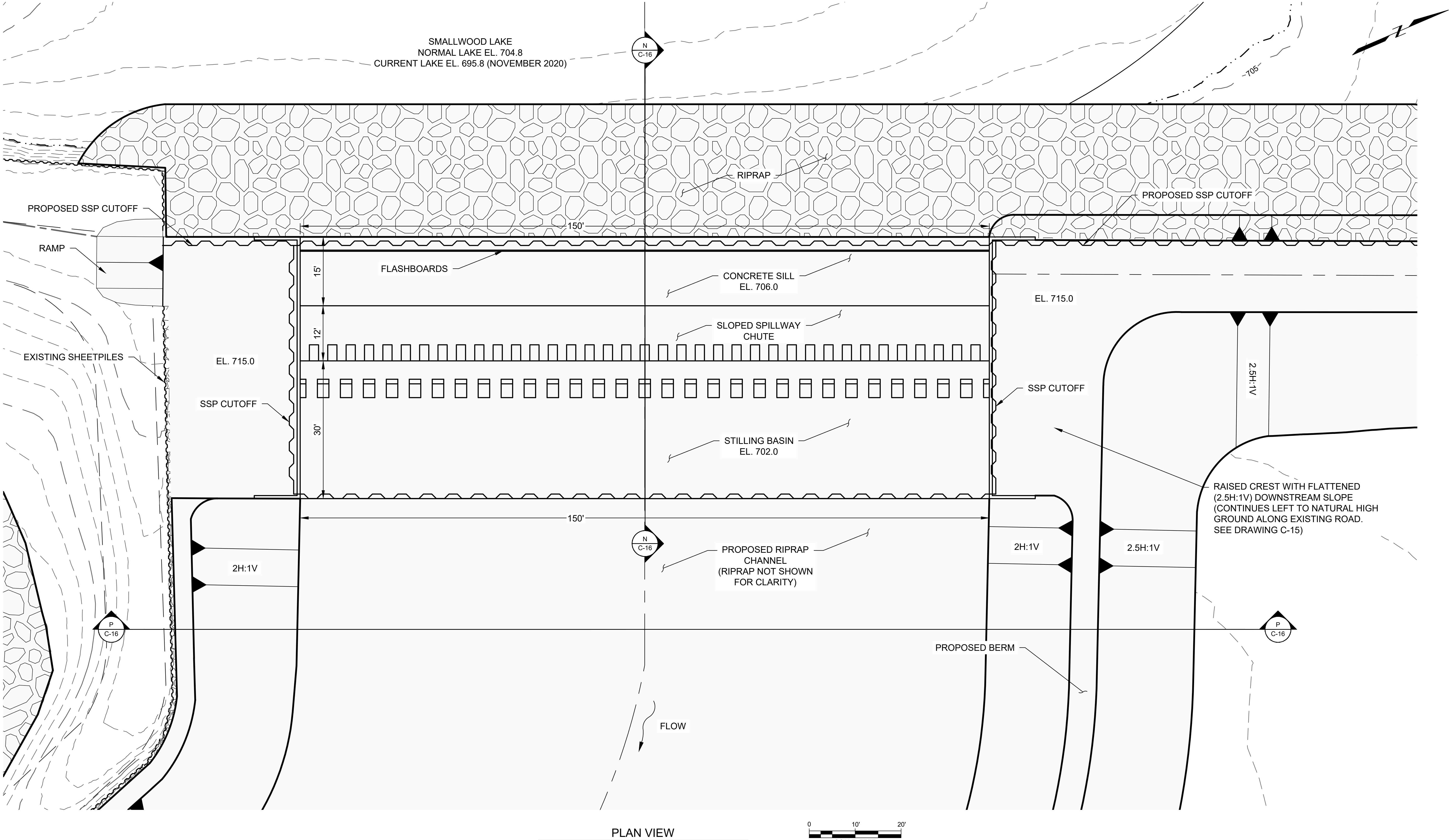

PLAN VIEW

PROPOSED AUXILIARY SPILLWAY

0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-
NO.	DATE	ISSUE/REVISION	APP

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Smallwood Dam
Gladwin County, Michigan

AUXILIARY SPILLWAY -
PROPOSED PLAN VIEW

DWG. NO. C-15

SHEET NO. 17

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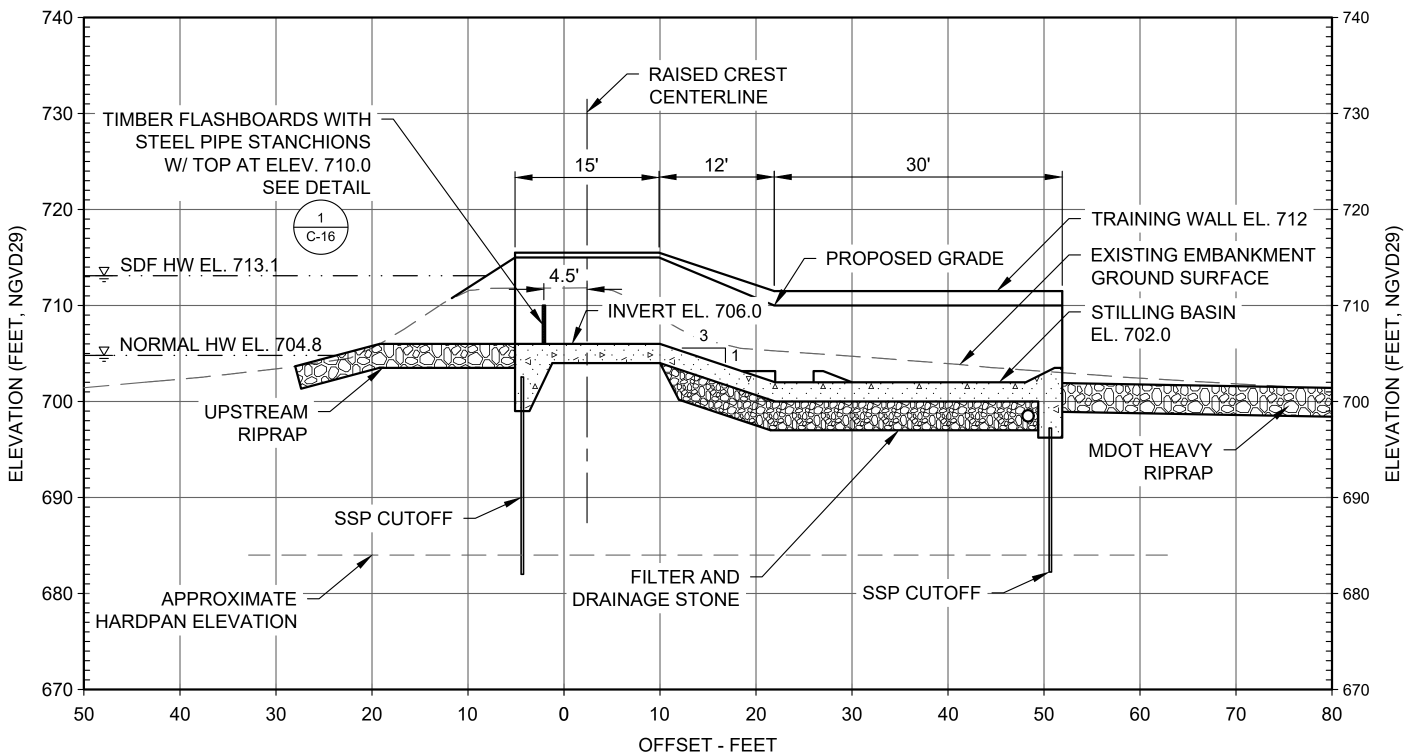
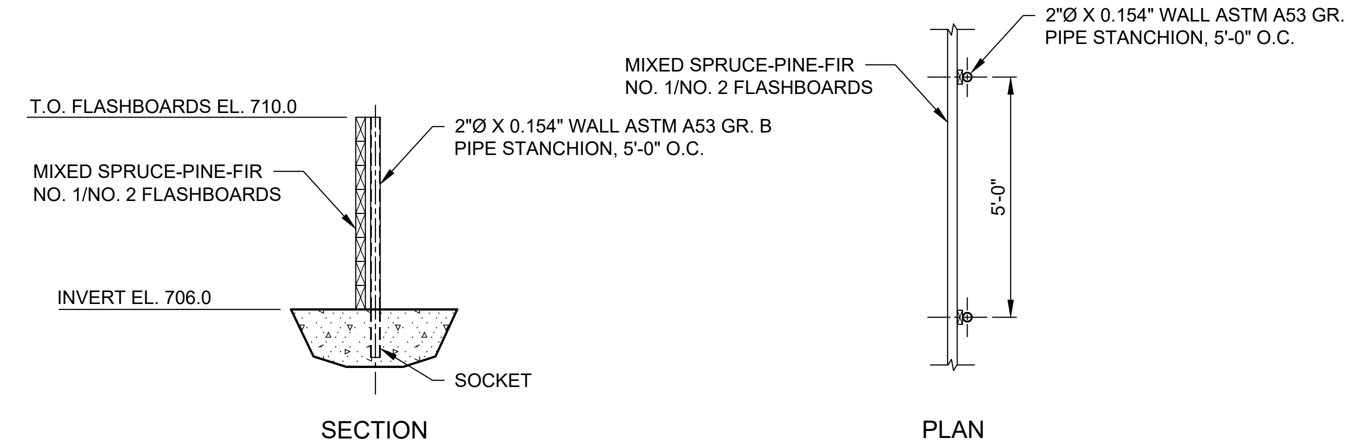


N
C-15

SECTION
PROPOSED SPILLWAY

HORIZONTAL SCALE, FEET
0 10 20

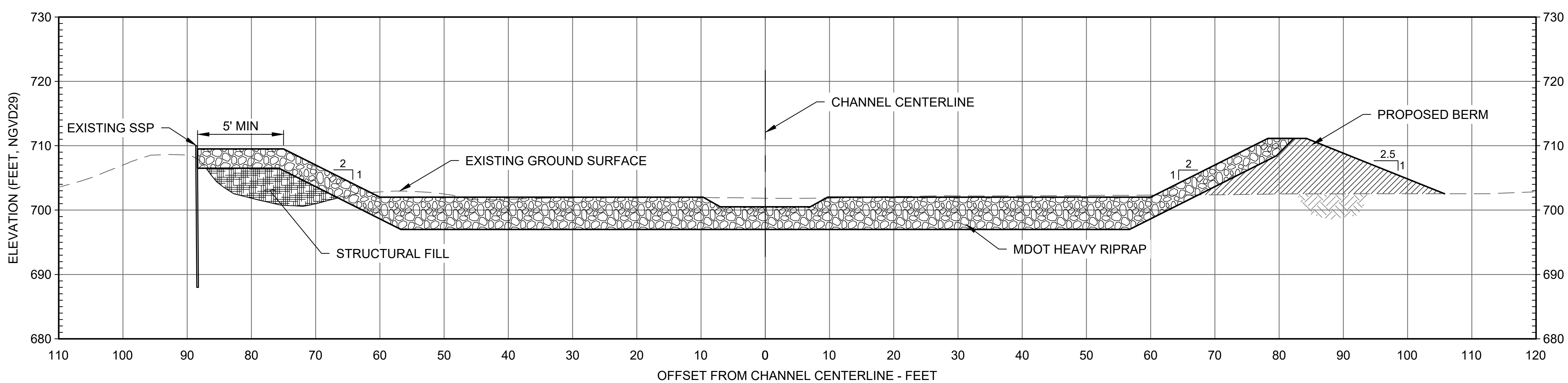
0 10 20
VERTICAL SCALE, FEET
NO VERTICAL EXAGGERATION



1
C-16

DETAIL

0 2' 4'
SCALE, FEET



P
C-15

SECTION
PROPOSED SPILLWAY CHANNEL

HORIZONTAL SCALE, FEET
0 10 20

0 10 20
VERTICAL SCALE, FEET
NO VERTICAL EXAGGERATION

Attention:
0 1"
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0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-

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GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

AUXILIARY SPILLWAY - PROPOSED SPILLWAY & CHANNEL CROSS SECTIONS, SPILLWAY DETAILS

DWG. NO.
C-16

SHEET NO.
18

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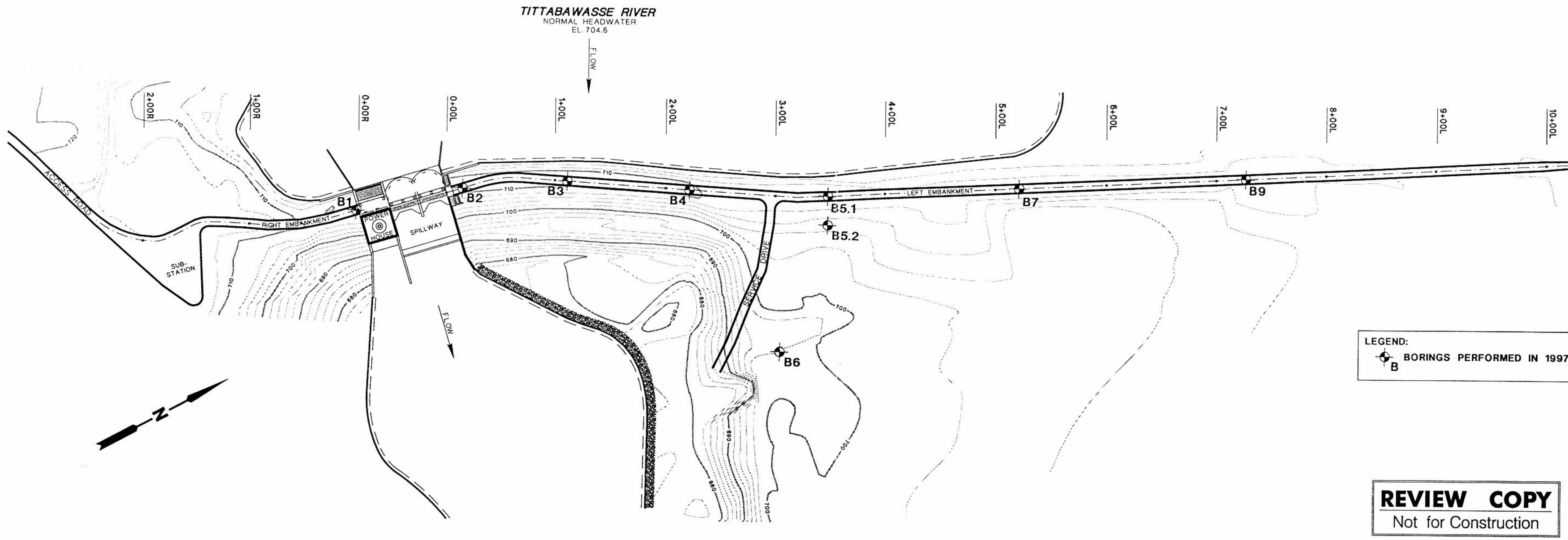
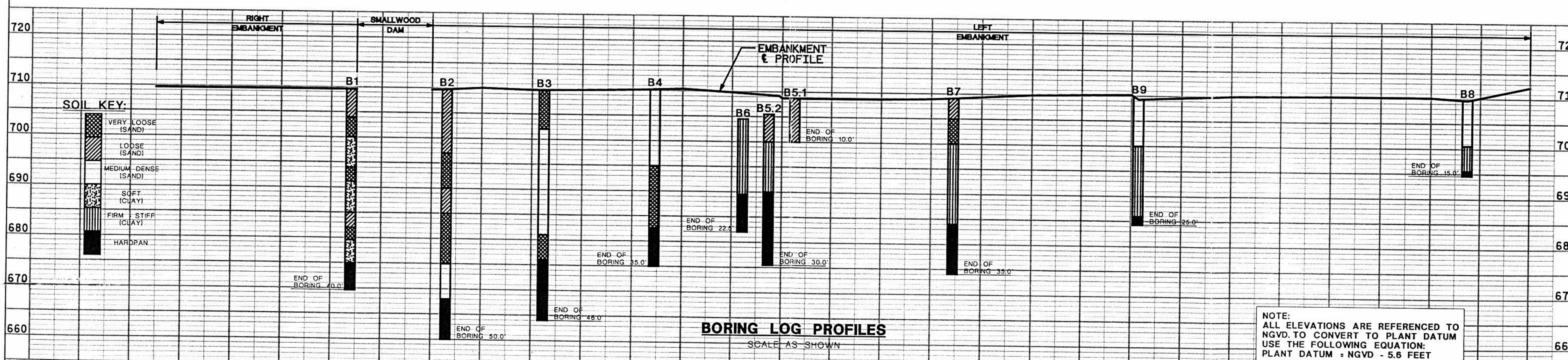
Appendix D

Summary of Available Existing Subsurface Information



BORING LOCATION PLAN

50' 25' 0 50' 100'



BORING LOG PROFILES

SCALE: AS SHOWN

NOTE:
ALL ELEVATIONS ARE REFERENCED TO NGVD. TO CONVERT TO PLANT DATUM USE THE FOLLOWING EQUATION:
PLANT DATUM = NGVD - 5.6 FEET

NO.	DATE	REVISION	INITIAL	NO.	DATE	REVISION	INITIAL
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-

WOLVERINE POWER CORPORATION
SMALLWOOD HYDRO PROJECT
DAM MODIFICATIONS FOR SPILLWAY UPGRADE

Soil Boring Plan and Profile

SCALE: AS SHOWN
DATE: MARCH 1998

DESIGNED -
DRAWN DMS
SURVEYED -
CHECKED -
APPROVED -

MEAD & HUNT
ENGINEERS ARCHITECTS SCIENTISTS PLANNERS
MEAD & HUNT INC.
6501 Watts Road, Suite 101
Madison, Wisconsin 53719-2700
Phone: 608-273-6380
Fax: 608-273-6391

A8721-02
JOB NO. W206-97B
REV. -

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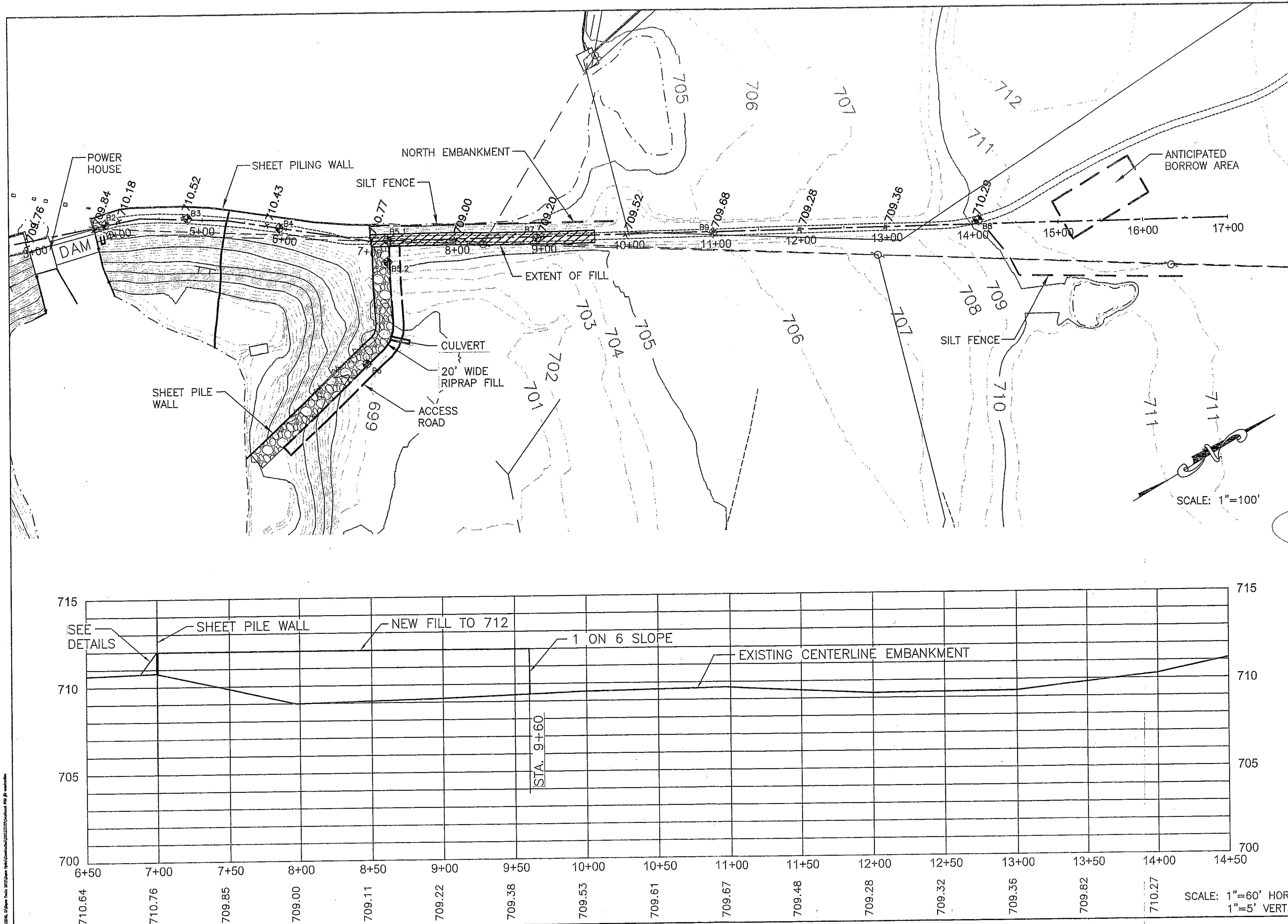

BOYCE HYDRO, LLC

Lee W. Mueller, Architect, Co-Member Manager

Frank O. Christie, P.E. General Manager

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EDENVILLE, MI 48620
(989) 689-3161

DESIGN ENGINEER

FRANK O. CHRISTIE, P.E.
CHRISTIE ENGINEERING
PO BOX 297
ONEKAMA, MI 49675
(231) 889-3262

LICENSE STAMP

REVISIONS

NO.	DATE	BY
DESCRIPTION		
0	02/09/2011	MDF
DRAWING ORIGINATION		
1	07/22/2013	MDF
REVISED TO PLAN & PROFILE		
2	07/02/2014	MDF
ADDED RIPRAP FILL		
3	08/22/2014	MGM
CHANGE BORROW AREA		
4	11/04/2014	MDF
FILL AND EXCAVATION AREAS		
5	04/21/2015	MGM
ADD SILT FENCING		
6	06/08/2015	MGM
RELEASED FOR CONSTRUCTION		
7	08/26/2016	MGM
AS BUILT CONDITION		

THIS DRAWING IS SCALED TO PRINT ON 11" x 17" PAPER

PROJECT

FERC PROJECT No. 10810
SMALLWOOD HYDRO PLANT
MODIFICATIONS FOR PFM #8

DRAWING TITLE

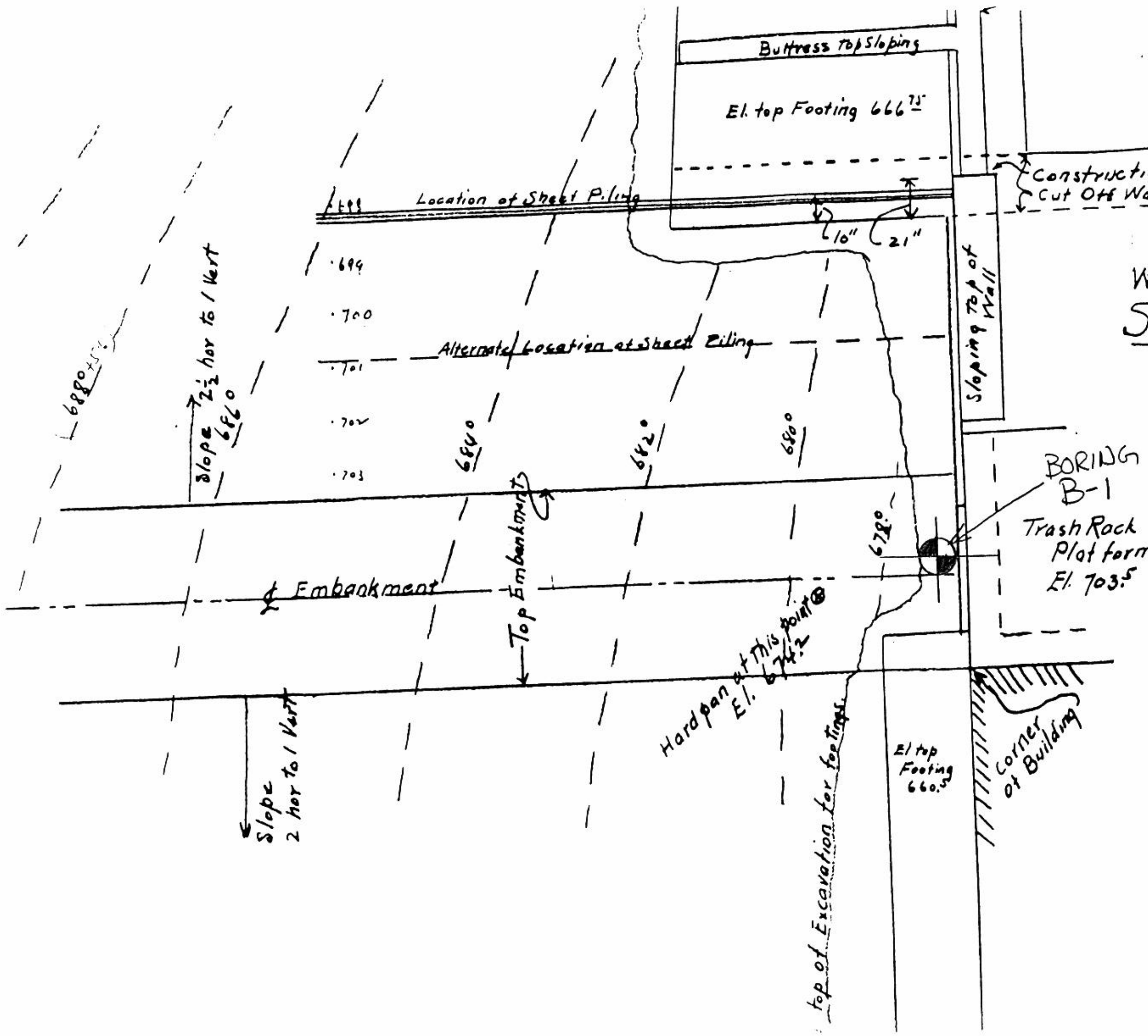
SITE PLAN

FILE	Smallwood PFM #8 construction
SCALE	AS NOTED
DRAWN	MDF
CHECKED	FOC
APPROVED	
REV. DATE	8/23/2016

DRAWING NO.

SITE #114, PROJECT #02

0.1.00



F. I. Wixom - Receiver
Wolverine Power Company
SMALLWOOD PLANT

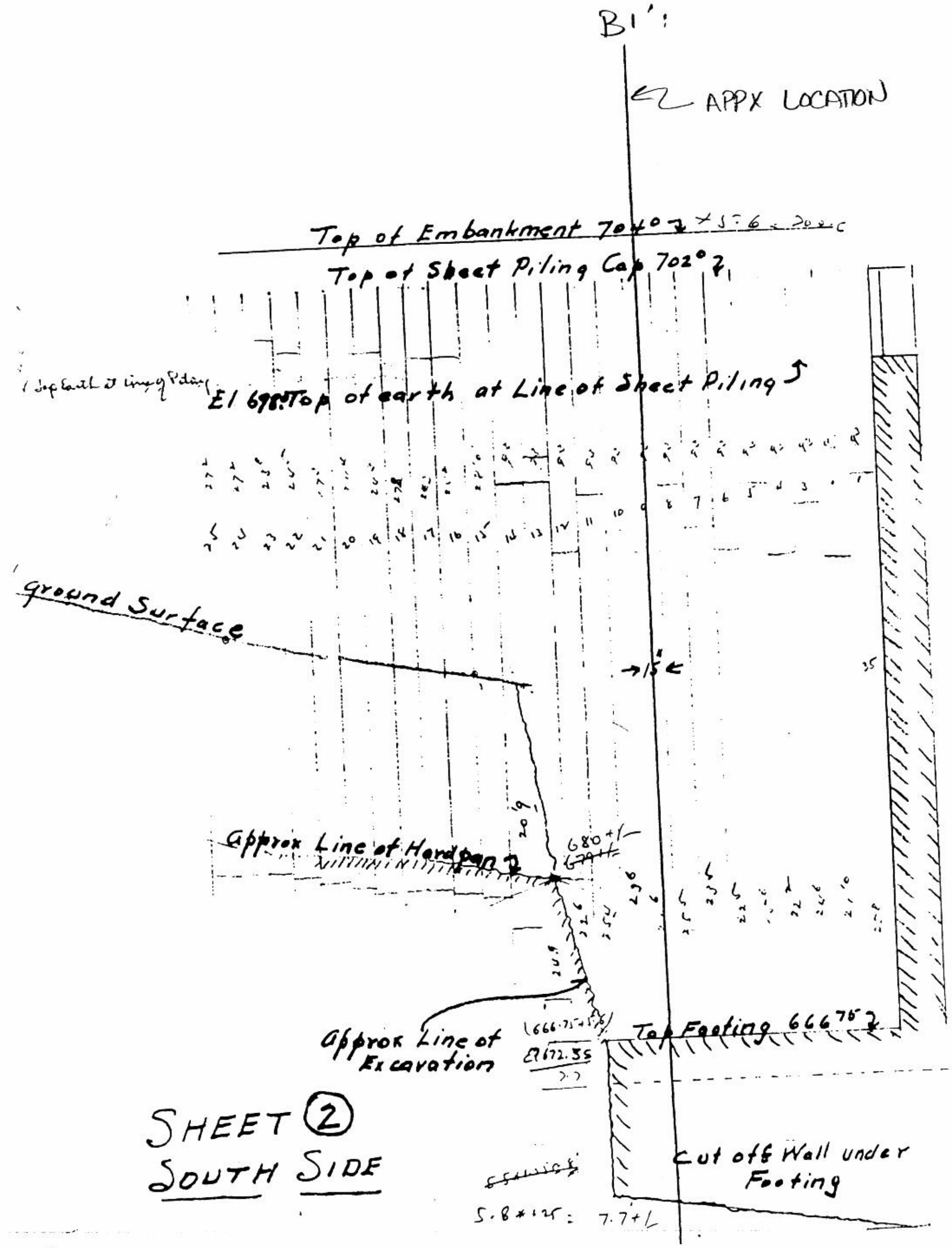
Sheet Piling Location
South Side

Scale ¼" = 1'

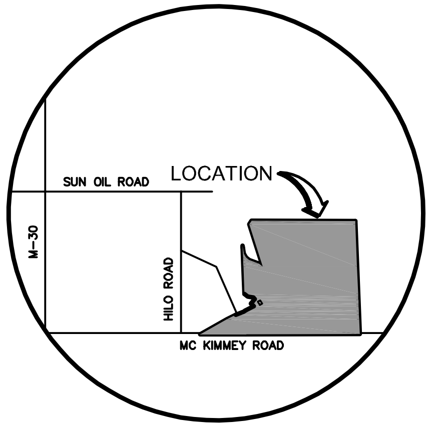
HOLLAND, ACKERMAN & HOLLAND
CONSULTING ENGINEERS
106 E. LIBERTY ST.
ANN ARBOR, MICHIGAN

SHEET (1)
OF 4 Sheets

NOTE: BORING B-1 TAKEN IN CUT FOR POWERHOUSE EXCAVATION. ALSO, EXISTING SHEET PILE EXTENDS TO LEFT BEYOND THE CUT LINE INTO BETTER SOILS. THEREFORE ANALYSIS SHOULD BE PERFORMED W/ AVG. SOIL PROPERTIES FROM OTHER BORINGS.



MONITOR WELL PLAN



PART OF SECTION 15, T.18N.-R.1E., HAY TOWNSHIP,
GLADWIN COUNTY, MICHIGAN

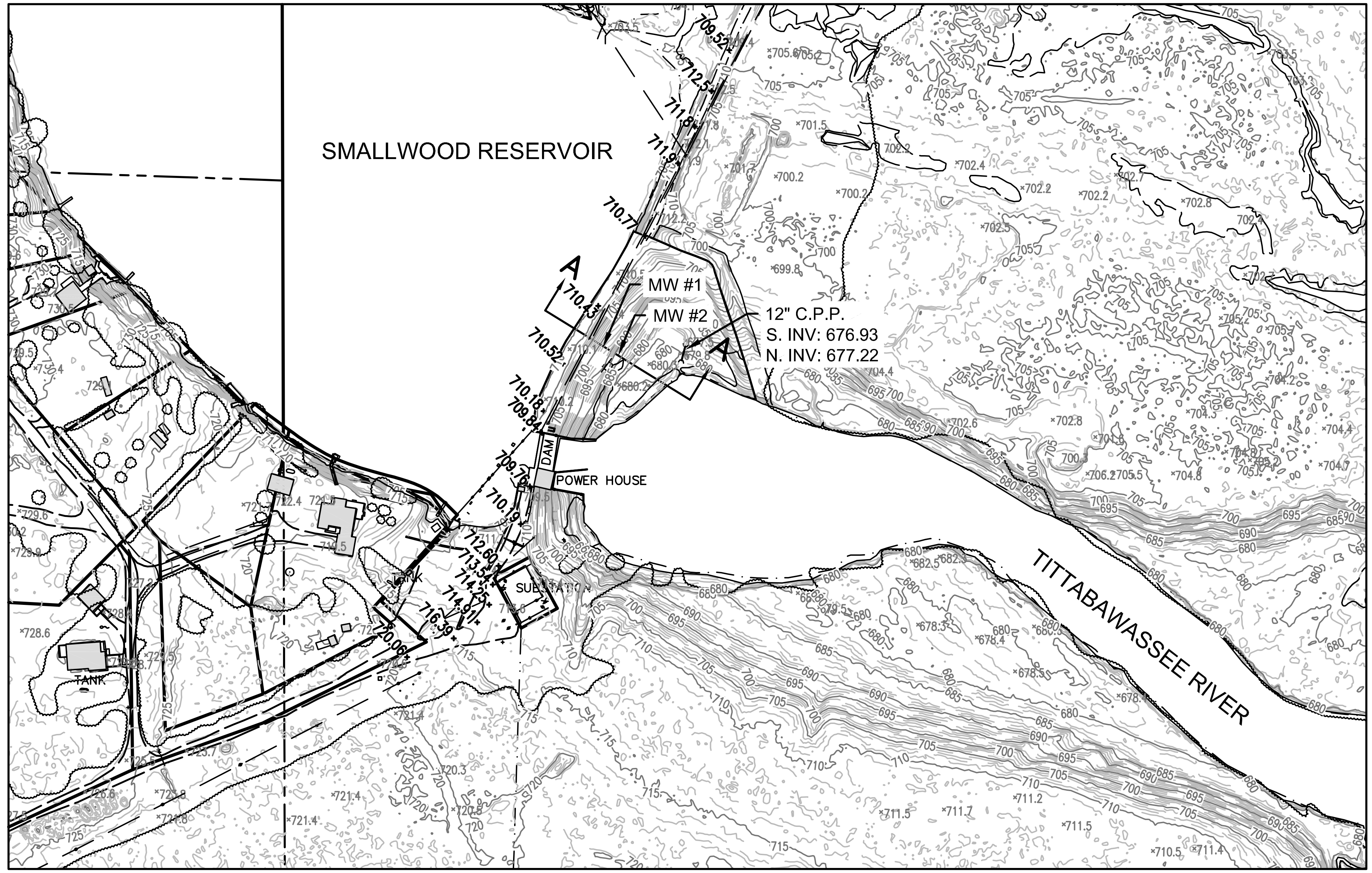
LOCATION MAP

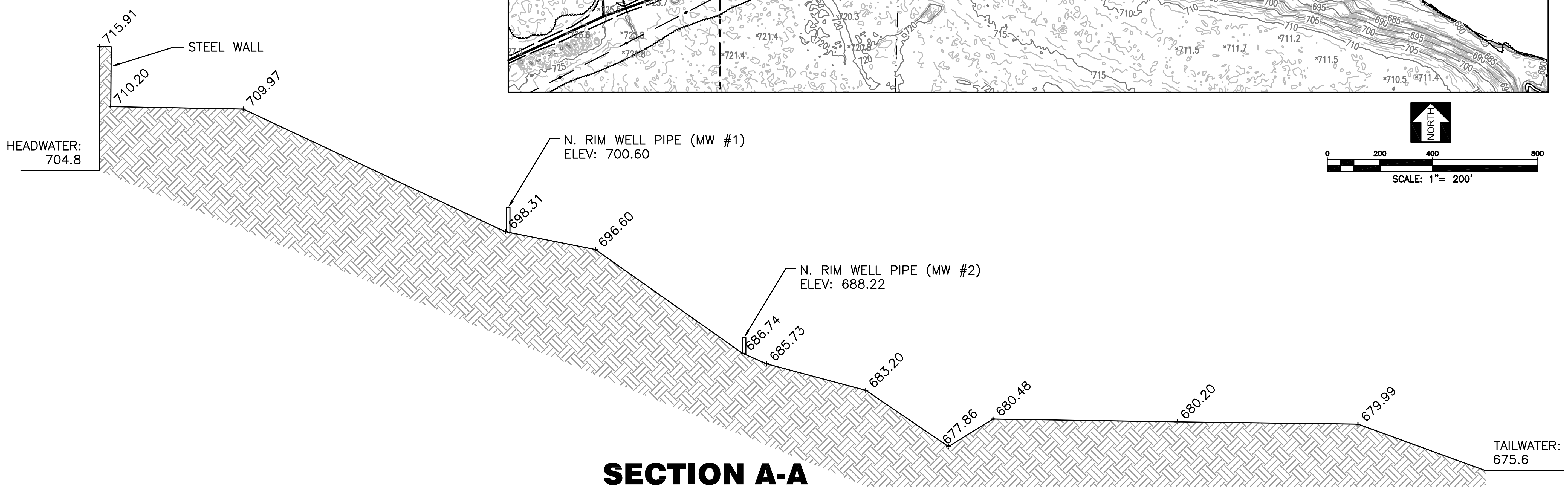
(NO SCALE)

LEGEND:

- O/W — OVERHEAD UTILITY LINE
- UTILITY POLE
- ANTENNA / TOWER
- BM#1 — BENCHMARK LOCATION
- MONITOR WELL
- CATCH BASIN

WELL	TOP OF PIPE	GROUND ELEV.
MW#1	700.6	698.31
MW#2	688.22	686.74





SECTION A-A

SCALE: 1" = 10'

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BOYCE HYDRO, LLC

Lee W. Mueller, Architect
Co-Member Manager

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EDENVILLE, MI 48620
(989) 689-3161

LICENSE STAMP

CONSULTANT

DRAWING ISSUED FOR

	CLIENT APPROVAL
	PLANNING APPROVAL
	PLAN CHECK #1
	PLAN CHECK #2
	BIDDING
	PERMIT
	CONSTRUCTION

REVISIONS

NO.	DATE	BY
DESCRIPTION		
1	12/12/2018	MDF
UPDATED TOPO/ROAD ELEVATIONS		

PROJECT

BOYCE HYDRO POWER LLC
FERC PROJECT #10810
SMALLWOOD LAKE

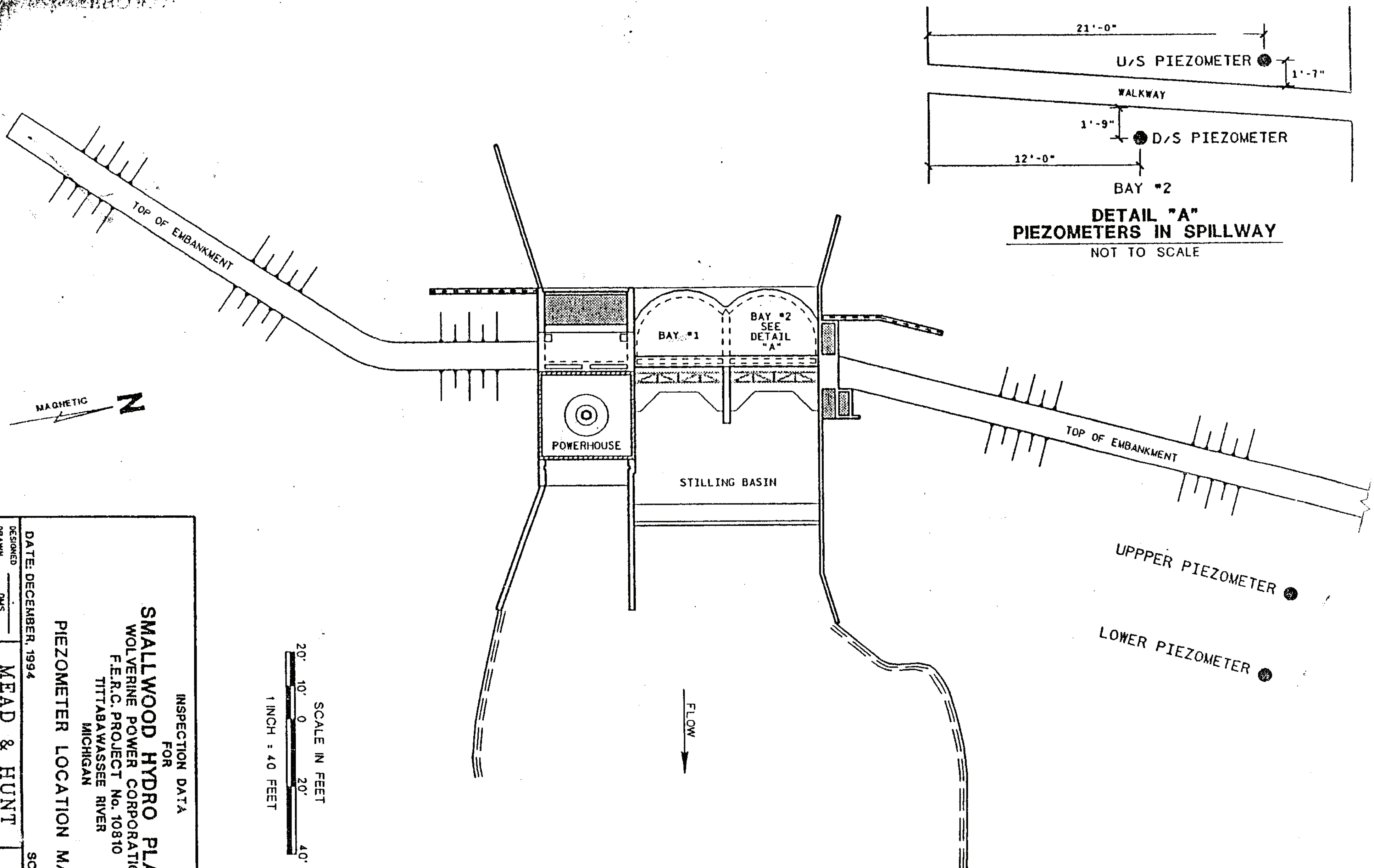
OWNER

BOYCE HYDRO POWER LLC
PO BOX 15
EDENVILLE, MI 48620
989-689-3161

DRAWING TITLE

MONITORING WELL PLAN DRAWING SMALLWOOD

FILE	SMWD-SMP 2018
SCALE	AS NOTED
DRAWN	MGM/MDF
CHECKED	
DATE	12/12/2018
	DRAWING NO.



INSPECTION DATA
FOR
SMALLWOOD HYDRO PLANT
WOLVERINE POWER CORPORATION
F.E.R.C. PROJECT No. 10810
TITTABAWASSEE RIVER
MICHIGAN

PIEZOMETER LOCATION MAP

DATE: DECEMBER, 1994

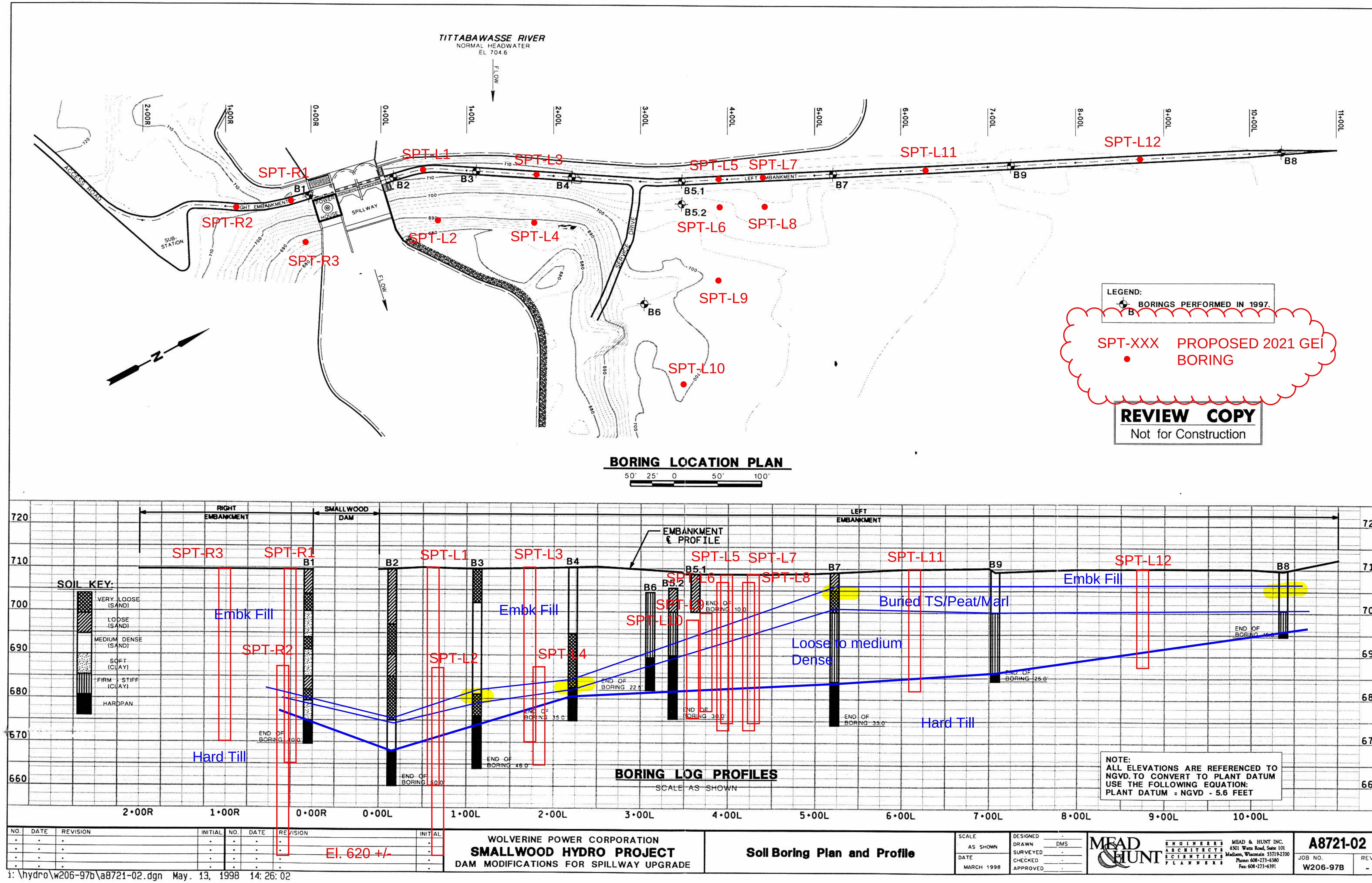
SCALE: AS SHOWN

DESIGNED	
DRAWN	DMS
SURVEYED	
CHECKED	EAV
APPROVED	

MEAD & HUNT
Consulting Engineers
6501 Watts Road Suite 101
Madison, Wisconsin 53719-2700
(608) 273-6380 / FAX (608) 273-6391

EXHIBIT 5
SHEET 1 OF 2

JOB NO. W206-94B
REV. -


TITTABAWASSE RIVER
NORMAL HEADWATER
EL 704.6
FLOW
ACCESS ROAD
SUB-STATION
RIGHT EMBANKMENT
POWER HOUSE
SPILLWAY
LEFT EMBANKMENT
SERVICE DRIVE
2+00R
1+00R
0+00R
0+00L
1+00L
2+00L
3+00L
4+00L
5+00L
6+00L
7+00L
8+00L
9+00L
10+00L
11+00L
B1
B2
B3
B4
B5.1
B5.2
B6
B7
B8
B9
SPT-R1
SPT-R2
SPT-R3
SPT-L1
SPT-L2
SPT-L3
SPT-L4
SPT-L5
SPT-L6
SPT-L7
SPT-L8
SPT-L9
SPT-L10
SPT-L11
SPT-L12
LEGEND:
BORINGS PERFORMED IN 1997.
SPT-XXX PROPOSED 2021 GEI BORING
REVIEW COPY
Not for Construction
BORING LOCATION PLAN
50' 25' 0 50' 100'
RIGHT EMBANKMENT
SMALLWOOD DAM
LEFT EMBANKMENT
EMBANKMENT ℄ PROFILE
720
710
700
690
680
670
660
SOIL KEY:
VERY LOOSE (SAND)
LOOSE (SAND)
MEDIUM DENSE (SAND)
SOFT (CLAY)
FIRM - STIFF (CLAY)
HARDPAN
Embk Fill
Buried TS/Peat/Marl
Loose to medium Dense
Hard Till
END OF BORING 40.0'
END OF BORING 50.0'
END OF BORING 46.0'
END OF BORING 35.0'
END OF BORING 22.5'
END OF BORING 10.0'
END OF BORING 30.0'
END OF BORING 35.0'
END OF BORING 25.0'
END OF BORING 15.0'
El. 620 +/-
BORING LOG PROFILES
SCALE AS SHOWN
NOTE:
ALL ELEVATIONS ARE REFERENCED TO NGVD. TO CONVERT TO PLANT DATUM USE THE FOLLOWING EQUATION:
PLANT DATUM = NGVD - 5.6 FEET
NO. DATE REVISION INITIAL
WOLVERINE POWER CORPORATION
SMALLWOOD HYDRO PROJECT
DAM MODIFICATIONS FOR SPILLWAY UPGRADE
Soil Boring Plan and Profile
SCALE AS SHOWN
DATE MARCH 1998
DESIGNED
DRAWN DMS
SURVEYED
CHECKED
APPROVED
MEAD & HUNT
ENGINEERS ARCHITECTS SCIENTISTS PLANNERS
MEAD & HUNT INC. 6501 Watts Road, Suite 101 Madison, Wisconsin 53719-2700 Phone: 608-273-6380 Fax: 608-273-6391
A8721-02
JOB NO. W206-97B
REV. -
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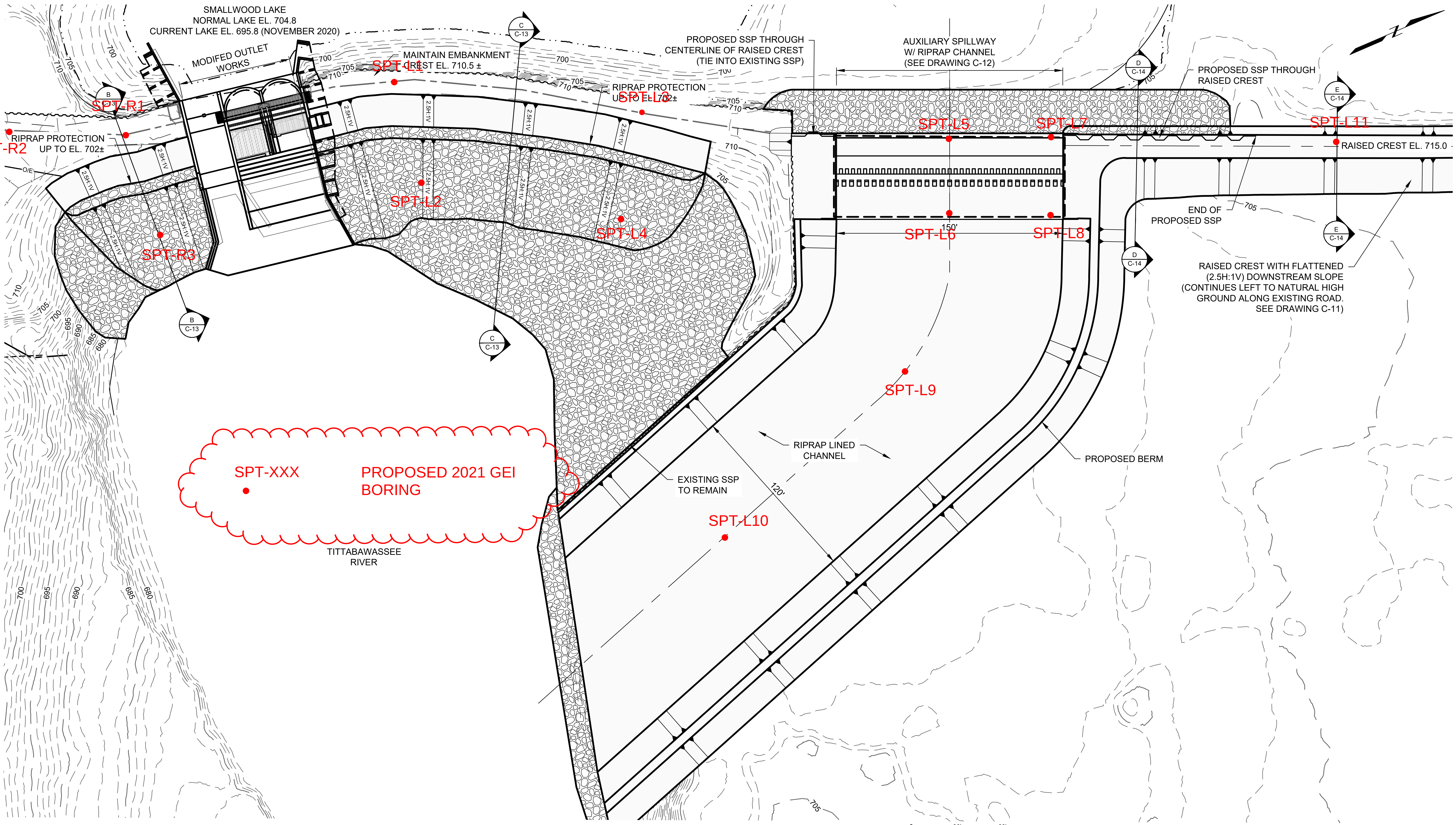

SITE PLAN - PROPOSED MODIFICATIONS

0 30' 60'
SCALE, FEET

0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-
NO.	DATE	ISSUE/REVISION	APP

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

DRAFT

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Saginaw, MI 48607 Tel.
989-754-4717 Fax.
989-754-4440
www.SpicerGroup.com

GEI Consultants
GEI CONSULTANTS OF MICHIGAN, P.C.
10501 WEST RESEARCH DRIVE
G100
MILWAUKEE, WI 53226
(414)930-7540

Designed: P. DREW
Checked: P. DREW
Drawn: A. SAMPSON
Approved By: B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

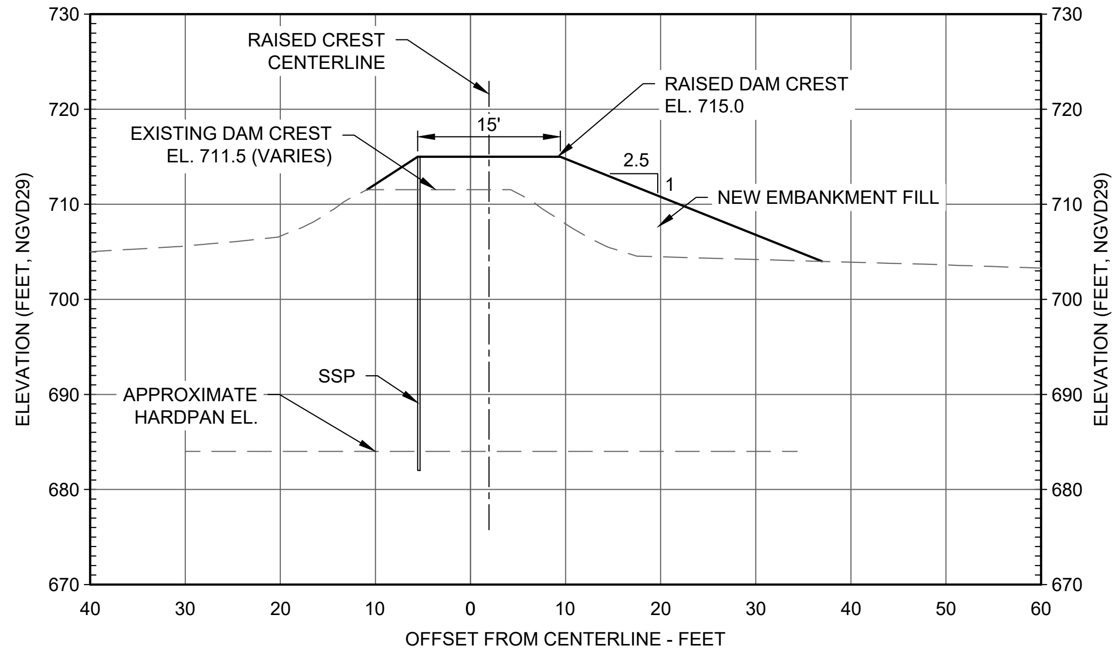
Smallwood Dam
Gladwin County, Michigan

SITE PLAN -
PROPOSED MODIFICATIONS

DWG. NO. C-06

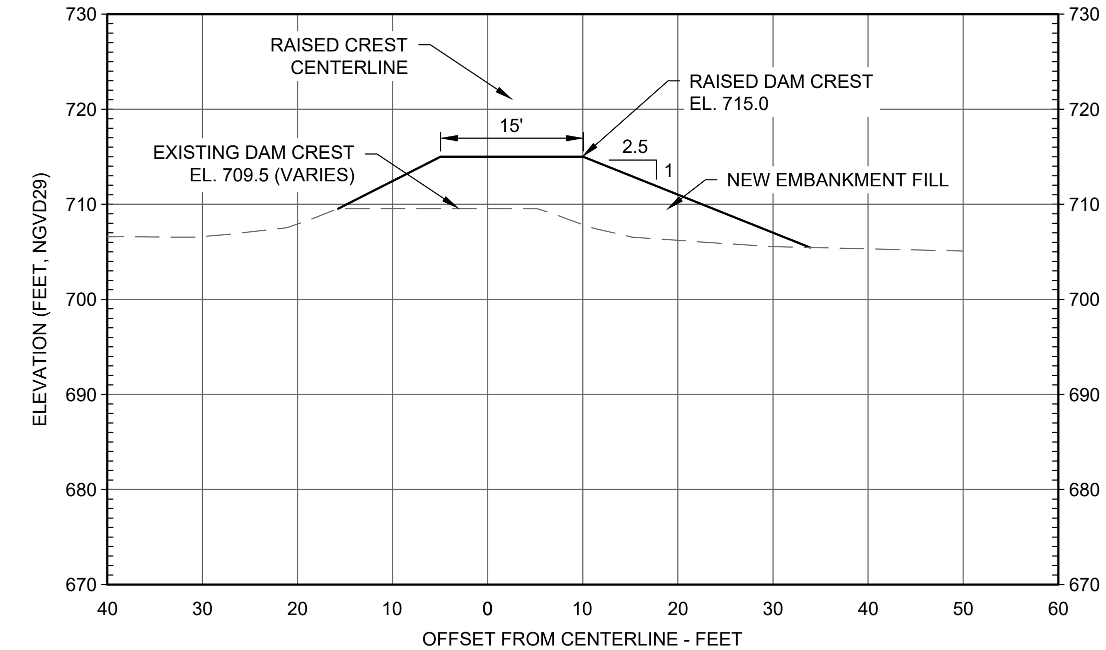
SHEET NO. 8

\\MSN1L-AMICH C:\Temp Local C\FLTF\Smallwood\CAD\Task4.3_Concept_Design\C-06,15_PLANS_AUXSPILLWAY_GRADING.dwg - 12/4/2020



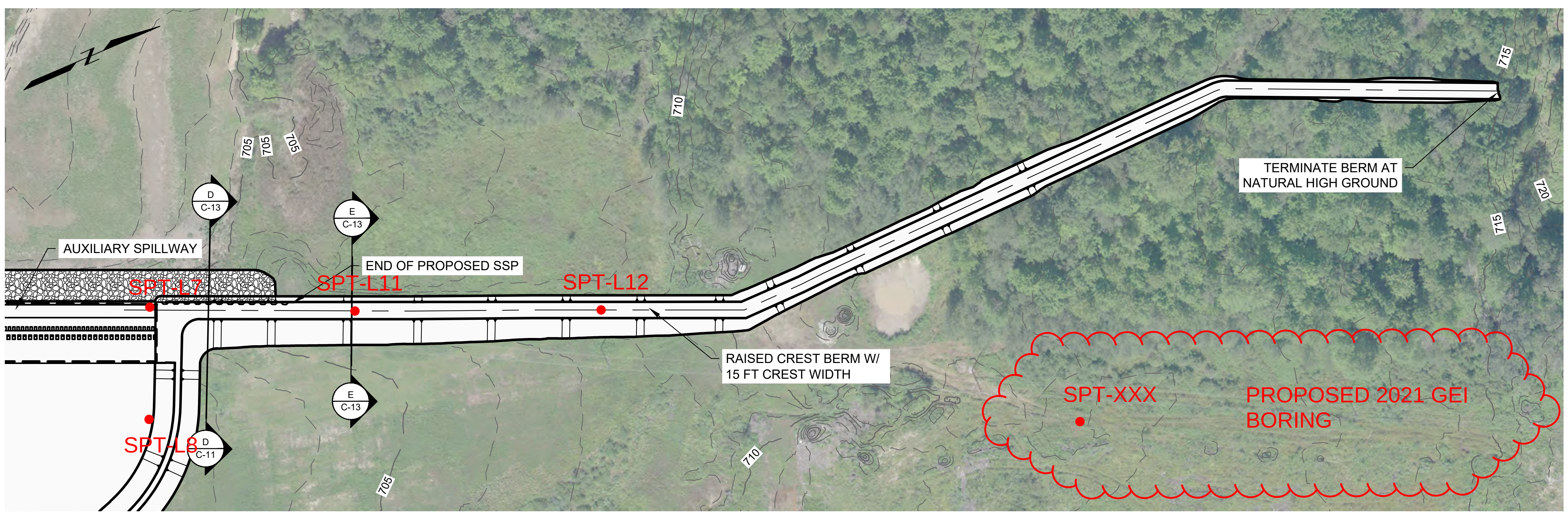
D SECTION
C-06 C-14 LEFT EMBANKMENT W/ SSP CUTOFF

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION



E SECTION
C-06 C-14 LEFT EMBANKMENT BERM DETAIL

HORIZONTAL SCALE, FEET 0 10 20
VERTICAL SCALE, FEET 0 10 20
NO VERTICAL EXAGGERATION



LEFT EMBANKMENT PLAN

SCALE, FEET 0 60' 120'

0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	-
NO.	DATE	ISSUE/REVISION	APP

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(414)930-7540

Designed: P. DREW
Checked: P. DREW
Drawn: A. SAMPSON
Approved By: B. WALTON

Four Lakes Task Force
FERC Project No. 10810

GEI Project 2002879

Smallwood Dam
Gladwin County, Michigan

EMBANKMENTS - MODIFICATIONS
SECTIONS (SHEET 2 OF 2)

DWG. NO. C-14
SHEET NO. 16

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Appendix E

Conceptual Cofferdam Designs

GEI Consultants	Client	Four Lakes Task Force			Page	
	Project	FLTF Post-May 2020 Flood Services			Pg. Rev.	
	By	M. Guay	Chk.	M. Flynn	App.	
	Date	2021-03-02	Date	2021-03-02	Date	
Project No.	2002879	Document No.				
Subject	Secord and Smallwood Dam – Cofferdam Conceptual Design					

Purpose

The purpose of this document is to present the conceptual design and rough order of magnitude costs for the cofferdam construction at Secord and Smallwood Dams.

Background

Secord Dam:

Secord Dam consists of a 650-foot-long left embankment; a 25-foot-wide powerhouse, a 43.5-foot-wide gated spillway, and an approximately 350-foot-long left embankment. The reinforced concrete spillway structure is a hollow reinforced concrete arch structure with two tainter gate bays. The left tainter gate is 20.5-feet-wide by 10-feet-high and the right tainter gate is 23.6-feet-wide by 10-feet-high. The spillway ogee crest is at elevation 742.8 feet.

Smallwood Dam:

Smallwood Dam consists of a 1,000-foot-long left embankment, a 52.2-foot-wide gated spillway, a 25-foot-wide powerhouse, and a 125-foot-wide right embankment. The reinforced concrete spillway is a hollow reinforced concrete arch structure with two tainter gate bays. The left and right tainter gate is 25.4-feet-wide by 10-feet-high. The spillway ogee crest is at elevation 694.8 feet.

Proposed Repairs at Spillway:

The proposed repairs at both dams includes partial demolition of the tainter gates to be replaced with hydraulic crest gates to increase spillway capacity. Additionally, the powerhouse will be decommissioned, and the draft tube bay converted to a low-level outlet and the remaining water passaged filled with lightweight grout or mass concrete.

Proposed Cofferdam Approach

Our conceptual design for the cofferdam consists of sheet pile cells constructed in three stages at the powerhouse and each bay. Stage 1 is constructed at the powerhouse to allow conversion to the low-level outlet while the spillway remains open to flow. Stage 1 requires an upstream cofferdam only. Stage 2 would occur at one of the bays to allow replacement of the gate and concrete repairs. The opposite bay and the outlet at the powerhouse would remain open to flow. Finally, Stage 3 would occur at the last bay and similar to Stage 2 the opposite bay and the outlet at the powerhouse would remain open to flow. Stages 2 and 3 requires upstream and downstream cofferdams.

The cofferdams will consist of steel sheet piles braced internally with three levels of wales and struts. All three levels of bracing will be required to be installed prior to dewatering, which will require some underwater installation. Sheet piles running upstream/downstream will be cut with the arch and require a closure connection between the sheet pile and concrete to create a watertight seal. The internal bracing will react against the end walls, the powerhouse structure, or the interior pier.

Our conceptual design is presented in Figures CD-01 to CD-05.

GEI Consultants	Client	Four Lakes Task Force			Page	
	Project	FLTF Post-May 2020 Flood Services			Pg. Rev.	
	By	M. Guay	Chk.	M. Flynn	App.	
	Date	2021-03-02	Date	2021-03-02	Date	
Project No.	2002879	Document No.				
Subject	Secord and Smallwood Dam – Cofferdam Conceptual Design					

Design Criteria:

Secord Dam

- 100-year HW = El. 751.5 ft
- 100-year TW = El. 710 ft
- U/S Top of Cofferdam = El. 752.5 ft (100-year + 1 ft freeboard)
- D/S Top of Cofferdam = El. 711 ft (100-year + 1 ft freeboard)
- U/S Interior Cofferdam Water = El. 720 (max dewatered)

Smallwood Dam

- 100-year HW = El. 711 ft
- 100-year TW = El. 693 ft
- U/S Top of Cofferdam = El. 712 ft (100-year + 1 ft freeboard)
- D/S Top of Cofferdam = E. 694 ft (100-year + 1 ft freeboard)
- U/S Interior Cofferdam Water = El. 680 (max dewatered)

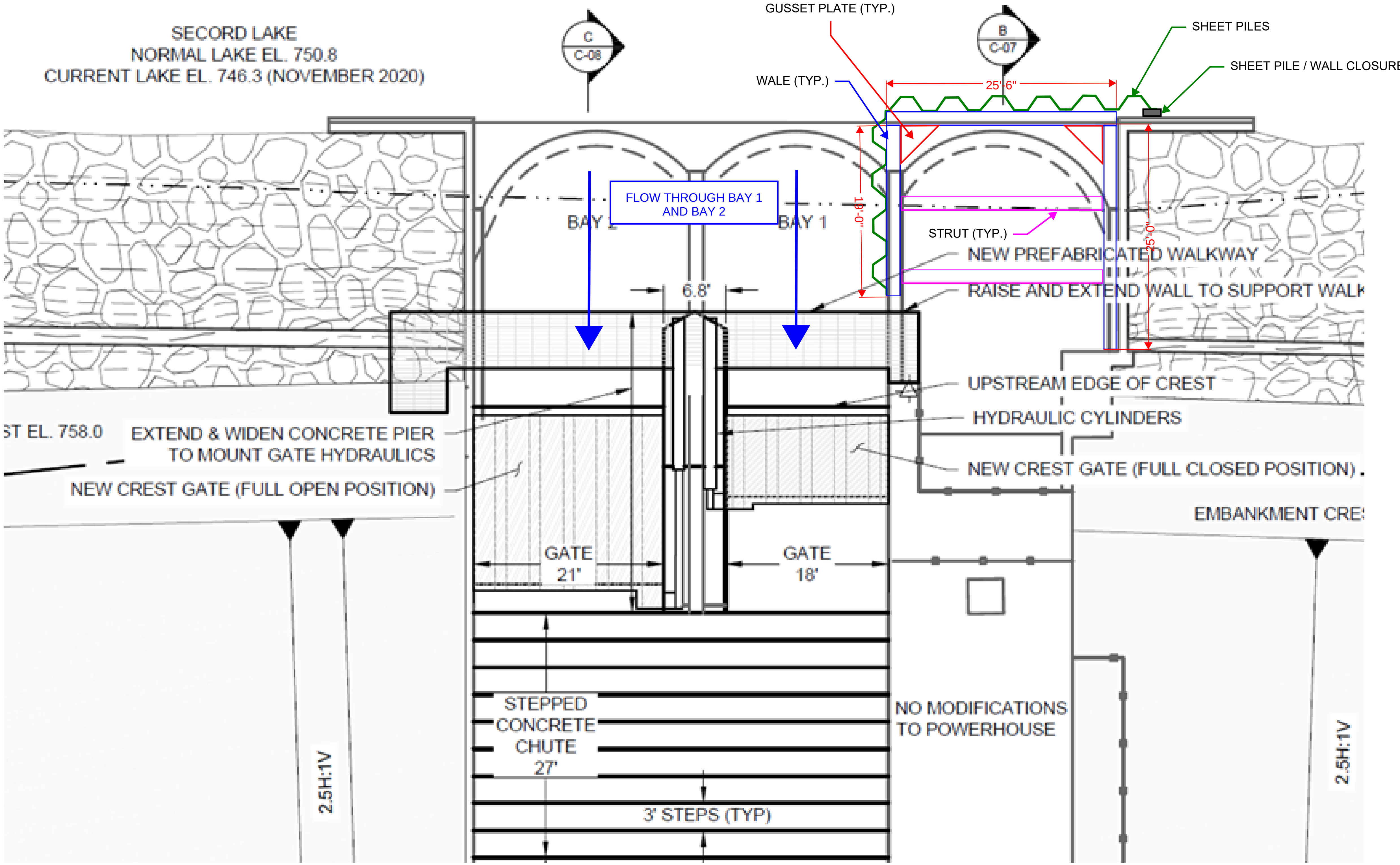
Conceptual Design:

We performed lateral analyses to estimate wall stresses and brace loading. We prepared a preliminary cofferdam layout and sized bracing and sheet piles based on our analyses. Based on our analyses, we estimate PZC-26 sheet piles or similar. There are three brace levels on the upstream cofferdam cells, the upper two levels are supported by W24 wales and struts. The lower level is supported by a double W24 wale. There are two levels of bracing on the downstream side supported by W24 wales. The downstream cofferdams for Secord Dam are about half the height of Smallwood due to the lower tailwater condition.

Based on our preliminary design, we estimate the following:

- PZC-26 Sheet Pile: 17,250 s.f. of wall, (275 tons)
- Bracing: 120 tons of steel

Based on the quantities, size and sequence indicated above, we estimate approximately $1.1 million and $1.3 million to furnish and install the cofferdams at Secord and Smallwood, respectively. Our opinion of cost is based costs from similar projects, engineering judgement, and published cost data and intended as a rough order of magnitude estimate.

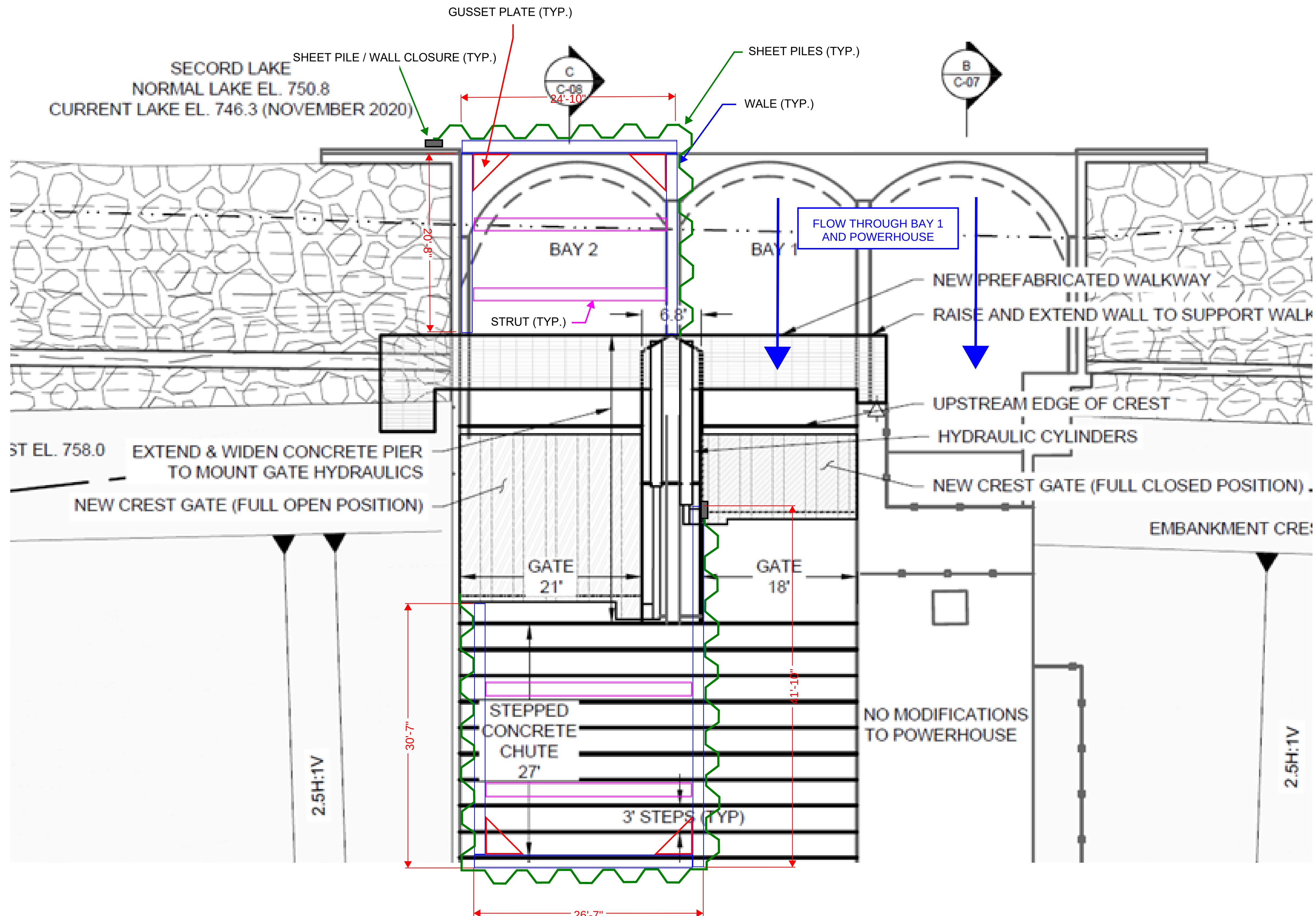


MATERIALS:

SHEET PILES: PZC-26, 50 ksi min.
WALES: W24x104 (Level 1 and 2), (2) W24x176 (Level 3), 50 ksi min.
STRUTS: W12x72 (Level 1 and 2), W24x176 (Level 3), 50 ksi min.
GUSSET PLATES: 24-Inch (Level 2 and 3), 50 ksi min.

CONCEPTUAL DESIGN ONLY

SECORD AND SMALLWOOD DAM	GEI Consultants	SECORD DAM COFFERDAM PHASE 1 PLAN: POWERHOUSE
FOUR LAKES TASK FORCE	Project 2002879	February 2020 — Fig. CD-01



CONCEPTUAL DESIGN ONLY

MATERIALS:

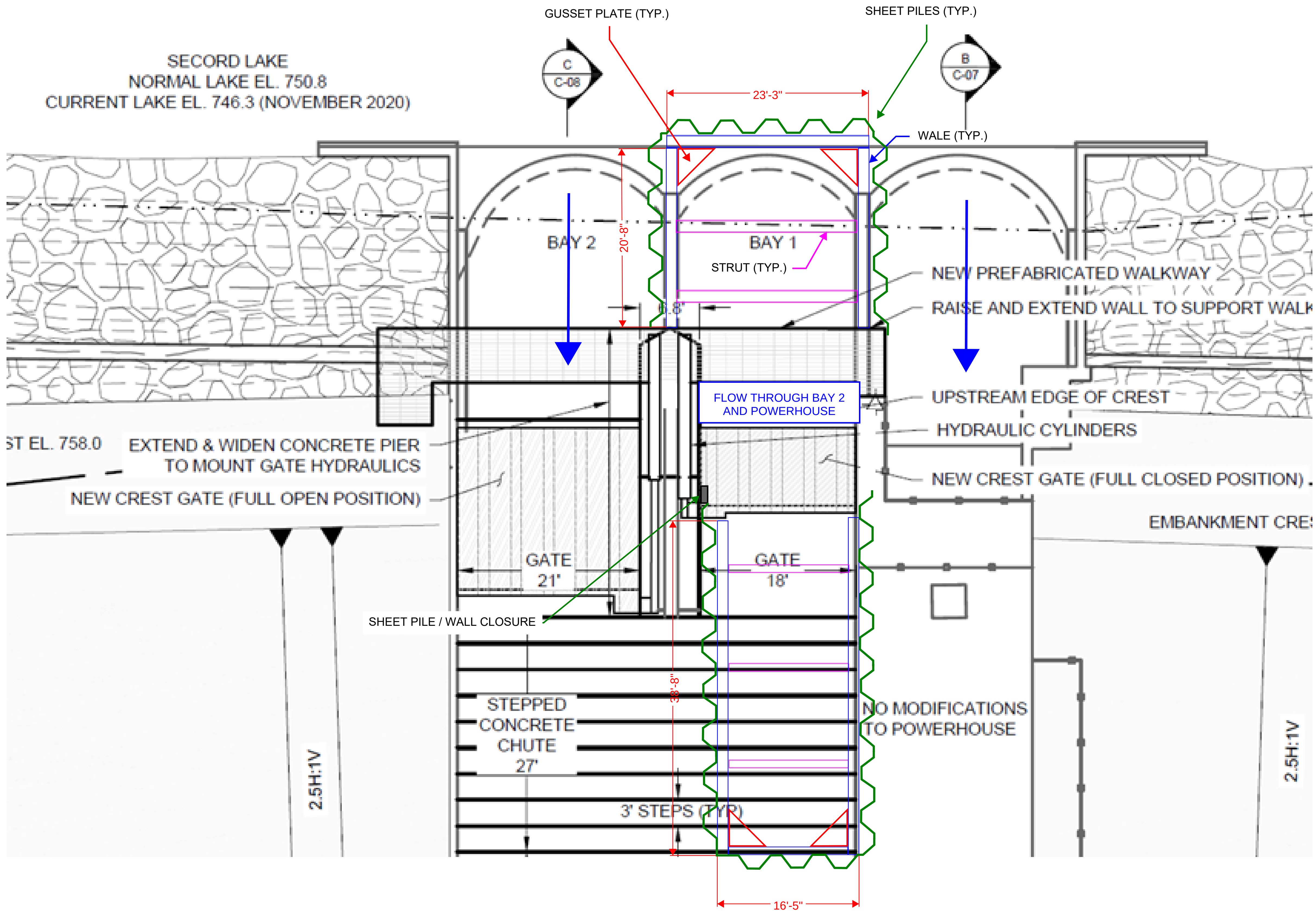
SHEET PILES: PZC-26, 50 ksi min.

WALES: Upstream: W24x104 (Level 1 and 2), (2) W24x176 (Level 3); Downstream: W24x104 (Level 1), (2) W24x176 (Level 2), 50 ksi min.

STRUTS: Upstream: W12x72 (Level 1 and 2), W24x176 (Level 3); Downstream: W12x72 (Level 1), W24x176 (Level 2) 50 ksi min.

GUSSET PLATES: Upstream: 24-Inch (Level 2 and 3); Downstream: 24-Inch (Level 2), 50 ksi min.

SECORD AND SMALLWOOD DAM	GEI Consultants	SECORD DAM COFFERDAM PHASE 2 PLAN: POWERHOUSE
FOUR LAKES TASK FORCE	Project 2002879	February 2020 Fig. CD-02



CONCEPTUAL DESIGN ONLY

MATERIALS:

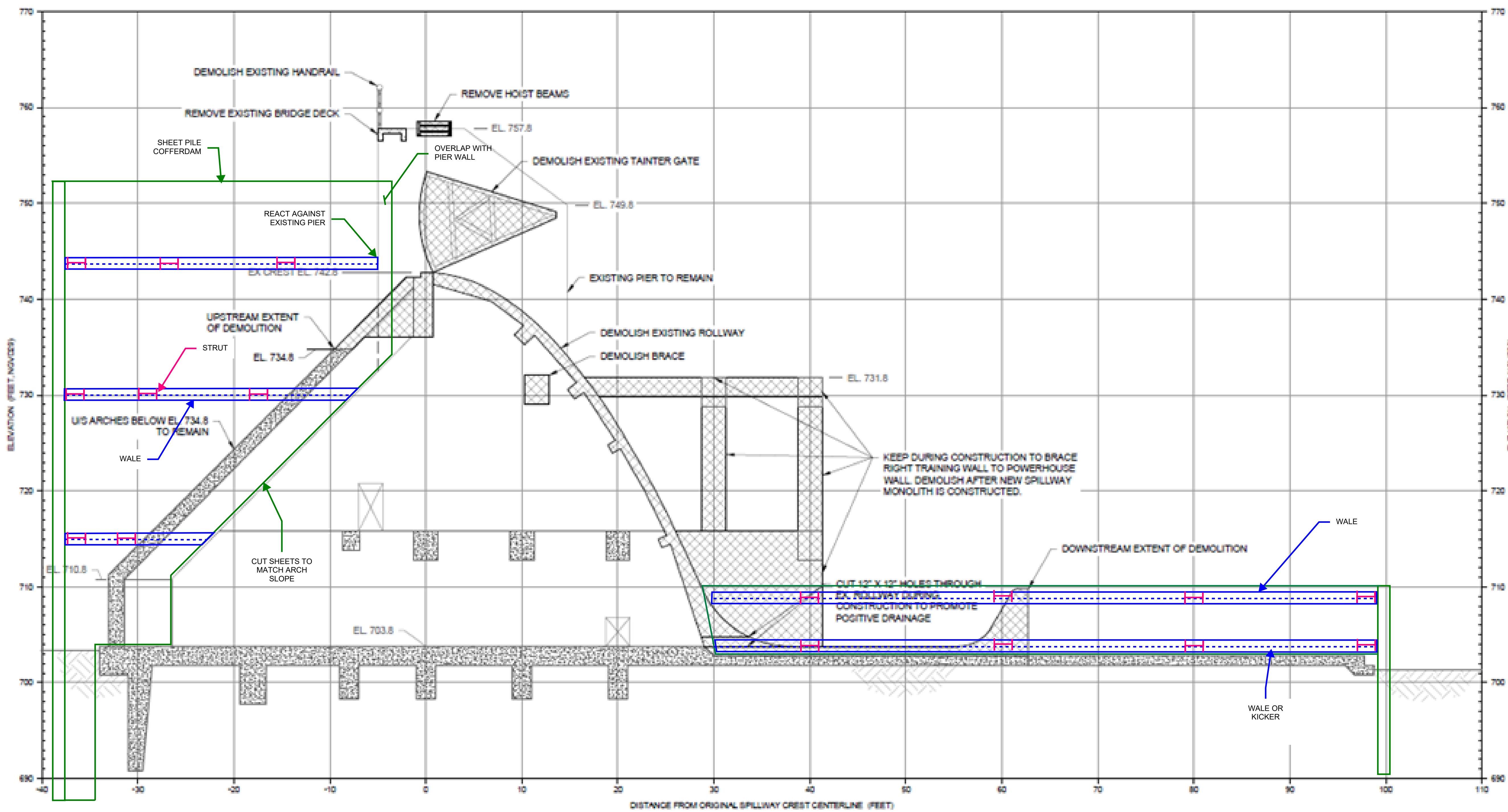
SHEET PILES: PZC-26, 50 ksi min.

WALES: Upstream: W24x104 (Level 1 and 2), (2) W24x176 (Level 3); Downstream: W24x104 (Level 1), (2) W24x207 (Level 2), 50 ksi min.

STRUTS: Upstream: W12x72 (Level 1 and 2), W24x176 (Level 3); Downstream: W12x72 (Level 1), W24x176 (Level 2) 50 ksi min.

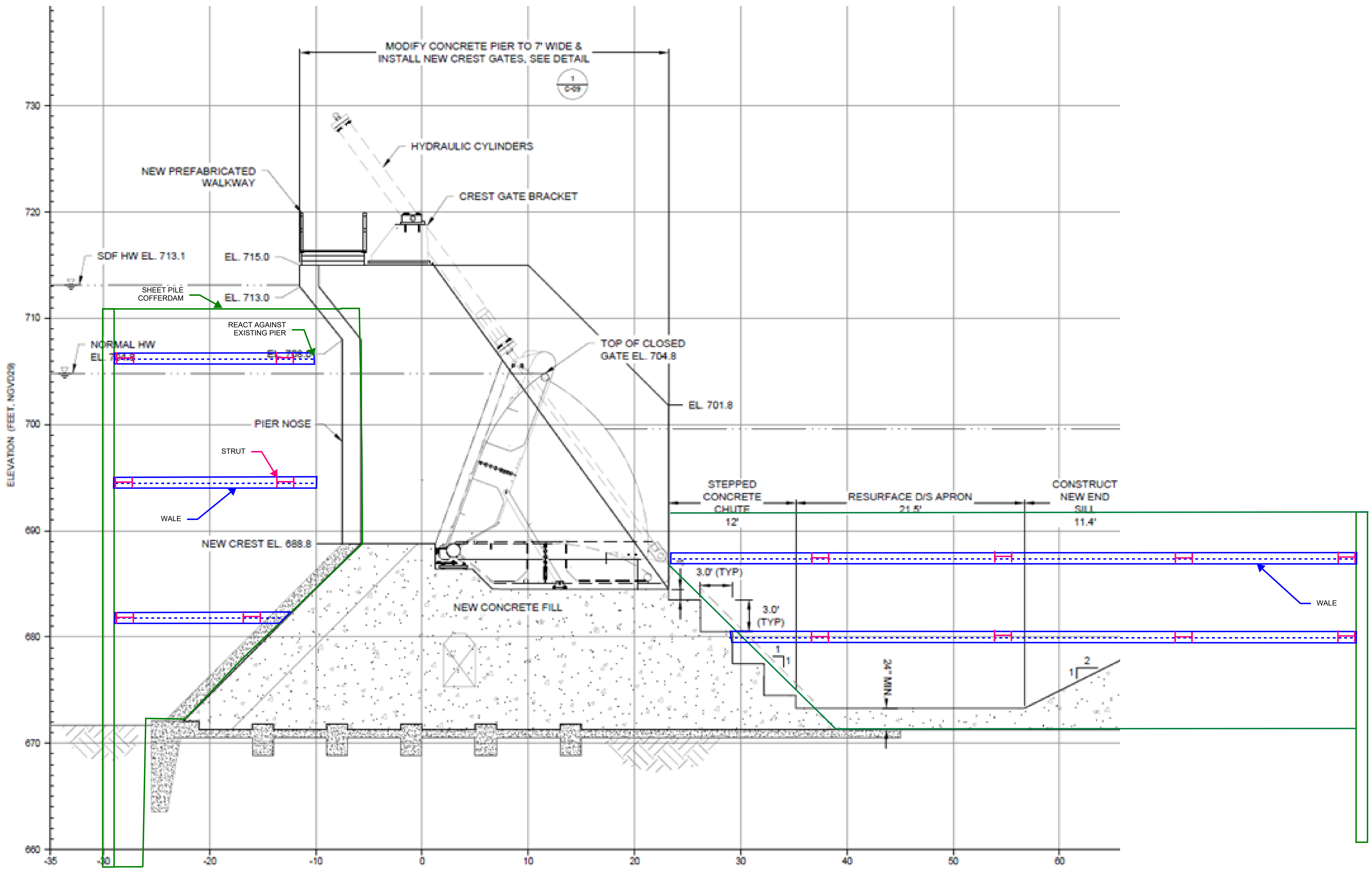
GUSSET PLATES: Upstream: 24-Inch (Level 2 and 3); Downstream: 24-Inch (Level 2), 50 ksi min.

SECORD AND SMALLWOOD DAM	GEI Consultants	SECORD DAM COFFERDAM PHASE 3: PLAN: POWERHOUSE
FOUR LAKES TASK FORCE	Project 2002879	February 2020 Fig. CD-03



CONCEPTUAL DESIGN ONLY

SECORD AND SMALLWOOD DAM	GEI Consultants	SECORD DAM COFFERDAM
FOUR LAKES TASK FORCE	Project 2002879	February 2020 Fig. CD-04



CONCEPTUAL DESIGN ONLY

SECORD AND SMALLWOOD DAM	GEI Consultants	SMALLWOOD DAM COFFERDAM	
FOUR LAKES TASK FORCE	Project 2002879	February 2020	Fig. CD-05

Appendix F

Opinions of Probable Construction Costs (OPCC) Worksheets

OPINION OF PROBABLE COST - CONCEPTUAL
Project: Smallwood Dam
Client: Four Lakes Task Force (FLTF)

Project No.: 2002879
Date: 2/8/2021
Estimated by: A. Michaud, P. Grodecki
Checked by: P. Drew, W. Walton, R. Anderson

Item	Description	Quantity	Units	Unit Price	Total Cost	Notes
0.00	**General Conditions**					
0.01	Contractor Mobilization / Demobilization	1	LS	$ 612,000	$ 612,000	5% of Other Costs
0.02	Bonds and Insurance	1	LS	$ 245,000	$ 245,000	2% of Other Costs
0.03	Construction Permits	1	LS	$ 10,000	$ 10,000	
				Subtotal	**$ 867,000**	
1.00	**Site Preparation**					
1.01	Erosion and Sediment Control	1	LS	$ 20,000	$ 20,000	
1.02	Temporary Access Roads, Facilities and Laydown Areas	1	LS	$ 200,000	$ 200,000	
1.03	Cofferdams	1	LS	$ 1,250,000	$ 1,250,000	
				Subtotal	**$ 1,470,000**	
2.00	**Site Demolition (Spillway & Powerhouse)**					
2.01	Gated Spillway Demolition and Disposal	1	LS	$ 100,000	$ 100,000	
2.02	Gated Spillway Concrete Demolition	285	CY	$ 100	$ 28,485	
2.03	Powerhouse Training Wall Demolition	55	CY	$ 100	$ 5,481	
2.04	Mechanical and Electrical Equipment Demolition and Disposal	1	LS	$ 250,000	$ 250,000	
2.05	Mass Concrete Fill within Sluiceway	239	CY	$ 700	$ 167,129	
2.06	Reinforced Concrete Wall at Sluiceway	11	CY	$ 700	$ 7,834	
				Subtotal	**$ 558,929**	
3.00	**Left Embankment Repair and Stabilization Berm (Left of New Auxiliary Spillway)(L = 1,280 feet)**					
3.01	Sheet Pile Cutoffs	4,550	SF	$ 65	$ 295,750	Assumes SSP length of 35 ft
3.02	Embankment Fill	5,268	CY	$ 30	$ 158,043	
3.03	Crest Gravel	356	CY	$ 35	$ 12,444	
3.04	Topsoil, Seed and Temporary Erosion Protection	426	CY	$ 45	$ 19,162	
				Subtotal	**$ 485,399**	
4.00	**Left Embankment Repair and Stabilization (Right of New Auxiliary Spillway) (L = 360 feet)**					
4.01	Excavation	2,254	CY	$ 20	$ 45,081	
4.02	Embankment Fill	1,181	CY	$ 30	$ 35,432	
4.03	Filter Sand	497	CY	$ 40	$ 19,871	
4.04	Drainage Stone	1,007	CY	$ 40	$ 40,263	
4.05	Downstream Riprap Protection	4,479	CY	$ 125	$ 559,829	
4.06	Bedding Stone	636	CY	$ 45	$ 28,621	
4.07	Crest Gravel	90	CY	$ 35	$ 3,160	
4.08	Topsoil, Seed and Temporary Erosion Protection	113	CY	$ 45	$ 5,089	
				Subtotal	**$ 737,345**	
5.00	**Right Embankment Repair and Stabilization (L = 340 feet)**					
5.01	Excavation	133	CY	$ 20	$ 2,660	
5.02	Embankment Fill	75	CY	$ 30	$ 2,256	
5.03	Filter Sand	391	CY	$ 40	$ 15,635	
5.04	Drainage Stone	513	CY	$ 40	$ 20,538	
5.05	Downstream Riprap Protection	1,154	CY	$ 125	$ 144,249	
5.06	Bedding Stone	291	CY	$ 45	$ 13,089	
5.07	Crest Gravel	28	CY	$ 35	$ 972	
5.08	Topsoil, Seed and Temporary Erosion Protection	39	CY	$ 45	$ 1,747	
				Subtotal	**$ 201,146**	
6.00	**New Crest Gated Spillway and Outlet Works**					
6.01	Mass Concrete (includes Stepped Rollway)	1,278	CY	$ 700	$ 894,911	
6.02	Reinforced Concrete Downstream Apron	313	CY	$ 700	$ 218,815	
6.03	Reinforced Concrete End Sill	111	CY	$ 700	$ 77,428	
6.04	Reinforced Concrete Structure Piers	138	CY	$ 900	$ 124,192	
6.05	Crest Gates (Shallow) - Installed with Hoists and Controls	2	LS	$ 750,000	$ 1,500,000	From Steel Fab
6.06	Steel Frame Operators Deck	1	LS	$ 750,000	$ 750,000	
6.07	Reinforced Concrete - Left and Right Training Wall Extensions	175	CY	$ 900	$ 157,073	
6.08	CLSM Backfill Behind Raised Training Walls	473	CY	$ 200	$ 94,501	
				Subtotal	**$ 3,816,920**	
7.00	**Powerhouse Rehabilitation**					
7.01	Misc. surface concrete and masonry repairs	1	EA	$ 200,000	$ 200,000	
7.02	Convert water passages to low level outlet	1	EA	$ 1,000,000	$ 1,000,000	
7.03	Head Gate and Hoist	1	EA	$ 300,000	$ 300,000	
				Subtotal	**$ 1,500,000**	
8.00	**New 150' Auxiliary Spillway**					
8.01	Excavation	3,751	CY	$ 20	$ 75,015	
8.02	Reinforced Concrete Sill Slab	243	CY	$ 700	$ 169,944	
8.03	Reinforced Concrete Chute Slab	133	CY	$ 700	$ 93,333	
8.04	Reinforced Concrete Stilling Basin Floor Slab	332	CY	$ 700	$ 232,556	
8.05	Reinforced Concrete Energy Dissipators	14	CY	$ 700	$ 9,592	
8.06	Reinforced Concrete End Sill	71	CY	$ 700	$ 50,011	
8.07	Flashboards and Stanchions	1	LS	$ 60,000	$ 60,000	
8.08	Reinforced Concrete Spilllway and Stilling Basin Walls	37	CY	$ 700	$ 25,627	
8.09	Steel Sheet Pile Cutoffs (Add downstream to quantity and side walls, update dra	6,960	SF	$ 65	$ 452,400	
8.10	Upstream Riprap	390	CY	$ 125	$ 48,704	
8.11	Bedding	97	CY	$ 45	$ 4,383	
8.12	Geotextile	5,260	SF	$ 2	$ 10,520	
8.13	Filter Sand	321	CY	$ 40	$ 12,822	
8.14	Drainage Stone	329	CY	$ 40	$ 13,178	
8.15	Drain Pipe (Solid and Slotted)	170	LF	$ 25	$ 4,250	
				Subtotal	**$ 1,262,335**	
9.00	**New Discharge Channel for Auxiliary Spillway**					
9.01	Excavation	22,044	CY	$ 20	$ 440,889	
9.02	Downstream Heavy Riprap (Riprap Lined Channel)	11,448	CY	$ 125	$ 1,430,944	
9.03	Structural Fill	1,085	CY	$ 35	$ 37,987	
9.04	Geotextile	195	SF	$ 2	$ 390	
9.05	Left Berm	3,278	CY	$ 30	$ 98,344	
9.06	Topsoil, Seed and Temporary Erosion Protection	302	CY	$ 45	$ 13,593	
9.07	Channel Exit - Heavy Riprap	274	CY	$ 125	$ 34,261	
9.08	Channel Exit - Bedding Stone	69	CY	$ 45	$ 3,084	
				Subtotal	**$ 2,059,492**	
10.00	**Site Restoration**					
10.01	Place Overburden, Seed, Fertilize, and Mulch Slopes	1	LS	$ 100,000	$ 100,000	
10.02	Dam Safety Monitoring Instrumentation	1	LS	$ 50,000	$ 50,000	
				Subtotal	**$ 150,000**	
	Subtotal				$ 13,108,567	
	Contingency			25%	$ 3,277,000	
	Construction Subtotal				**$ 16,385,567**	
	Engineering Investigations, Design and Construction Engineering	-	-		**$ 1,550,000**	
	Total Estimated Cost				**$ 17,935,567**	
				say	**$ 17,936,000**	

Information presented on this sheet represents our opinion of probable costs in 2021 dollars. Unit and lump-sum prices are based on costs for similar projects, engineering judgment, and/or published cost data. Client administrative/engineering costs and regulatory fees not included. 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.