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Conceptual Design Basis Report
Rehabilitation of Edenville Dam

Gladwin County, Michigan

Submitted to:
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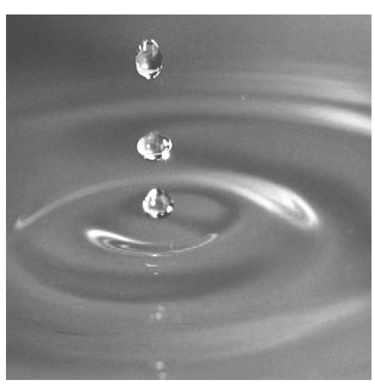

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1. Introduction

1.1 Background

Following the May 19, 2020, storm event that resulted in a catastrophic failure (breach) of the Edenville and Sanford Dams, severe damage to the Smallwood Dam, and minor downstream erosion damage to the Secord Dam, 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, which were formerly owned by Boyce Hydro, LLC (Boyce) and licensed by the Federal Energy and Regulatory Commission (FERC).

As documented in the July 2020 Post Failure Reconstruction Cost Analysis prepared by GEI (Ref. GEI, 2020a), we developed engineer's opinions of 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-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 Edenville 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:

- Prior to the Edenville dam failure, the Tainter gate spillway could pass approximately 20,670 cubic feet of flow per second (cfs) before water begins overtopping the embankment on the Tittabawassee River side of the impoundment. According to the latest flood analysis, a total spillway capacity of approximately 37,845 cfs is needed to safely pass the ½ PMF as currently required by the Michigan EGLE without overtopping the dam structures.
- The gated spillways, integral to a two-unit 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 water line where 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 hydro operation, there is no low-level outlet to draw down or drain the impoundment below the invert of the spillway sill.
- A significant reach of the embankments right of the Tittabawassee spillway were damaged due to rapid reservoir drawdown. Remaining sections of embankment that were not breached are overly steep, have narrow crests, insufficient slope stability under normal and flood pool conditions, and no seepage cutoff or internal filters and drains to protect against seepage-induced internal erosion.
- The failed left embankment and Tittabawassee spillways need to be reconstructed in their original footprint following the Edenville Dam Failure on May 19, 2020, ongoing Phase I Edenville Dam Stabilization construction, and construction of the Phase II Edenville Dam Stabilization scheduled for Summer 2021.

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

- Provide updated earth and concrete structures that will have a 75+ year design service life.
- Temporary cofferdams and diversion structures to have the ability to safely pass base river flows plus flood flows (assumed 100 or 200-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.
- Remove the three Tainter gate spillways and one of the two powerhouse units (left unit razed) and converted to three new wider and deeper crest gates.
- 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.
- Transform one of the powerhouse units (right side unit) to a gated low-level outlet structure using the intake, scroll case, a fixed Francis wheel and draft tube to release 200 to 300 cfs base flows 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 30% design drawings and prepare an engineer’s opinions of probable construction costs.

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 Edenville Dam is located on the Tittabawassee and Tobacco Rivers in the town of Edenville, Michigan, approximately 22 river miles upstream of the City of Midland, Michigan (see **Figure 1**). The facility is owned and operated by the FLTF. Construction of the dam was completed in 1925 to provide storage and headwater control for the purpose of hydroelectric power generation. From left to right, the Tittabawassee River portion of the project consists of a 680-foot-long left embankment with a minimum crest at El. 682.1, a 68.6-foot-wide gated spillway with three Tainter gates, a 50.6-foot-wide powerhouse containing two turbine generating units with a combined rated capacity of 6 MW with an operating head of 45 feet, and a 2,800-foot-long right embankment that extends to the Michigan M-30 Highway embankment to the west.

From left to right and prior to the May 2020 breach, the Tobacco River portion of the project consisted of a 520-foot-long left embankment with a minimum dam crest at El 683.1, a 72.2-foot-wide gated spillway with three Tainter gates, and a 2,050-foot-long right embankment that extends to Hunter Road.

The Edenville Dam structures impound Wixom Lake and the dam is classified as having a high hazard potential based on estimated downstream impacts in the event of a failure. The Exhibit F Drawings from the original FERC license, illustrating the typical plan and sections for each of the existing project structures are included in **Appendix A**.

<u>Tittabawassee Tainter Gate Spillway</u>
The reinforced concrete spillway is a hollow reinforced concrete arch structure with three Tainter gate bays. The left gate (Bay 6) is 23.6-feet-wide by 9.5-feet-high and the center and right Tainter gates (Bay 5 and Bay 4) are 20.0-feet-wide by 9.5-feet-high. The gates are operated by hydraulically operated chain and single cable hoist and reel system with the operators located directly adjacent to the hoist above each gate on an elevated platform. The gates are now fully open and dogged off and flows currently pass through the breach channel.

<u>Tittabawassee Powerhouse</u>
The powerhouse is located immediately to the right of the Tittabawassee Tainter Gate Spillway. The powerhouse is approximately a 50.6-foot-wide powerhouse containing two generating units with a combined rated capacity of 6 MW. The normal headwater and tailwater pools at the Edenville Spillway are 675.8 and 630.8 feet, respectively.

<u>Tittabawassee Embankments</u>
The (former) left embankment was approximately 680-feet long, with maximum structural height of 46 feet near the spillway. The embankment was reportedly constructed of native, poorly

graded sand from onsite sources. The embankment slopes are 2.5H:1V on the upstream slope and 2H:1V on the downstream slope. Riprap protection was placed along the upstream slope of the embankment. A failed steel sheet pile cutoff wall once extended from the left upstream side of the Tainter gate spillway into the upstream slope of the left embankment for approximately 80 feet.

The remaining right embankment is approximately 2,800-feet long, with a maximum structural height of 46 feet near the spillway. The embankment was reportedly constructed of native, poorly graded sand from onsite sources. The embankment slopes are 2.5H:1V on the upstream slope and 2H:1V on the downstream slope. Riprap protection is placed along the upstream slope of the embankment. A steel sheet pile cutoff wall extends from the left upstream side of the spillway into the upstream slope of the left embankment for a distance of approximately 65 feet. A toe filter drain was constructed on the downstream slope of the right embankment in 2005 due to observed seepage.

<u>M-30 Causeway</u>
The former and soon to be replaced M-30 County Highway Bridge separates the east side (Tittabawassee River) from the west (Tobacco River) side of Wixom Lake. The hydraulic capacity of the former and newly eroded channel under the M-30 Bridge is insignificant compared to the hydraulic capacity of the Tittabawassee and Tobacco Tainter gate spillways and acts as a water surface equalization causeway between the two sides of the impoundment (Wixom Lake).

<u>Tobacco Tainter Gate Spillway</u>
The reinforced concrete spillway is a hollow reinforced concrete arch structure with three Tainter gate bays. The left gate (Bay 3) and right gate (Bay 1) are 23.6-foot-wide by 9.5-feet-high and the center Tainter gate (Bay 2) is 20.0-feet-wide by 9.5-feet-high. The gates are operated by hydraulic hoist with the operators located directly adjacent to the hoist above each gate on an elevated platform. The normal headwater and tailwater pools at Tobacco Spillway are El. 675.8 and 630.8 feet, respectively. At the time of this report, the three Tainter gates have been removed and modifications completed to get the Tobacco River flowing, over a lower ungated concrete broad-crested weir, to its original channel.

<u>Tobacco Embankments</u>
The left embankment is approximately 520-feet long, with maximum structural height of 37 feet near the spillway. The embankment was reportedly constructed of native, poorly graded sand from onsite sources. The embankment slopes are 2.5H:1V on the upstream slope and 2H:1V on the downstream slope. A steel sheet pile cutoff wall extends from the left upstream side of the spillway into the upstream slope of the left embankment for a distance of approximately 77 feet. A toe filter drain was constructed on the downstream slope of the right embankment in 2005 due to observed seepage.

The right embankment is approximately 2,050-feet long, with a maximum height of 46 feet near the spillway. The embankment was constructed of native, poorly graded sand from onsite sources. The embankment slopes are 2.5H:1V on the upstream slope and 2H:1V on the downstream slope. A steel sheet pile cutoff wall extends from the left upstream side of the spillway into the upstream slope of the left embankment for a distance of approximately 75 feet. In addition, there is a short steel sheet pile section in the upstream slope of the right embankment located approximately 900 feet to the right (west) of the Tobacco spillway. A toe filter drain was constructed on the downstream slope of the right embankment in 2005 due to observed seepage.

Key project data for the Edenville Dam are provided in **Table 2**.

Table 2: Key Existing Project Data

Parameter	Tittabawassee Portion of Edenville Dam	Tobacco Portion of Edenville Dam
Min. Dam Crest El. (feet)	682.1	683.1
Normal Operating Pool El. (feet)	675.8	
Normal Operating Tailwater El. (ft)	630.8	
Spillway Invert El. (feet)	667.8	667.8
# Tainter Gates	3	3
Gate Numbering (left to right looking downstream)	3 to 1	3 to 1
Gate 1 Width (feet)	20	23.6
Gate 1 Max Opening (feet)	9.5	9.5
Gate 2 Width (feet)	20	20
Gate 2 Max Opening (feet)	8.9	4.5
Gate 3 Width (feet)	23.6	23.6
Gate 3 Max Opening (feet)	9.6	8.9
Auxiliary Spillway Type	-	-
Auxiliary Spillway Sill El. (ft)	-	-
Auxiliary Spillway Length (feet) (Left Embankment Overflow)	-	-
Left Embankment Length (feet)	680	520
Left Embankment Dam Crest El. (feet)	682.1	683.1
Left Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1	2.5:1 / 2:1
Right Embankment Length (feet)	2,800	2,050
Right Embankment Dam Crest El. (feet)	682.1	683.1
Right Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1	2.5:1 / 2:1

2.2 Edenville Dam Failure

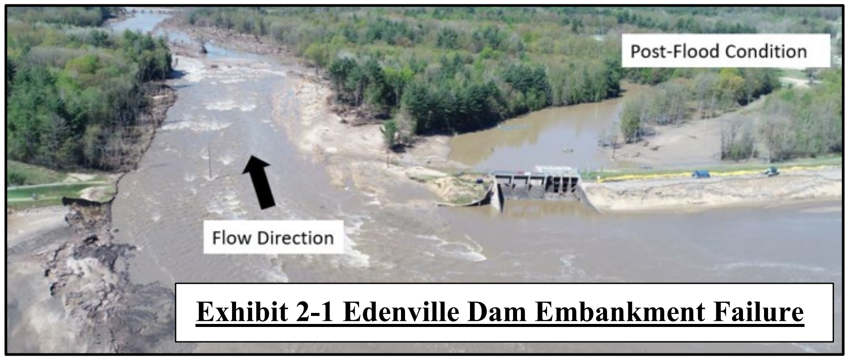


Exhibit 2-1 Edenville Dam Embankment Failure

Over a two-day period from May 16 to May 18, 2020, the Tittabawassee and Tobacco River watersheds incurred heavy rainfall totals, ranging from 6 to 8 inches concentrated in Gladwin and Midland Counties. Saturated ground conditions combined with additional rainfall starting in the evening of May 18th through the early afternoon of May 19th, 2020, resulted in the Tittabawassee and Tobacco Rivers surpassing flood stages in many areas. During the flood event, Boyce opened all six (6) Tainter Gates (Tobacco Bays No. 1 through No. 3, and Tittabawassee Bays No. 4 through No. 6) were opened (8 feet to 9 feet) to keep up with the flows of the Tittabawassee River. At approximately 5:30 p.m. Eastern Standard Time (EST), the Wixom Lake water surface elevation rose to El. 680.6 within 1.5 feet of the embankment crest (El. 682.1) and a portion of the left embankment failed due to saturation of the downstream shell and excessive seepage gradients that resulted in a downstream slope failure that breached the dam crest and caused an uncontrolled release of the reservoir.

The internal erosion failure of the left embankment resulted in a breach channel that extended approximately 500 feet from the left abutment to immediately adjacent to the Tittabawassee Tainter gate spillway. The flood wave was conveyed south through approximately 1,300-feet-long, 400-foot-wide and 40-feet-deep (from the former embankment crest) breach channel formed by the failure. The left embankment failure and breach channel are illustrated in **Exhibit 2-1**. During the failure, the Tittabawassee River side of the impoundment drained, rapidly forcing increased flow and velocities through the M-30 Bridge resulting in scour and erosion that eventually led to the failure of the M-30 Bridge (See **Exhibit 2-2**). The headwaters of the Tobacco River bypassed the limited capacity of the Tobacco Tainter gate spillway and head cut a breach channel that extended from the M-30 Bridge to the Tittabawassee River breach channel.


Exhibit 2-2 Tobacco Spillway and M-30 Highway Post Failure

The downstream embankment adjacent to the concrete training walls and toe of the embankment were severely damaged from high tailwater circulation, splash, and spray erosion above the downstream training walls. The splash and spray and high tailwater elevation resulted in significant erosion and loss of embankment material on the downstream embankment slope flanking the spillways with tailrace training wall lengths and heights (see **Exhibit 2-2**).

2.3 Reservoir Operations

Prior to the failure, the project was operated as a "run-of-river." Per the former FERC license, the reservoir is to be operated at a summer and winter elevation with three feet of difference. The summer headwater level is maintained higher with the normal summer level at elevation 675.8 feet. The winter headwater level is maintained lower with the normal winter level at elevation 672.8 feet. Currently, the Tainter gates are in the fully open position and Tittabawassee River bypasses the Tainter gate spillway through the breach channel at approximate Wixom Lake El. 645.0 ±. The Tobacco River is currently passing through the Tobacco spillway at approximate Wixom Lake El. 648.0 ±.

2.4 Edenville Dam Stabilization

The ongoing Edenville Dam interim stabilization consists of two construction phases as part of the State of Michigan EGLE, Water Resources Division Conditional Permit (Emergency Permit). The permit was issued on November 19, 2020, and includes permit conditions for Wixom Lake (Edenville Dam impoundment), and the Tobacco and Tittabawassee Rivers.

Exhibit 2-3 Phase I Interim Stabilization at Tobacco Spillway

Phase I construction of the Edenville Dam stabilization is currently underway on the Tobacco spillway and includes lowering the existing Tainter gate spillway, reinforcing the training walls and restoring the natural flow path of the Tobacco River. The Phase I construction is expected to be completed in in Summer 2021 (see **Exhibit 2-3**).

Phase II stabilization encompasses the Tittabawassee reach of the Edenville Dam. The primary goal of the Phase II stabilization task is to divert the Tittabawassee River flow from the current breach channel to the natural flow path through the existing spillway and river channel. Phase II is being designed under the FLTF in close coordination with EGLE. GEI is currently developing an alternatives analysis of four (4) potential stabilization approaches for the project. The four proposed stabilization alternatives are presented in **Table 3**. Alternative No. IV is the current preferred alternative that is being progressed toward final design and includes demolishing the

Tainter gate spillway, stabilizing the powerhouse and training walls and constructing a rock-filled berm with steel sheet pile in the left embankment breach channel. The concept drawings for the four alternatives are presented in **Appendix B** and the recommended Alternative No. IV is illustrated on **Exhibit 2-4** below.

Exhibit 2-4 Phase I Interim Stabilization Alternative IV Elevation View

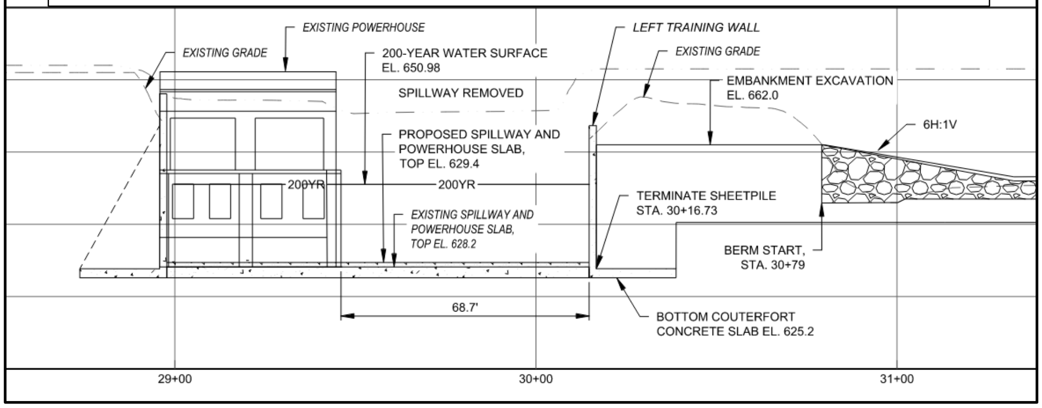


Table 3: Proposed Alternatives for Edenville Dam Interim Stabilization

Alternative No.	Description
I	Demolish powerhouse, spillway bays, and counterfort training walls down to the concrete slab. Concrete slab and apron to remain. Spillway side slopes graded with riprap and bedding; rock-filled berm to El. 652.0.
II	Demolish left training wall and Tainter gate spillway down to the concrete slab. Concrete slab, apron, and powerhouse to remain. Left spillway side slope graded with riprap bedding; rock-filled berm to El. 652.0.
III	Demolish left half powerhouse and Tainter gate spillway down to the concrete slab. Left training wall, counterforts, concrete slab, apron, and left half of powerhouse to remain. Existing embankment excavated to El. 662.0; rock-filled berm at El. 652.0.
IV	Demolish Tainter gate spillway down to the concrete slab. Left training wall, counterforts, concrete slab apron, and powerhouse to remain. Existing embankment excavated to El. 662.0; rock-filled berm at El. 652.0.

See the 2021 GEI Alternatives Evaluation Report – Edenville Dam Interim Stabilization report for more information (Ref. GEI, 2021b).

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 Edenville Dam project:

- Edenville Hydropower Plant Design Drawings, 1923
- Supporting Technical Information Document (STID), 2005
- 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 only used 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 during existing conditions (pre-failure) are summarized in **Table 4** 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 4: Edenville Dam Flood Routing Results – Existing Conditions

Parameter or Modeling Result	½ PMF	PMF
Peak Inflow (cfs)	41,260	116,525
Peak Outflow (cfs)	37,845	115,885
Maximum Reservoir El. (feet)	684.2	686.8
Freeboard (Dam Crest El. 682.1)	-2.1	-4.7

As indicated in **Table 4**, the Edenville Dam ½ PMF results in a peak inflow of 41,260 cfs, a maximum reservoir elevation of 684.2 feet, a peak discharge of 37,845 cfs and an overtopping depth of 2.1 feet. The PMF results in a peak inflow of 116,525 cfs, a maximum reservoir elevation of 686.8, a peak discharge of 115,885 cfs and an overtopping depth of 4.7 feet.

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 5** summarizes the results of the available PMF studies for the Secord, Smallwood, Edenville and Sanford Projects.

Table 5: 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 5**, the 2020 PMF study by Ayres 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, including the May 2020 flood event. 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 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 projects 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, we understand 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. 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.

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 conceptual 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 conceptual design phase, the selected IDF is the ½ PMF plus a 15% to 30% increase in peak inflow (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 peak inflows are summarized in **Table 6**.

Table 6: Summary of Inflow Design Flood (1/2 PMF + Design Storm)

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 labyrinth-type 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. 681.5 with 4.0 feet of freeboard below the dam crest.
- Reconstruct the embankments to minimum crest El. 685.5.
- 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 to assist in safely passing the ½ PMF + design storm without human intervention.
- The proposed auxiliary spillways 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 spillways. The winter pool drawdown will reduce ice loads on crest gates and auxiliary spillway labyrinth weir.

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.

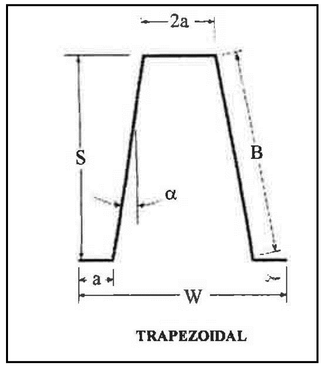
The effective length **L** of a spillway crest used in spillway discharge computations is expressed by the equation: $\mathbf{L = L' - 2(NK_p + K_a)\, H_e}$, where:

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 Labyrinth Spillways

Conceptual-level proposed labyrinth spillway rating curves were developed using the methods prescribed in *The Hydraulic Design of Labyrinth Weirs* (Ref. Falvey, 2003). The discharge characteristics of labyrinth weirs are primarily a function of the following:

- P – Weir Height
- S - Cycle Depth
- B – Cycle Length
- h – depth of flow over the weir
- W- Width of the weir
- L – Developed Length of the Labyrinth
- α – Wall Angle
- Crest Length, L = 2B+4a *ƒ*
- Magnification, M = L/W



The discharge can be expressed as Q = *ƒ* (h/P, L/W, α Shape). The supporting rating curve calculations are provided in **Appendix C**.

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 was 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 estimating 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 Edenville 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 new spillway configuration for Edenville Dam, the ½ PMF + design storm results in a peak inflow of 52,280 cfs, a maximum reservoir water surface at El. 681.2, a peak discharge of 47,000 cfs, and a minimum of 4.0-feet of dam crest freeboard at El. 685.5. The Edenville Dam ½ PMF + design storm inflow, outflow, and stage hydrographs are shown on **Figure 2**. Based on the configuration described above, the proposed Edenville Dam spillway configuration would have sufficient discharge capacity to safely pass the ½ PMF + design storm with over 4.0 feet of freeboard.

The proposed Edenville Dam crest gate 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 up to a headwater level of El. 681.2, 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. 651.0, which is approximately 8.8 feet lower than the spillway crest El. 659.8; therefore, the tailwater submergence ratio 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 7**.

Table 7: Edenville Dam Flood Routing Results – Proposed Conditions

Parameter or Modeling Result	½ PMF + Design Storm
Initial Water Surface El. (feet)	675.8
Peak Inflow (cfs)	52,280
Peak Outflow (cfs)	47,000
Maximum Reservoir El. (feet)	681.2
Freeboard (Dam Crest El. 685.5)	4.3

The Highway 30 (M-30) causeway that separates the Tobacco and Tittabawassee sides of Wixom Lake was modeled based on the Temporary M-30 bridge alignment included in the MDOT bridge plans dated October 28, 2020. The overall bridge span is approximately 234 feet with a clear span of 204 between the temporary steel sheet piling on the north and south abutments. The HEC-RAS model results suggest that the headwater during the ½ PMF + design storm is at El. 682.0 on the Tobacco side and El. 681.7 on the Tittabawassee side, resulting in a headwater differential of 0.3 feet. Approximately 7,000 cfs is bypassed through the M-30 bridge during the ½ PMF + design storm to route the excess flows from the Tobacco side to the labyrinth auxiliary spillway on the Tittabawassee side (see **Figure 4**). These results suggest that the construction of the temporary M-30 bridge does not significantly impact or hydraulically limit the spillway capacity of the proposed labyrinth auxiliary spillway on the Tittabawassee River portion of the project. However, during the ½ PMF + design storm, the M-30 causeway bridge is likely overtopped and would potentially cutoff dam operator and emergency vehicle access during extreme flood events. We understand that the M-30 causeway will be temporary, and a new permanent M-30 causeway bridge will be constructed in the future. The FLTF have engaged initial discussions with MDOT regarding flood levels during the design storm and will provide hydraulic flood routing results prior to the planning and design of the permanent bridge crossing.

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 Edenville Tainter gate spillway and powerhouse will be demolished and the three (3) Tainter gate spillway bays will be replaced with hydraulically operated crest gates at sill El. 659.8 to increase the spillway capacity. Each gate will be 24-feet wide by 16-feet high. The hydraulic gate operators will be supported on new, reinforced concrete piers. The gates will discharge into a concrete rollway and new reinforced concrete stilling basin. The leftmost powerhouse bay will be converted into an additional crest gate bay and the rightmost draft tube bay converted to a low-level outlet. Remaining sections of hollow bays and water passages will be filled with mass concrete. The proposed design drawings for the spillway improvements are provided in **Appendix D**.

The Tobacco Dam Tainter gate spillway will be partially demolished and the three (3) Tainter gates will be replaced with automated hydraulically operated crest gates at El. 659.8 to increase spillway capacity. The left and right crest gates (Bay No. 3 and Bay No. 1) will be 18.3-feet wide by 16-feet high and the center crest gate (Bay No. 2) will be 15.5-feet wide by 16-feet high. A new low-level outlet structure will be constructed as a means to pass base river flow. The proposed design drawings are provided in **Appendix D**.

4.2 Auxiliary Spillway

A new reinforced concrete 250-foot-wide 12-cycle labyrinth auxiliary spillway will be constructed at El. 678.0 within the former left embankment of the Edenville Dam to provide additional spillway capacity during the ½ PMF + design storm. The proposed spillway structure will discharge through a 250-foot-wide concrete spillway chute. The new chute slope would be constructed at 2.5H:1V. To meet current freeboard requirements, the new chute walls will vary from approximately 30-feet high downstream of the labyrinth spillway to approximately 20-feet high in the steep portion of the chute. The new chute reinforced concrete slab would be a minimum of 2-feet thick and would have an upstream sheet pile cutoff extended into the glacial till foundation and would include an appropriate sand filter and gravel underdrainage system to reduce hydrostatic uplift. A concrete cutoff wall would also be constructed at the downstream end of the auxiliary spillway chute for scour protection. The overflow spillway will discharge into a 250-foot wide USBR Type III stilling basin to dissipate energy and to reduce scour and erosion in the discharge channel. Further downstream of the stilling basin, the ½ PMF + design storm is routed approximately 1,200 feet downstream to the confluence with the Tittabawassee River through the Edenville Dam breach channel. The proposed design drawings are provided in **Appendix D.**

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 the Edenville Dam to minimize active daily ice management. For the long-term reconstruction, we are proposing to retrofit the existing powerhouse to pass base flows (200 to 300 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. The low-level outlet conceptual design was developed by GEI, Essex and SGI. The proposed low-level outlet design consists of the following:

- Demolish the leftmost turbine bay.
- Fill the abandoned sluice bay below the rightmost right powerhouse intake with either cellular grout or mass concrete.
- The total impoundment drawdown potential is from El. 675.8 to El. 647.2 ±.
- Construct new vertical slide gates with integrated bulkhead slots upstream of existing head gate.
- Remove the generator, turbine shaft, and wicket gates.
- Construct a new steel bulkhead over the runner pit in the powerhouse floor slab.
- Affix (weld) the runner in place to the new bulkhead.
- Re-establish the trash racks upstream of the vertical slide gates.
- The upstream slide gates will be used to throttle base flows to pass 200 to 300 cfs.
- 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 powerhouse modifications is illustrated on Drawing C-13 included in **Appendix D.**

4.4 Tobacco Low-Level Outlet

The low-level outlet for the Tobacco River side could be a HDPR siphon over the crest of the dam designed to pass 200 to 300 cfs, or a low-level outlet could be installed in a mass pour under one of the crest gates.

4.5 Embankment Modifications

The former left embankment will be re-constructed with a minimum 15-foot crest width at El. 685.5 and minimum 2.5H:1V upstream and downstream slopes to provide adequate stability in accordance with EGLE stability requirements under normal and flood pool loading criteria. A hot-rolled steel sheet pile cutoff with interlock sealants will be provided along the upstream edge of the crest and be founded in the clay glacial till to provide a continuous seepage cutoff. A vertical filter sand chimney immediately downstream of the sheet pile cutoff and a horizontal filter and blanket drain will be provided under the downstream embankment shell to provide additional seepage conveyance and protection against seepage-induced internal erosion. Appropriately sized riprap and bedding layers to prevent internal erosion (e.g., nonwoven geotextile under bedding stone under the upstream slopes and reverse sand the gravel layer under the bedding stone on downstream slopes) will also be provided along the upstream and downstream slopes to protect against drawdown, wave-induced erosion and high tailwater, respectively. The former right embankment will be reconstructed with a new permanent steel sheet pile cutoff and extend into the clayey glacial till to provide a seepage cutoff. General site plans and cross sections for the Edenville Dam rehabilitation are provided in **Appendix D**.

4.5.1 Embankment Fill

New embankment fill will be used to reconstruct the downstream slope of the embankment sections. The embankment fill will consist of material either salvaged from on-site excavations or imported from an approved off-site source, as required. All cobbles greater than 2/3 the lift thickness (e.g., remove cobbles larger than 8 inches for 12-inch lifts) will be screened out. The 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 term 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.

4.5.2 Reverse Filter and Toe Drain

A vertical chimney drain and horizontal blanket drain consisting of filter sand and drainage stone will be constructed downstream of the sheet pile cutoff and at the embankment – foundation contact, respectively, to mitigate against seepage and internal erosion of the embankment and foundation soils. The toe drain will generally consist of 18 inches of fine filter (MDOT 2NS natural sand) and 24 inches of coarse filter (MDOT 29A stone). The seepage will be collected in a minimum 8-inch diameter slotted 0.1 inch) flexible HDPE pipe surrounded by coarse filter material. The purposes are: 1) to provide an outlet to convey seepage toward the outlet to keep the phreatic surface from rising within the reverse filter, and 2) to collect and direct seepage flow entering the reverse filter to the downstream weir box so the flow volume and potential fines movement can be collected and monitored.

4.5.3 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 apron 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 upstream 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, labyrinth weir, chute stilling basin). The structural design criteria applicable to these structures are described in the following sections.

Geotechnical explorations, standard penetration test sampling, pressuremeter testing and soil-structure analyses will be performed at the Tobacco and Edenville Spillway Dam structures to quantify bearing capacity, subgrade moduli and estimate settlement of glacial till foundation 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 the steel crest gate and operators are installed. Based on Fisher's measurements at the lowered Tobacco Spillway weir, the 15.5 feet of new mass concrete caused the two piers and training walls to settle 0.3 inches with no observed distress to the wall and piers. Our design approach for the two spillways will be to model new normal or lightweight concrete on the existing spillway mat with and without grouted 100 to 200 ton battered drilled and grouted steel micropiles 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 extensions 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. The right training wall of the powerhouse has completely failed into the discharge channel and needs to be replaced.

5.1.1 Stability Analyses

Stability analyses of the multiple spillway training walls, spillway overflows, 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*.

5.1.2 Reinforced Concrete Design

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

5.2 Material Properties

The following material properties will be used to calculate the 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 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 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 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 two primary and one 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 8**:

Table 8: 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 two gravity spillway dams. 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 9**.

Table 9: 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 Low-Level Outlet (Retrofitted Powerhouse Floatation)

The required factors of safety for uplift (flotation) stability (FERC Load Case 1A) in accordance with FERC Engineering Guidelines Chapter 10 are shown in **Table 10**.

Table 10: Required Factors of Safety for 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

Based on available information, subsurface explorations and investigations were completed in 1924, 1987, 2005, 2010, 2020 and 2021.

The first exploration program was completed in 1987 by Soils and Materials Engineers, Inc. (SME) to evaluate the stability of the Tobacco right embankment. The exploration consisted of four borings (Borings 1 through 4) near Station 48+00 and laboratory strength and index testing (Ref. SME, 1987). The embankment fill consisted of a mixture of very loose to loose fine to medium sand, silty sand and silt. The embankment fill was underlain by an approximately 5-foot layer of medium dense native silty sand foundation soil and hard sandy clay till below.

A 2005 subsurface exploration was completed by McDowell & Associates and consisted of four borings. Borings 1 and 2 were located near Station 3+25 on the Tittabawassee left embankment and Borings 3 and 4 were located near Station 18+25 on the Tittabawassee right embankment (Ref. M&A, 2005-1). Boring 1 log dated July 6, 2005, was provided in the 2010 Liquefaction Analysis by Mill Road Engineering (Ref. Mill Road, 2010); however, no record of the other three borings was included. At Boring 1 near Station 3+25, very loose to loose sand, silty sand and silt fill was encountered to approximately 14 feet below the embankment crest. Soft to stiff clay fill was encountered to 31 feet where medium dense silty fine sand was encountered. A 2-foot layer of medium dense gravelly sand was encountered overlying the hard sandy clay till at approximately 38 feet. Note: that the embankment fill and most of the native foundation soils were lost downstream during the 2020 left embankment failure.

A second subsurface exploration was completed by McDowell & Associates in 2005 (Ref. M&A, 2005-2) and consisted of two borings near Station 3+00 on the Tittabawassee left embankment. Boring 1 was completed on the embankment crest and Boring 2 completed at the toe. Borings 1 and 2 were converted to Well Nos. 42A and 42B, respectively. The embankment fills generally consisted of loose to medium dense fine to medium sand and silty sand. Native dense sand and sand and gravel was encountered over hard sandy clay till.

Additional borings were performed by McDowell and Associates as part of the 2010 Liquefaction Analysis by Mill Road Engineering (Ref. Mill Road, 2010). The logs of two borings, Nos.1 and 2 each dated December 6, 2010, were included. Borings 1 and 2 were noted to have been completed at the toe of dam and top of dam, respectively. It is assumed that these borings were completed near Station 3+25 on the Tittabawassee left embankment; however, the actual locations of these borings are unknown as no boring location plan was found. Similar to the 2005 Boring 1, very loose to loose silty sand and silt overlying soft clay at 13 feet was encountered in the 2010 Boring 2 on the crest. The soft clay, with layers of silt and sand was generally present to 34 feet where medium dense native sand was encountered. Hard clay till was encountered at approximately 37 feet. The conditions reported at the 2010 Boring 1 at the embankment toe were consistent with the 2010 Boring 2 at the crest. Note: that the embankment fill and most of the native foundation soils were lost downstream during the 2020 left embankment failure.

A subsurface exploration was complete by Somat Engineering (Ref. Somat, 2020) to support designs to stabilized both the Tobacco and Tittabawassee sections after the 2020 breach. Two borings were completed at each structure. Boring Nos. 01 and 02 were completed from the crest and toe, respectively, of the Tobacco right embankment. Boring 03A was completed from the crest of the Tittabawassee right embankment. Boring 04 was completed from the left abutment adjacent to the Tittabawassee left embankment breach channel. A laboratory test program was also performed to estimate material strength and index properties. The Tobacco borings confirmed the results of the 1987 SME borings. The embankment fill consisted of very loose to loose, poorly graded fine to medium sand embankment material underlain by similar native fine and fine to medium sand, and then hard clayey till. Similar conditions were also encountered in the Tittabawassee left embankment boring B-03A. The Tittabawassee right embankment boring B-04 encountered very loose to loose granular fill overlying a layer of native stiff to very stiff clay and loose to medium dense sand. Hard clayey till material was encountered at depth.

As noted in the 2021 Alternatives Evaluation Report by GEI (Ref. GEI, 2021), two (2) test pits were performed on January 28, 2021, on the left side of the Tittabawassee spillway breach area upstream and downstream of the former left embankment alignment. The test pits were excavated from a ground surface about 1-foot above the breach flow at approximately El. 645 feet. Test Pit 1, located upstream of the left embankment historic and planned footprint, was excavated to a depth of 11 to 13 feet. Test Pit 2 was located downstream of the left embankment footprint, and excavated to a depth of 11 to 12 feet. The test pits were excavated into the glacial till comprised of dense clayey sands, clayey silts, and clayey gravels. Minor groundwater seeps entered the pits during the period of excavation through isolated fine sand layers.

6.2 Existing Stability Analyses

The stability of the Tobacco left embankment was first evaluated as part of the 1987 Geotechnical Evaluation Report by SME (Ref. SME, 1987). Material properties were developed from laboratory strength testing. The embankment section was evaluated for two loading conditions: normal headwater level at El. 670 feet and surcharge headwater level at El. 671.5 feet. The section was analyzed for circular arc failure surfaces using the Modified Bishop Method. The results indicated a factor of safety (FS) of 1.4 and 1.3 for the two loading conditions, respectively. The report recommended that a weighted and/or graded filter be implemented to improve the factor of safety and reduce the risk for piping.

In 2009, Mill Road Engineering performed stability analyses of the proposed embankment flattening and toe drain system planned near Station 48+00 of the Tobacco right embankment (Ref. MRE, 2009). The material properties used in the analysis were interpreted from the 1987

SME evaluation. The embankment was analyzed using the computer program PC STABLE6 for normal headwater EL. 670 feet and maximum headwater El. 683 feet. A rapid drawdown analysis was also performed on the upstream slope where headwater was rapidly lowered from normal or maximum headwater level down to the gate sill El. 655.8 feet. The section was analyzed for circular arc failure surfaces using the Modified Janbu Method.

The results of the analyses indicated normal pool FS=1.53 and maximum pool FS=1.40, and rapid drawdown FS=1.32 and 1.30 for normal pool and surcharged pool, respectively.

Given the limited information available and that all embankments will require significant repairs, we recommend that additional subsurface exploration be performed to inform the designs of these repairs. The stability of all embankment sections should be evaluated based on the results of the additional exploration and the new designs. The stability should be performed using more current software (i.e., GeoStudio) and utilize moment and force equilibrium method of analysis (i.e., Spencer or Morgenstern Price). We recommend the final scope for additional subsurface explorations be developed at a later date, and be based on the proposed repairs. The analyses show factors of safety summarized in **Table 11**.

Table 11: Summary of Embankment Stability

Loading Condition	Computed FS	FERC Required FS
Downstream Normal Pool	2.12	1.5
Downstream Earthquake at Normal Pool	1.76	1.0
Downstream Maximum Pool	1.80	1.5
Upstream Rapid Drawdown	0.95	1.2

6.3 Proposed Embankment Stability

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 (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 input into 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 the Spencer and 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.

6.4 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.

6.5 Material Properties

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

6.6 Phreatic Surface Assumptions

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

6.7 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

For the purposes of this report, we assumed the Phase I and Phase II stabilization construction is complete, and the Tobacco and Tittabawassee Rivers have been restored to their natural flow paths and project structures have been stabilized. For the long-term reconstruction of Edenville Dam, the anticipated upstream and downstream cofferdams for the Tobacco and Tittabawassee Rivers are as follows:

<u>Tobacco River</u>
The proposed upstream and downstream cofferdam design consists of internally braced steel sheet piles (SSP) with interlock sealants. The cofferdam cells can be constructed in three (III) phases at each bay. Phase I requires both an upstream and downstream cofferdam and is constructed at the

left Bay No. 3 to allow construction of the new concrete rollway, left pier, and left crest gate while Spillway Bays No. 1 and No. 2 remain open to pass base river flow. Phase II requires both an upstream and downstream cofferdam and would occur at Spillway Bay No. 1 while Spillway Bay No. 2 and the newly constructed Spillway Bay No. 3 pass base river flow. Phase II includes construction of the new concrete rollway, right pier and right crest gate. Finally, Phase III would occur at Spillway Bay No. 2 while Spillway Bays No. 1 and No. 3 pass base river flow. The 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 required to be installed prior to dewatering, which will require some underwater diver assisted installations. Steel 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, or the internal pier. The conceptual design is included in **Appendix E.**

Tittabawassee River

The proposed upstream and downstream cofferdam designs will consist of a combination of SSP I-Walls and hot-rolled flat pan SSP circular cellular cofferdams. The new spillway Tittabawassee spillway structures will be constructed in two phases. Phase I includes construction of a 70-foot-wide temporary bypass channel, consisting of tied-back or cantilevered SSP walls, to temporarily divert the Tittabawassee River flows around the left end of the former Tainter gate spillway while the new gated spillway is under construction. Phase II includes construction of cellular cofferdams upstream and downstream of the powerhouse and spillway to allow construction of the low-level outlet and new crest gate spillway while the stabilized bypass channel remains open to pass base river flow. Phase II also includes construction of I-Wall cofferdams upstream and downstream of the rock-filled berm across the breach channel in the former alignment of the left embankment. Phase II will allow reconstruction of the left embankment, labyrinth spillway and spillway chute. The conceptual design of the Tittabawassee cofferdams is included in **Appendix E**.

7.3 Reservoir Operations During Construction

The reservoir is currently drawn down to approximately El. 648 ± on the Tobacco River side and 640 ± on the Tittabawassee River side. 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 phases:

- Tobacco Phase I – Pass base river flow through Spillway Bays No. 1 and No. 2 while constructing the new Spillway Bay No. 3 left crest gate and concrete rollway.
- Tobacco Phase II – Pass base river flow through Spillway Bays No. 2 and No. 3 while constructing the new Bay No. 1 right crest gate and concrete rollway.
- Tobacco Phase III – Pass base river flow through Spillway Bays No. 1 and No. 3 while constructing the new Bay No. 2 center crest gate and concrete rollway.
- Tittabawassee Phase I – Pass base river flow through the former Tainter gate spillway concrete apron while constructing the new bypass channel.
- Tittabawassee Phase II – Pass base river flow through the bypass channel while constructing the Phase II cofferdams, new low-level outlet, gated spillway, left embankment, and labyrinth auxiliary spillway.

7.5 Anticipated Construction Sequence

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

Tobacco River

1. Phase I Edenville Interim Stabilization (Tobacco Portion) by AECOM and Fisher. Stabilize Tobacco Spillway structure, re-establish the Tobacco River through the Tobacco spillway, and stabilize flanking earth embankments by spring 2021.

2. Contractor mobilization from right abutment (Hunter Road) and develop laydown and contractor work areas.

3. Install the new sheet pile cutoff along the upstream edge of the left and right embankment crests, as shown on the drawings.

4. Construct rehabilitation repairs to the left and right embankments, including installation of filter sand, drainage stone, toe drains and additional embankment fill.

5. Install a temporary braced cofferdam upstream of Tainter Spillway Gate Bay No. 3 and downstream in the stilling basin area. Construct the reinforced concrete stepped chute, ogee crest, stilling basin overlay and new downstream stilling basin end sill. Install reinforcement and construct the widened left pier. Raise and extend the left spillway wall. Install the left crest gate, hydraulic operator, and controls. Test and commission the left gate.

6. Remove the upstream and downstream cofferdams from Spillway Bay No. 3 and relocate to Bay No. 1. Repeat Step 5 and commission the new right crest gate.

7. Remove the upstream and downstream cofferdams from Spillway Bay No. 1 and relocate to the center Bay No. 2. Construct the final segment of the reinforced concrete stepped chute, ogee crest, stilling basin overlay and new downstream stilling basin end sill. Install the center crest gate, hydraulic operator and controls. Test and commission the center gate.

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

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

Tittabawassee River

1. Phase II Edenville Interim Stabilization (Tittabawassee Portion) by GEI and Fisher. Demolish Tainter gate spillway, and stabilize left training wall, concrete slab, powerhouse, and right embankment. Construct rock-filled berm across breach channel and re-establish the Tittabawassee River through the former spillway.

2. Contractor mobilization from M-30, develop laydown and contractor work areas.

3. Construct temporary minimum 70-foot-wide braced cofferdam section through the rock-filled berm adjacent to the left counterfort training wall. Construct a minimum 70-ft wide structurally reinforced bypass channel slab and training walls within the temporary cofferdam.

4. Cut down the steel sheet pile in front of the bypass channel and divert Tittabawassee River base flow from the former Tainter gate spillway.

5. Construct circular 40-foot diameter SSP cellular cofferdams upstream and downstream of the former Tainter gate spillway and powerhouse. The circular cofferdams will have seal cells tied into upstream and downstream training walls.

6. Cut down the right embankment adjacent to the powerhouse to allow construction crane and material access to both upstream cofferdams.

7. Demolish the powerhouse superstructure and remove the turbine shaft, generator set and associated appurtenant mechanical and electrical equipment from within the powerhouse.

8. Cut down the barrel arch concrete upstream of the powerhouse intake to El. 651.6, fill the hollow structure with mass concrete, and install a new reinforced cast-in-place cap at the intake elevation upstream of the existing headgate.

9. Construct a new slide frame, slide gate and steel hoist frame structure downstream of the powerhouse intake and trash racks. Construct repairs to the powerhouse intake and outlet walls, intake, and draft tube outlet concrete, as needed. Raise and extend the left outlet

works retaining wall. Test and commission the new low-level outlet gate at the powerhouse.

10. Construct the new reinforced concrete spillway including stepped chute to El. 659.8, ogee crest, stilling basin overlay and new downstream stilling basin. Raise and extend the left and right training walls. Install the new crest gates, hydraulic operators, and controls.
11. Install new pre-engineered spillway operator's deck.
12. Concurrent with Step 5, construct I-Wall cofferdam upstream and downstream of the rock filled berm across the breach channel in the former alignment of the left embankment.
13. Reconstruct the former left embankment, including installation of new steel sheet pile cutoff wall, filter sand, drainage stone, toe drains, embankment fill and upstream riprap and bedding.
14. Construct the new auxiliary labyrinth spillway, concrete chute, stilling basin and place riprap.
15. Install the new sheet pile cutoff along the upstream edge of the right embankment crests, as shown on the drawings. Construct rehabilitation repairs to the right embankments, including installation of filter sand, drainage stone, toe drains and additional embankment fill.
16. Install temporary cofferdam upstream of the bypass channel and divert flow into the new crest-gated spillway. Close off the former bypass channel with new steel sheet pile cutoff extending to the left training wall. Finish rehabilitation of the left embankment including installation of filter sand, drainage stone, toe drains and embankment fill.
17. Install site instrumentation (piezometers, settlement points, etc.).
18. Site restoration and contractor demobilization.
19. Refill Wixom Lake and monitor performance and record instrumentation and deformation point performance on a routine basis.

8. Opinions of Probable Construction Cost

8.1 30% Design Cost Analysis

An engineer's opinions of probable construction costs (OPCC) were developed for the Edenville 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 Edenville Dam to pass the ½ PMF + design storm was approximately **$121** million. A summary of the ½ PMF + design storm OPPC for the Edenville project is summarized in **Table 12** and cost estimate worksheets are provided as **Appendix F**.

Table 12: Summary of Opinion of Probable Construction Costs

Item	Description	Estimated Cost
0.00	General Conditions	$ 6,163,000
1.00	Site Preparation, Cofferdams & 70 ft wide Edenville Bypass Channel	$ 33,250,000
2.00	Site Demolition (Spillway and Powerhouse)	$ 3,418,000
3.00	Edenville Left Embankment Repair and Stabilization	$ 3,489,000
4.00	Edenville Right Embankment Repair and Stabilization	$ 14,535,000
5.00	Tobacco Embankments Repair and Stabilization	$ 12,137,000
6.00	Edenville Crest Gate Spillway and Outlet Works	$ 7,958,000
7.00	Tobacco Crest Gate Spillway and Outlet Works	$ 4,695,000
8.00	Powerhouse Rehabilitation	$ 2,250,000
9.00	Labyrinth Auxiliary Spillway Structure	$ 3,213,000
10.00	Discharge Channel	$ 170,000
11.00	Site Restoration	$ 1,500,000
	Subtotal	$ 92,778,000
	Contingency (25%)	$ 23,195,000
	Construction Subtotal	$ 15,973,000
	Site Investigations, Engineering, Permitting and Construction Management	$ 5,000,000
	Total Estimated Cost	**$ 120,973,000**

8.2 Closing

Our opinions of probable cost 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.

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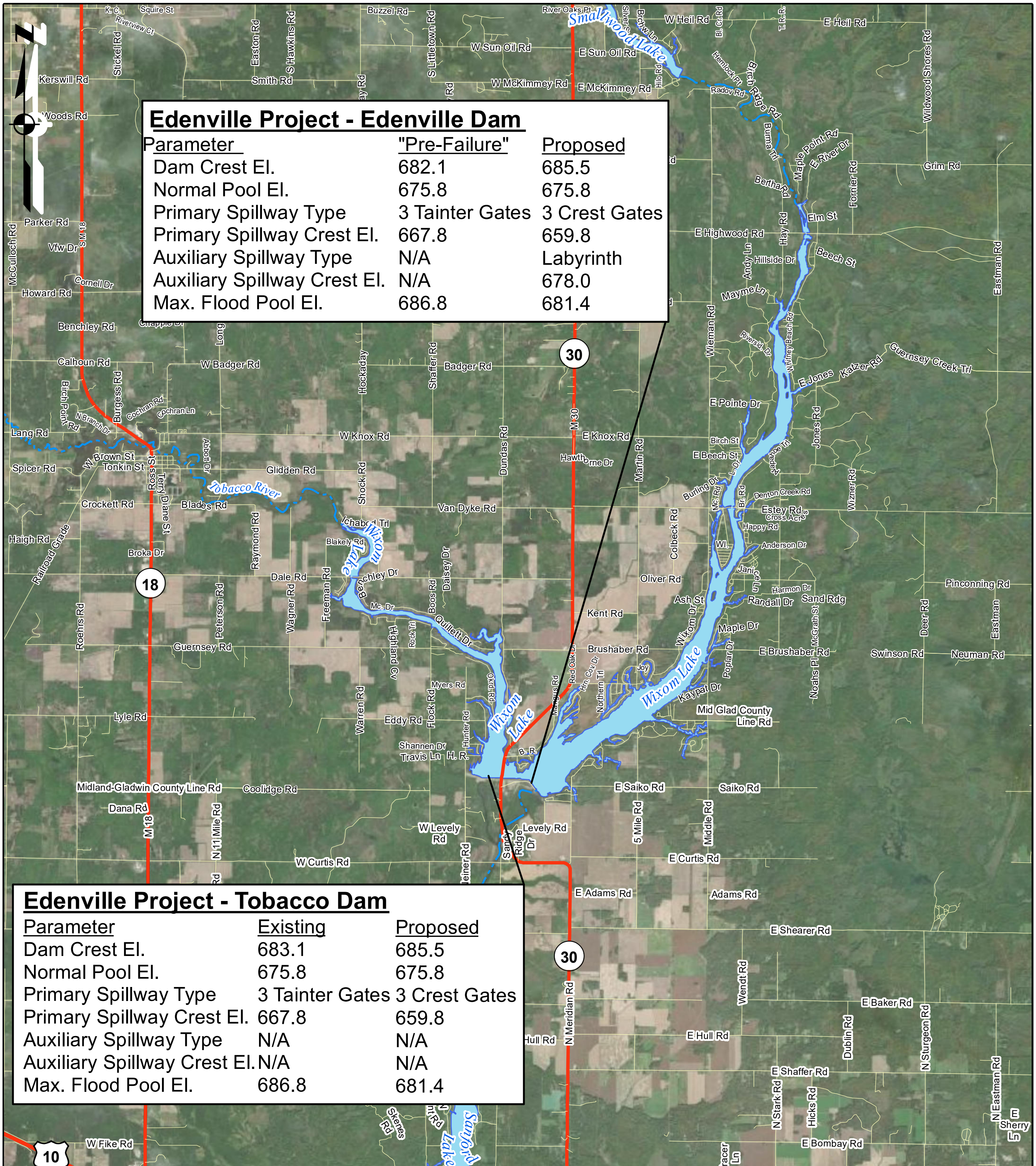
Figures



Edenville Project - Edenville Dam

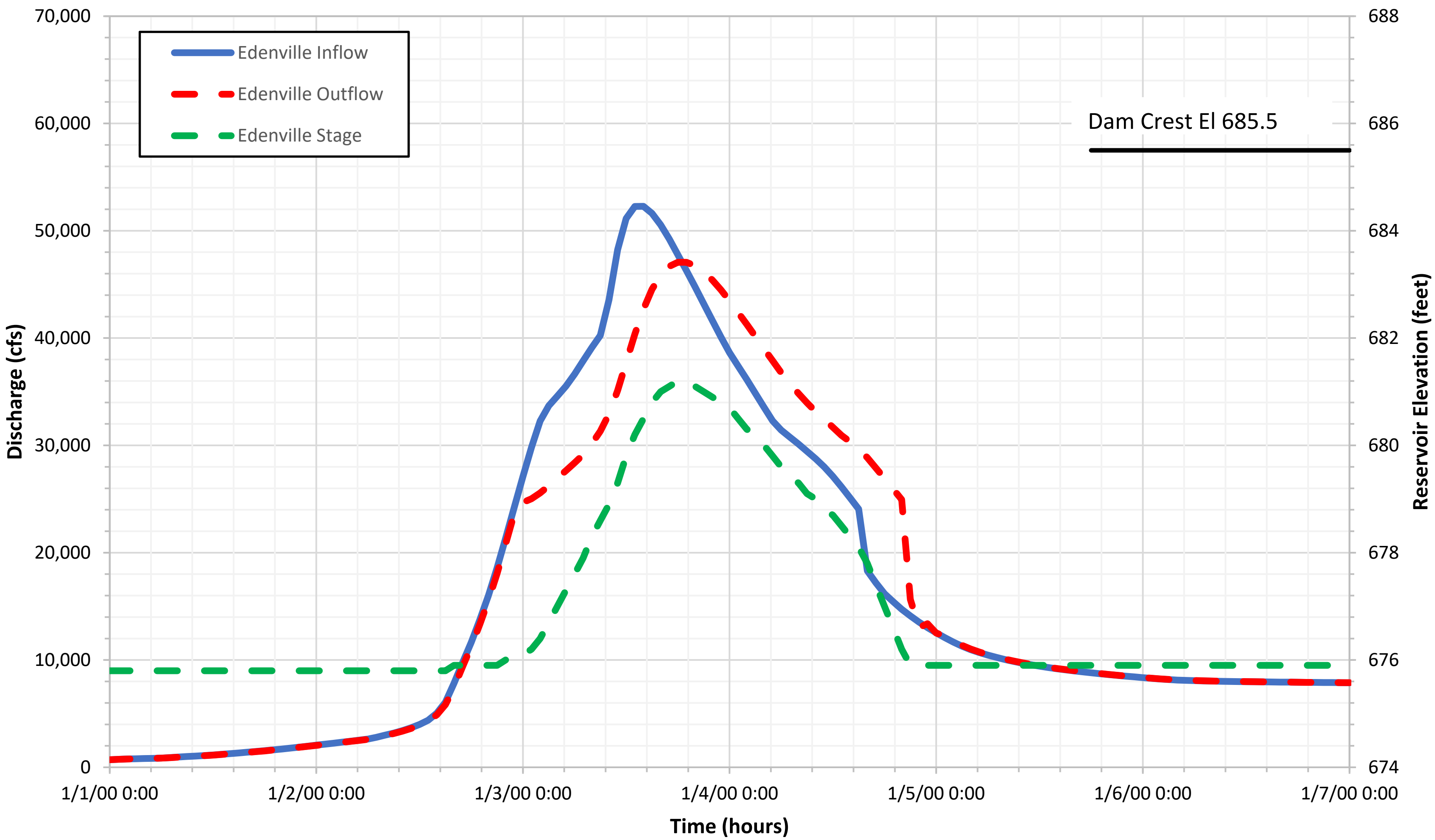
Parameter	"Pre-Failure"	Proposed
Dam Crest El.	682.1	685.5
Normal Pool El.	675.8	675.8
Primary Spillway Type	3 Tainter Gates	3 Crest Gates
Primary Spillway Crest El.	667.8	659.8
Auxiliary Spillway Type	N/A	Labyrinth
Auxiliary Spillway Crest El.	N/A	678.0
Max. Flood Pool El.	686.8	681.4

Edenville Project - Tobacco Dam

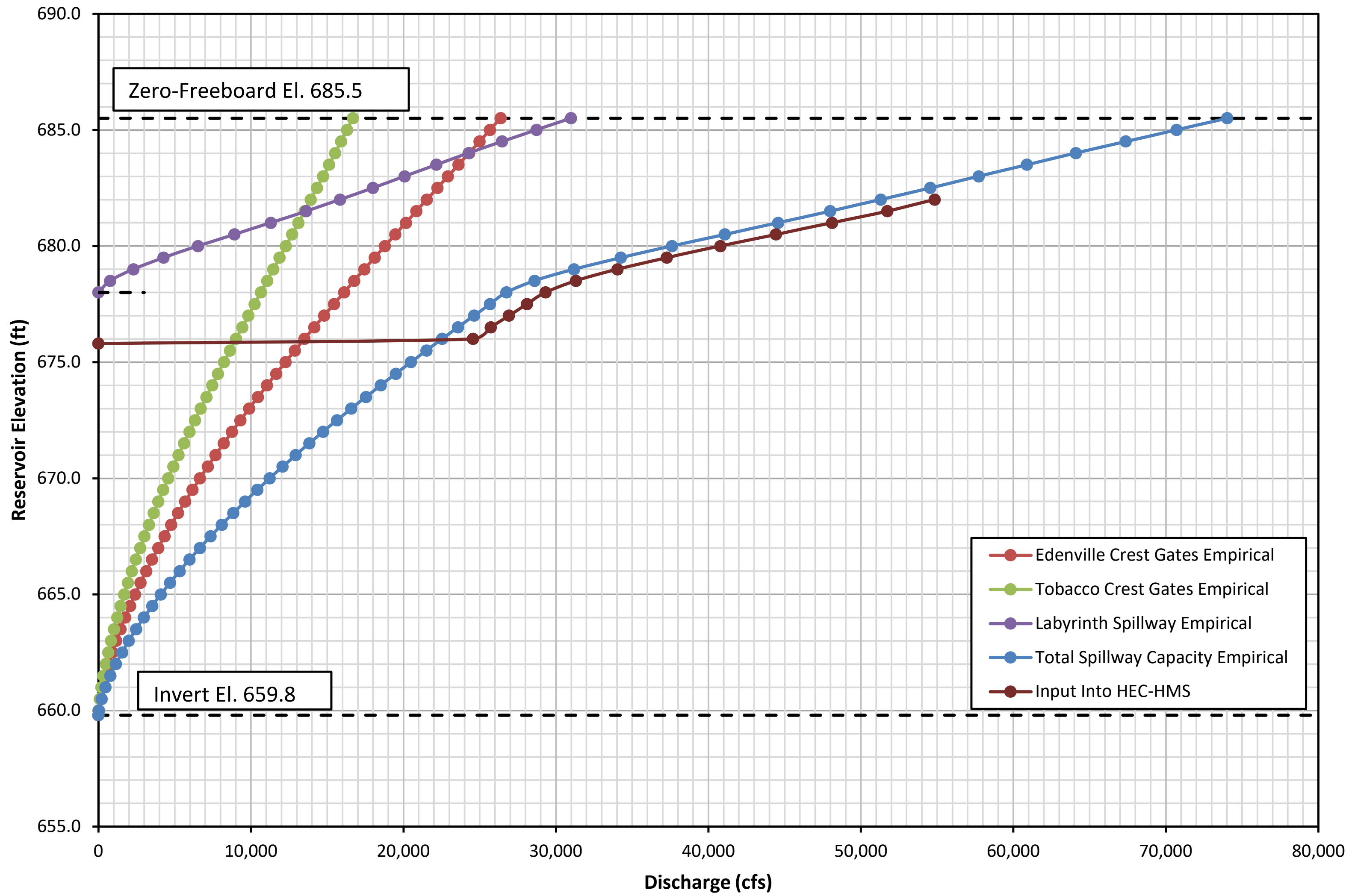
Parameter	Existing	Proposed
Dam Crest El.	683.1	685.5
Normal Pool El.	675.8	675.8
Primary Spillway Type	3 Tainter Gates	3 Crest Gates
Primary Spillway Crest El.	667.8	659.8
Auxiliary Spillway Type	N/A	N/A
Auxiliary Spillway Crest El.	N/A	N/A
Max. Flood Pool El.	686.8	681.4

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

Conceptual Design Basis Report Edenville Dam	GEI Consultants	EDENVILLE DAM SITE LOCATION MAP
Four Lakes Task Force Gladwin and Midland County, Michigan	Project 2002879	March 2021 Figure 1



Edenville 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**

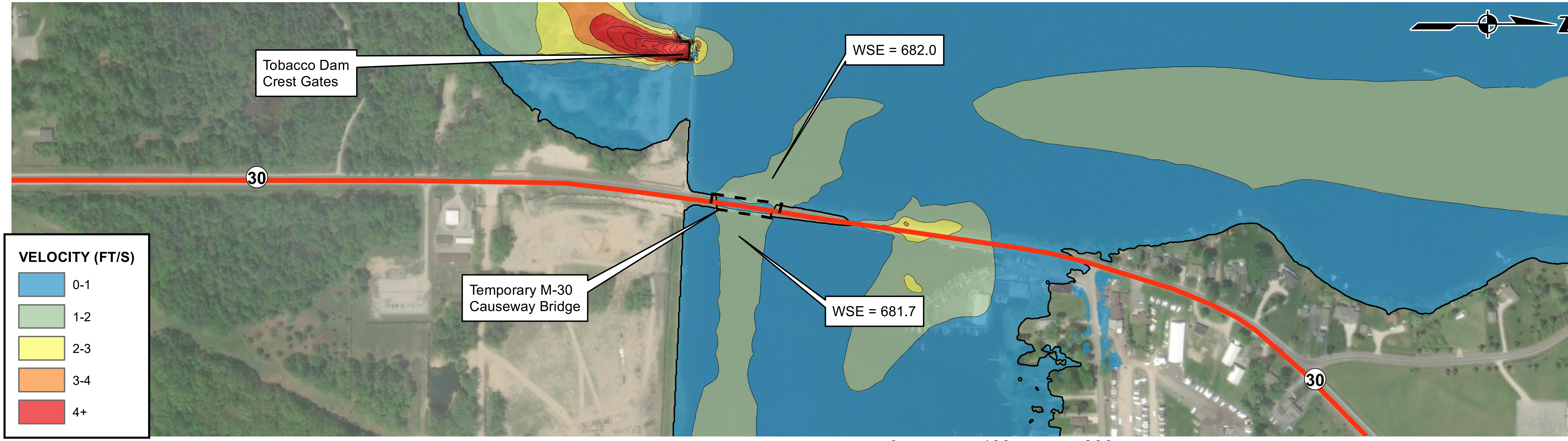


Edenville Dam
Client: Four Lakes Task Force
Location: Gladwin County, Michigan

GEI Consultants

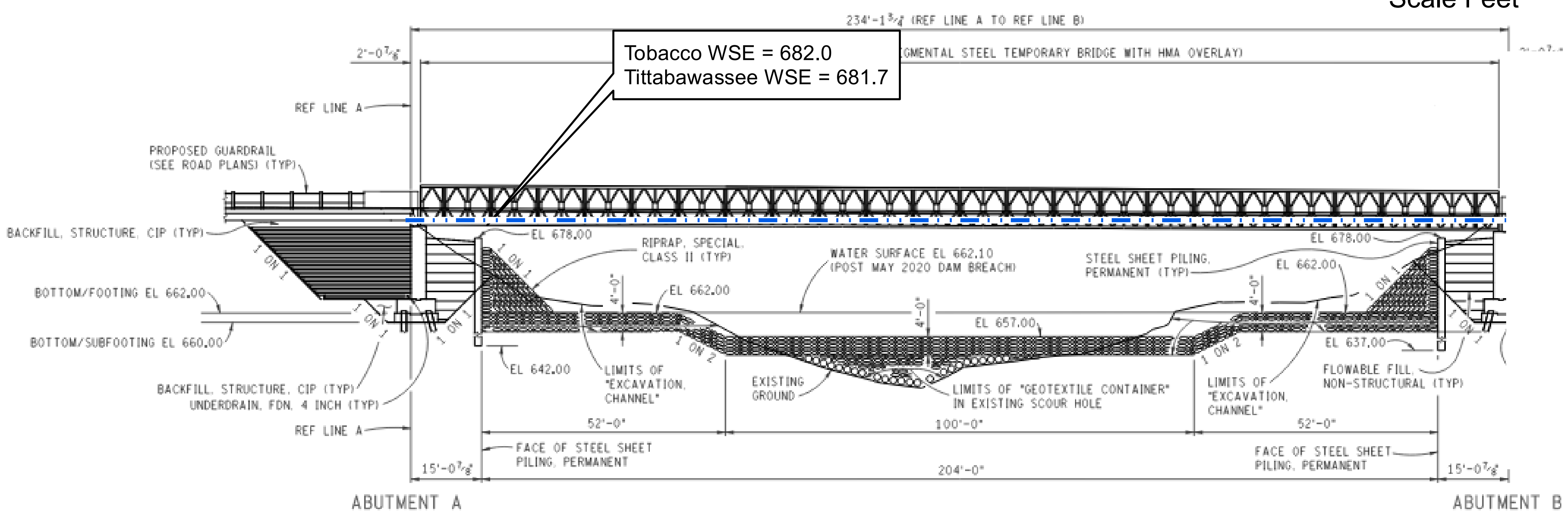
Edenville Dam 1/2 PMF + Spillway Rating Curves

Project 2002879	**March 2021**	**Figure 3**

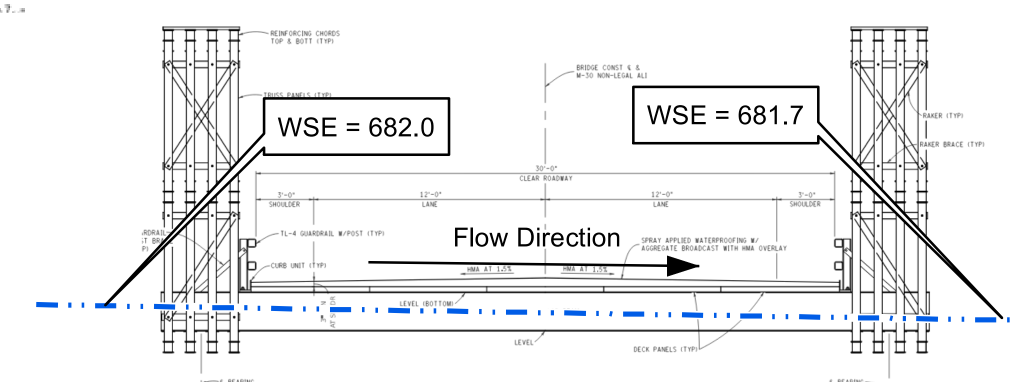


PLAN
M-30 CAUSEWAY VELOCITY

0 400 800
Scale Feet



ELEVATION
M-30 CAUSEWAY WATER SURFACE
NOT TO SCALE



SECTION
M-30 CAUSEWAY WATER SURFACE
NOT TO SCALE

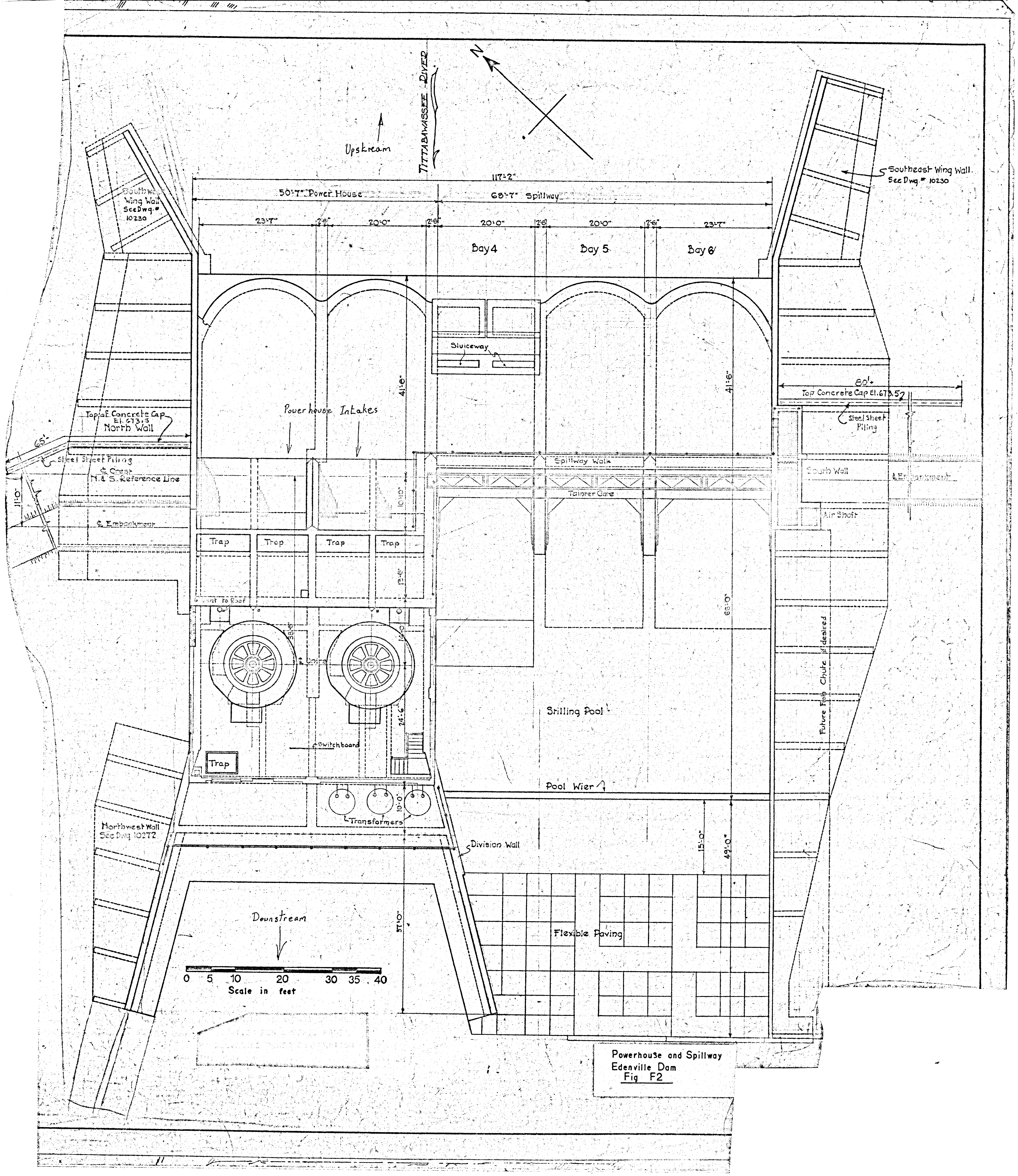
Notes:
1. All elevations referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). The acronym "El." represents Elevation.

Conceptual Design Basis Report Edenville Dam	GEI Consultants	EDENVILLE DAM M-30 CAUSEWAY BRIDGE FLOOD ROUTING
Four Lakes Task Force Gladwin and Midland County, Michigan	Project 2002879	March 2021 Figure 4

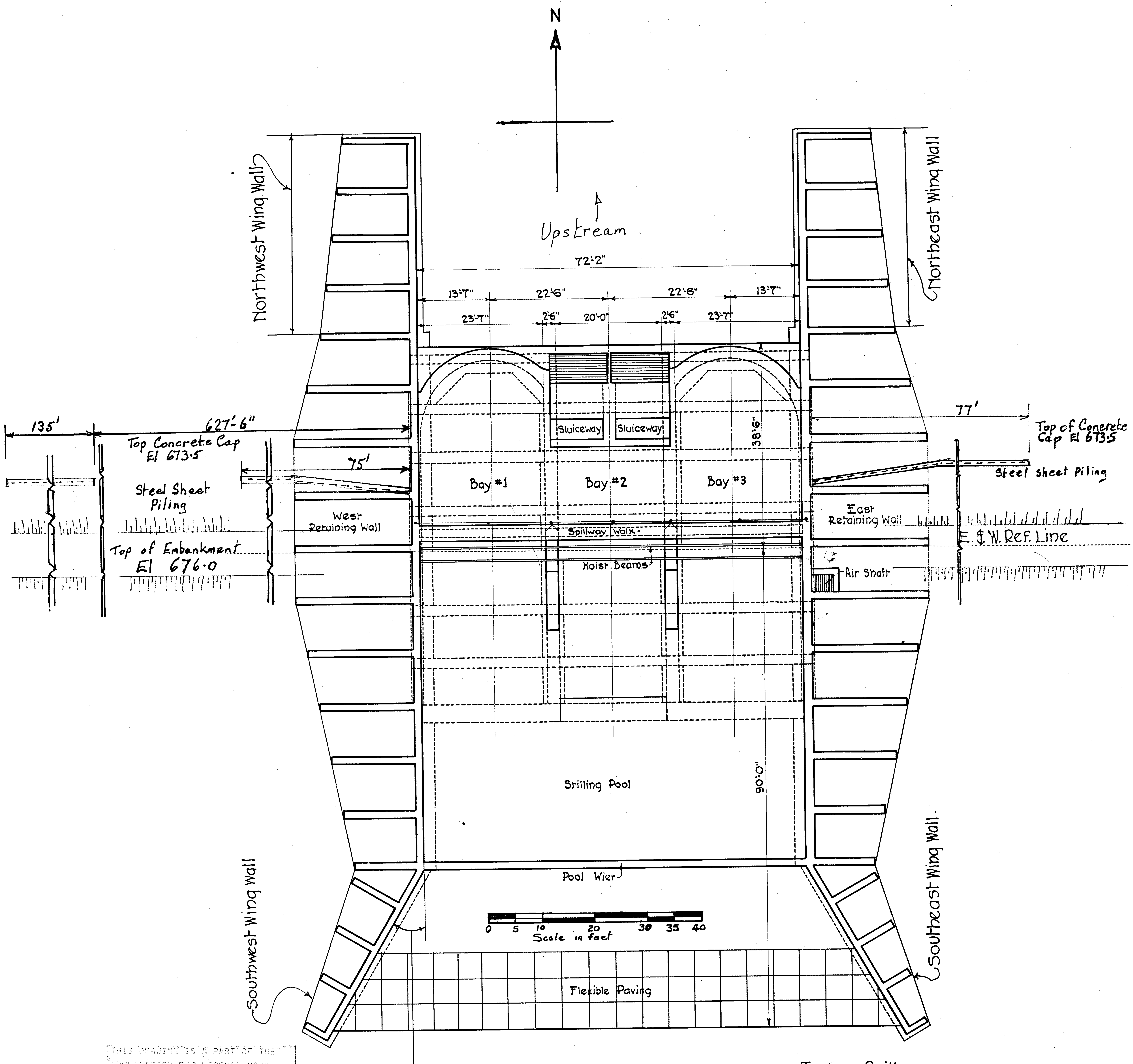
Appendix A

Exhibit F Drawings

N.
W.
E.
S
Canal
Bottom at El. 660±
TOBACCO RIVER
TITTABAWASSEE RIVER
GLADWIN CO. 35
MIDLAND CO. 2
36
1
TOBACCO TWP.
EDENVILLE TWP.
Scale in Feet (1" = 200')
2 - Generators 3750 K.V.A. each
2 - Turbines 3900 H.P. each @ 45' Hd.
SECTION THRU POWER HOUSE
SECTION THRU SPILLWAYS
PLAN OF POWER HOUSE
SECTION THRU CANAL
SECTION THRU EMBANKMENT
Pond El. 671.5
POWER HOUSE SECTION FIG. F4
SPILLWAY SECTION FIG. F5
EXHIBIT B2
WOLVERINE POWER CORPORATION.
EDENVILLE PLANT
PLAN AND SECTIONS
HOLLAND, ACKERMAN & HOLLAND
Consulting Engineers
Ann Arbor
CHICAGO
Scale: 1" = 200' / 30'
MARCH, 192
7606

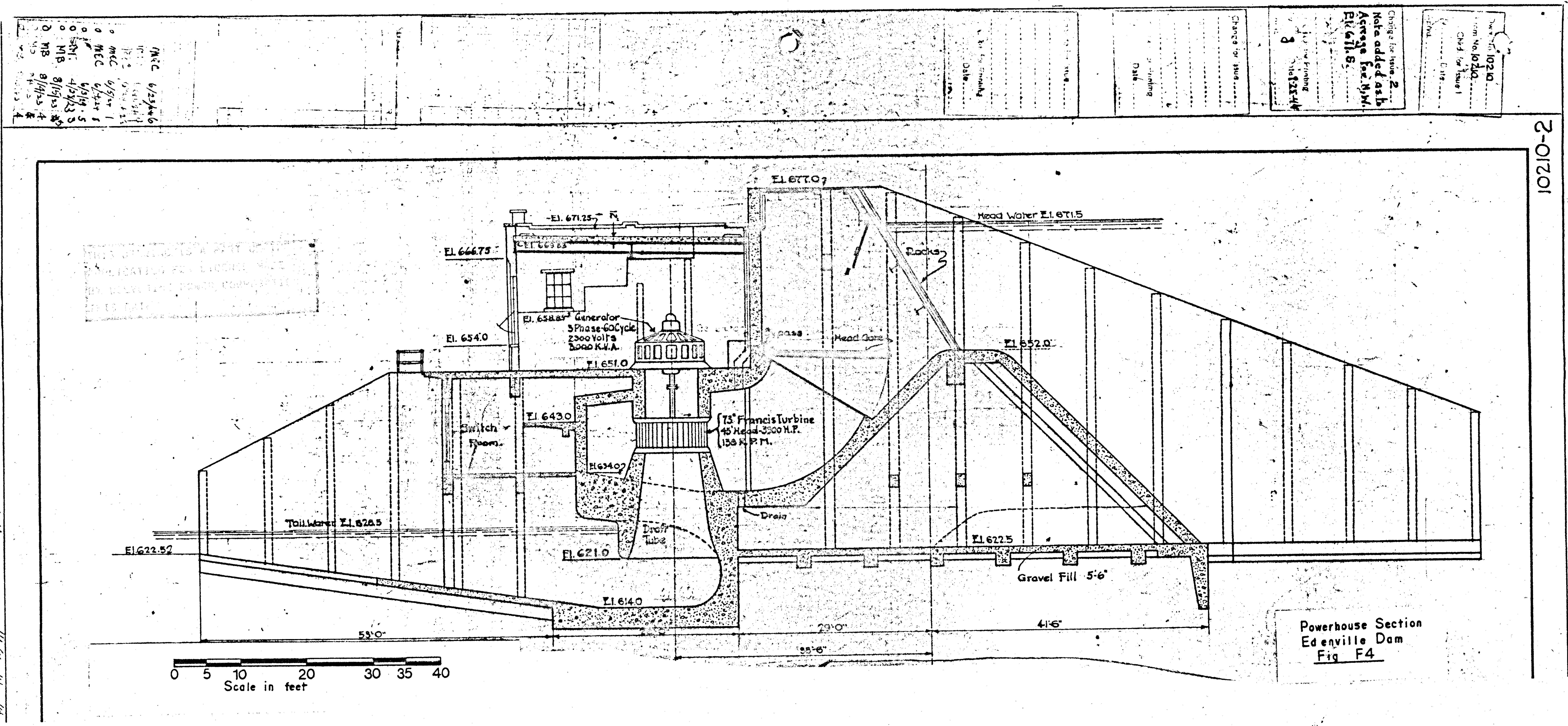


Powerhouse and Spillway
Edenville Dam
Fig F2

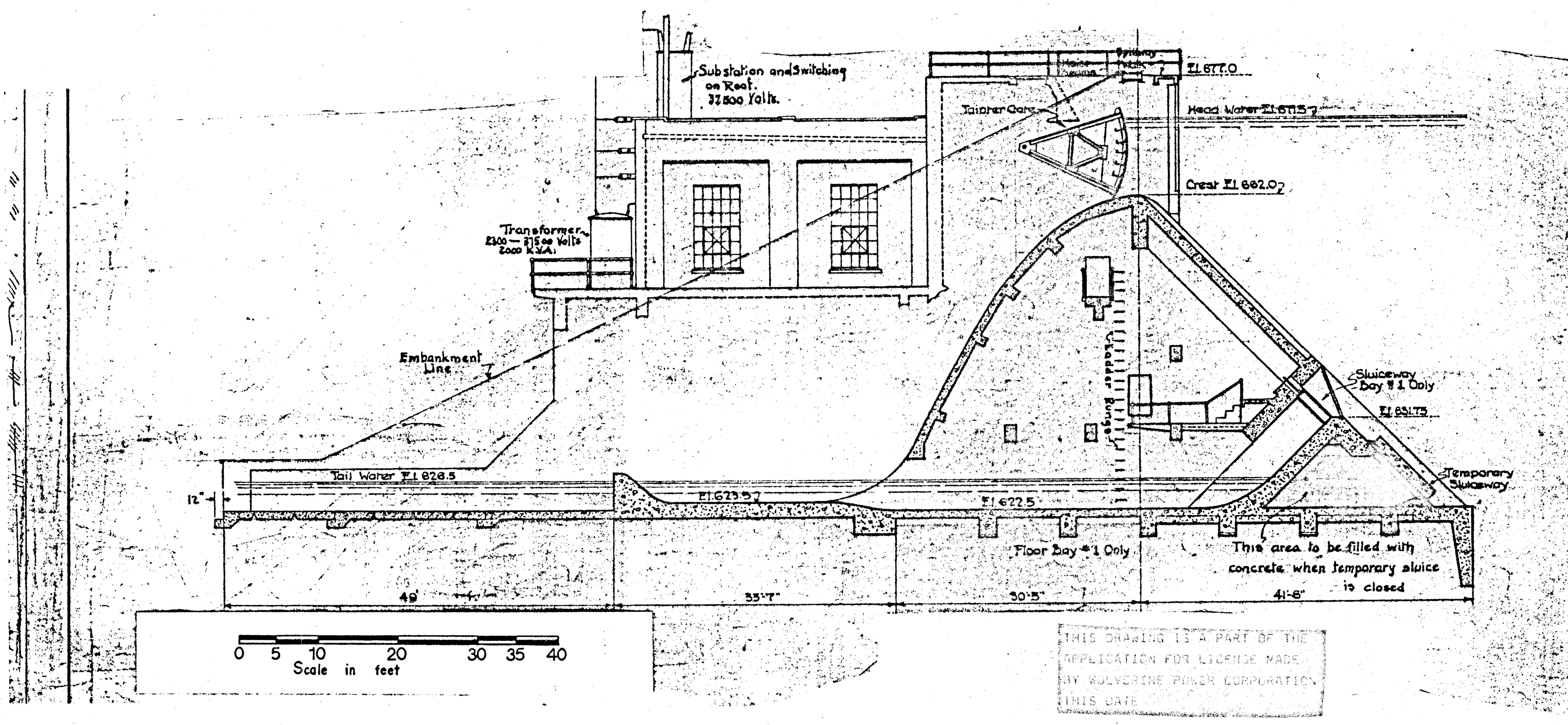


Tobacco Spillway
Edenville Dam
Fig F3

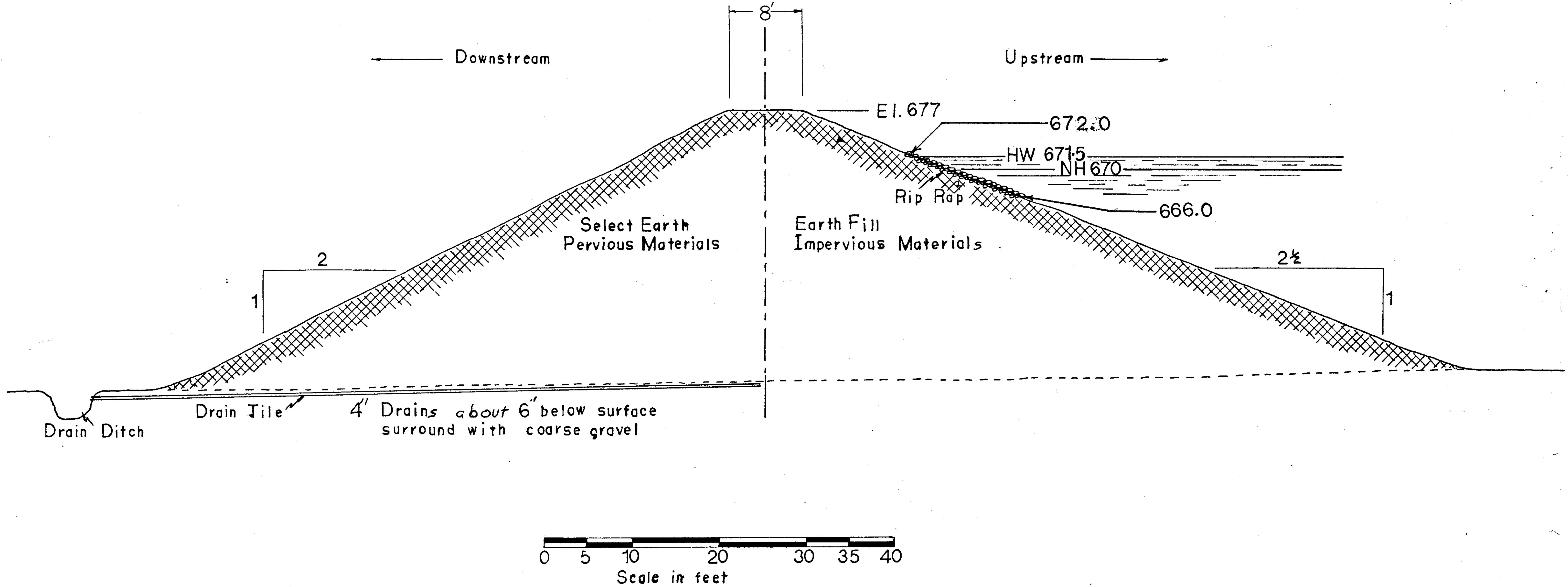
NOTE:-Angles of all wing walls to be determined in Field.



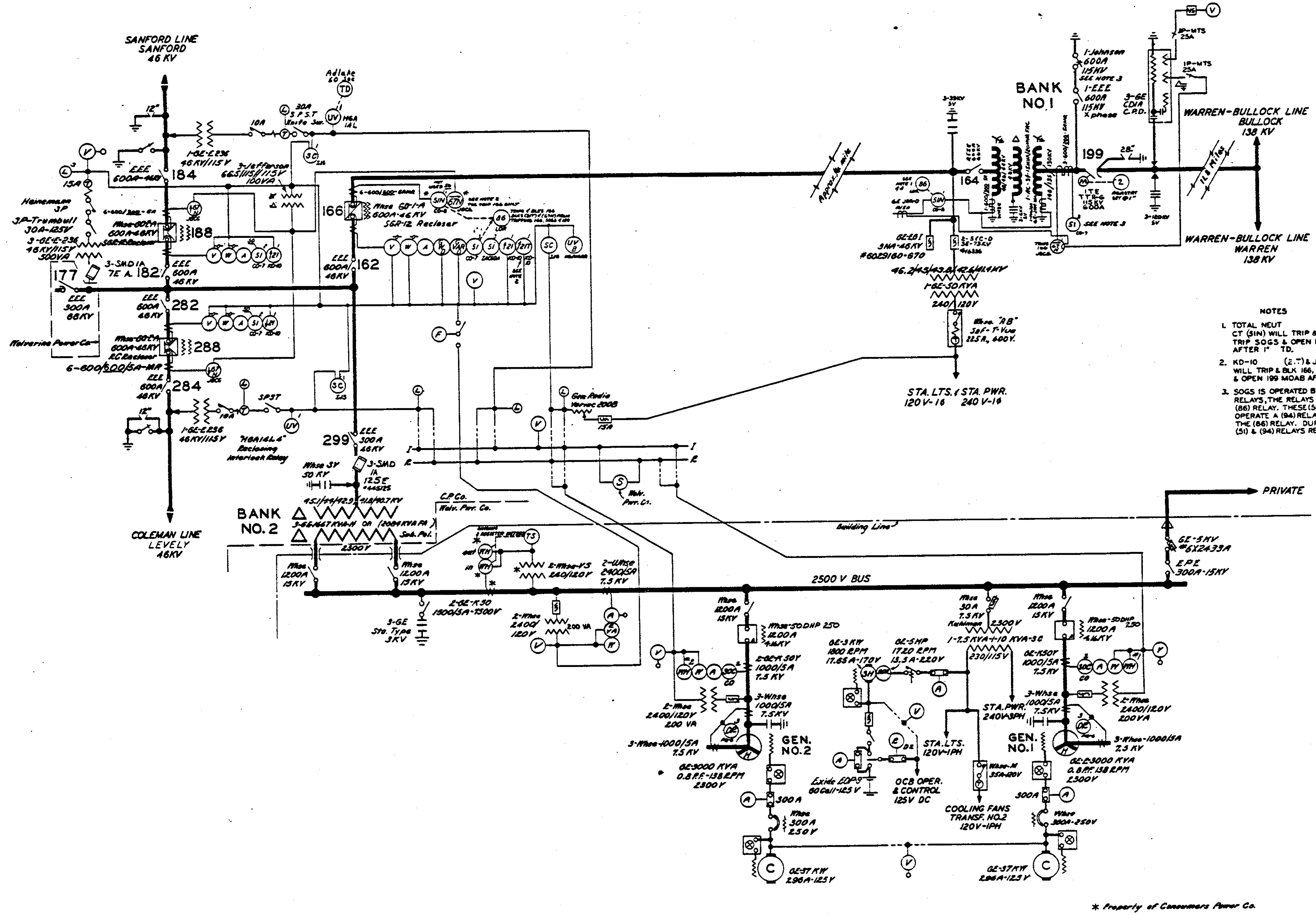
Powerhouse Section
Edenville Dam
Fig F4



Spillway Section
Edenville Dam
Fig F5



Embankment Section
Edenville Dam
Fig F6



NOTES

1. TOTAL NEUT
CT (51N) WILL TRIP & BLK 166,
TRIP SOGS & OPEN 199 MOAB
AFTER 1" TD.
2. KD-10 (2.T) & JBCC IOC (67N)
WILL TRIP & BLK 166, TRIP SOGS
& OPEN 199 MOAB AFTER 1" TD
3. SOGS IS OPERATED BY THE TB1 (51) RELAYS, THE RELAYS IN NOTE 2 & THE TB1 (86) RELAY. THESE (51) RELAYS ALSO OPERATE A (94) RELAY WHICH OPERATES THE (86) RELAY. DURING TEST THE (51) & (94) RELAYS REMAIN IN SERVICE.

REV AU 7-5-88 GTW APP.
MAINT 34CI-32ST.3
OCB 166 - ADDED LOR (86)

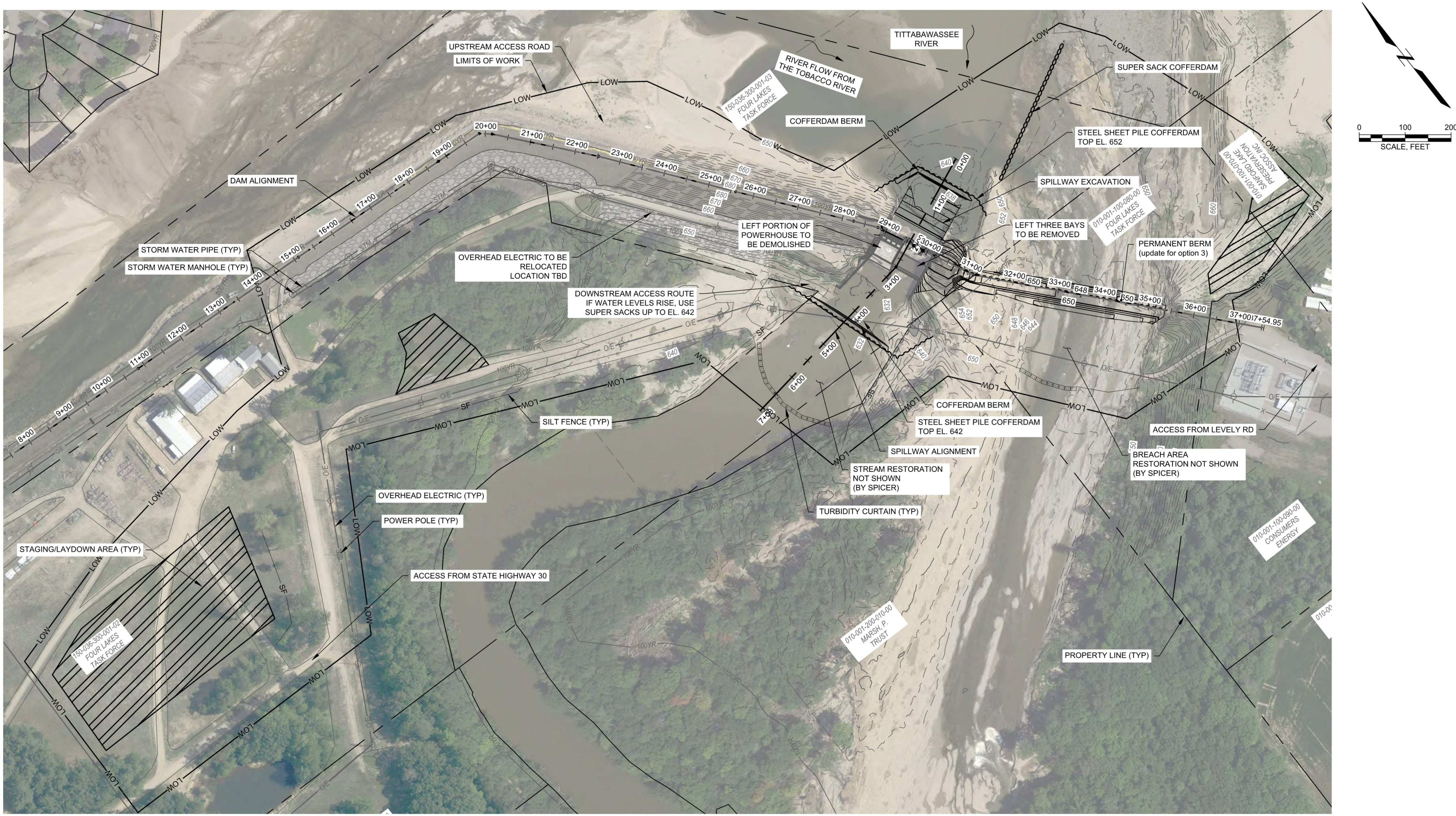
IN CCH
BATTERY – MCGRAW-EDISON, 3MEA-75, 24CELL, 75AH, 48V DC
BATTERY CHARGER – MCGRAW-EDISON, EBC48-10, 10A, 48V DC
IN SUB AT PLANT
BATTERY – EXIDE, 60-CA-9, 200AH, 125V DC
BATTERY CHARGER – PCP, SD-130-25, 125VDC, 25A
REMOTE ALARM TO SAGINAW POWER CONTROL

Fig. F7

DR GTWATTERS	3-5-81	CONSUMERS POWER CO. ELECTRIC ENGINEERING DEPARTMENT JACKSON, MICHIGAN	EDENVILLE DAM
APP E R Longm...	3-11-81		T EDENVILLE IMLNE
APP P Lolich	3-11-81		C REGION
APP S Grana-Girard	3-11-8·	CORRECTED TO 7-5-88 AU	NO. WD136 SHEET 1

Appendix B

Preliminary Phase II Interim Edenville Dam Stabilization Drawings



NOT FOR CONSTRUCTION

SOURCE:

1. EXISTING GROUND LIDAR SURFACE, SUPPLIED FROM SPICER, WAS FLOWN JUNE 1, 2020. ADDITIONAL CONTOURS WERE SUPERIMPOSED WITHIN THE BREACH AREA, UPSTREAM AND DOWNSTREAM OF SPILLWAY USING CONTOUR LOCATIONS TAKEN FROM THE AECOM'S EDENVILLE DAM MODIFICATIONS AND STABILIZATION MEASURE PROJECT PLAN SET, FILE NO. 761/21007.SAR.
2. AERIAL PHOTOGRAPH, SUPPLIED FOR SPICER, SHOWS PROJECT SITE ON JULY 2, 2020.

SURVEY NOTES:

1. HORIZONTAL COORDINATE ZONE: NAD83 MICHIGAN STATE PLANE, SOUTH ZONE, INTERNATIONAL FOOT
2. VERTICAL DATUM: NAVD88

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

Designed:	KP
Drawn:	TC/MS
Checked:	AB
Approved:	WW
P.E. No:	XXXXXX
GEI Project	2002879

GEI Consultants
GEI CONSULTANTS, INC.
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G100
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(414)930-7540

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Saginaw, MI 48607 Tel.
989-754-4717 Fax.
989-754-4440
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EDENVILLE DAM PROJECT
TITTABAWASSEE SPILLWAY AND BREACH TEMPORARY REPAIRS

GLADWIN COUNTY, MICHIGAN

NO	DATE	ISSUE/REVISION	APP
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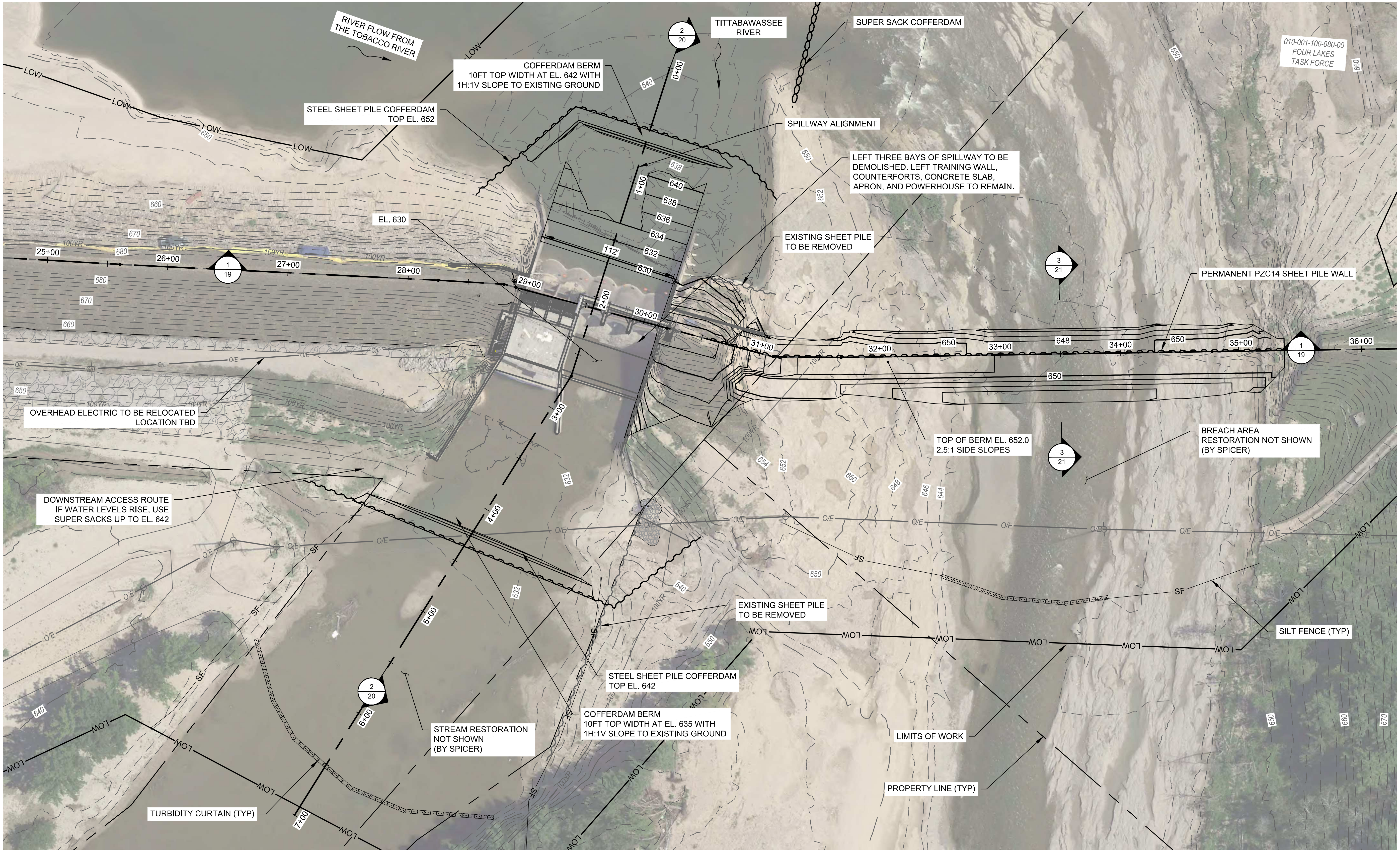
SHEET NAME: SITE PLAN - OPTION 4

SHEET NO.:

\\geiconsulta B:\Working\FOUR LAKES TASK FORCE\2002879 Post-May 2020 Flood Services\00_CAD\Design\Sheets\Options 1, 2, 3\Option 4\Site Plan - Option 4.dwg - 2/10/2021



NOT FOR CONSTRUCTION

SOURCE:

1. EXISTING GROUND LIDAR SURFACE, SUPPLIED FROM SPICER, WAS FLOWN JUNE 1, 2020. ADDITIONAL CONTOURS WERE SUPERIMPOSED WITHIN THE BREACH AREA, UPSTREAM AND DOWNSTREAM OF SPILLWAY USING CONTOUR LOCATIONS TAKEN FROM THE AECOM'S EDENVILLE DAM MODIFICATIONS AND STABILIZATION MEASURE PROJECT PLAN SET, FILE NO. 761/21007.SAR.
2. AERIAL PHOTOGRAPH, SUPPLIED FOR SPICER, SHOWS PROJECT SITE ON JULY 2, 2020.

SURVEY NOTES:

1. HORIZONTAL COORDINATE ZONE: NAD83 MICHIGAN STATE PLANE, SOUTH ZONE, INTERNATIONAL FOOT
2. VERTICAL DATUM: NAVD88

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

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Approved:	WW
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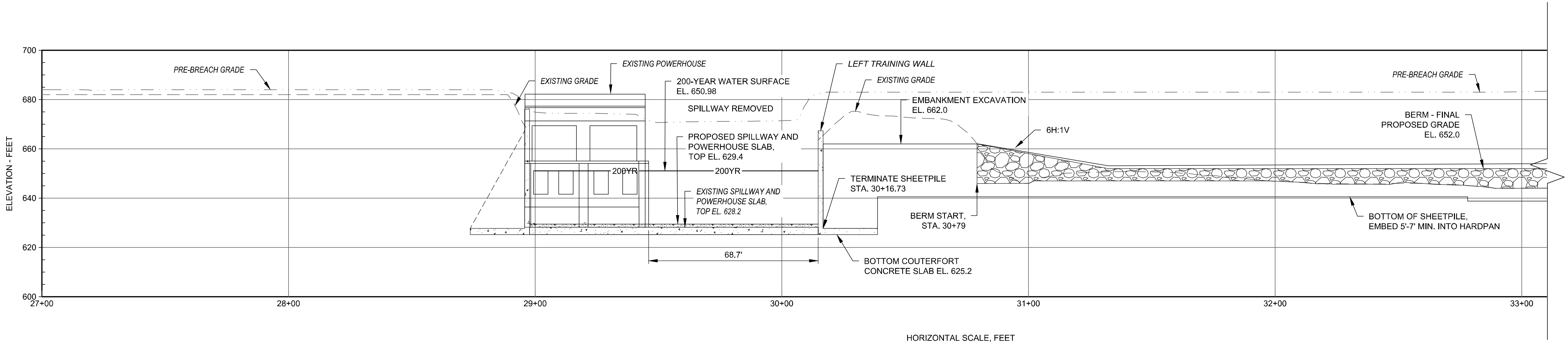
GLADWIN COUNTY, MICHIGAN

NO	DATE	ISSUE/REVISION	APP
0			

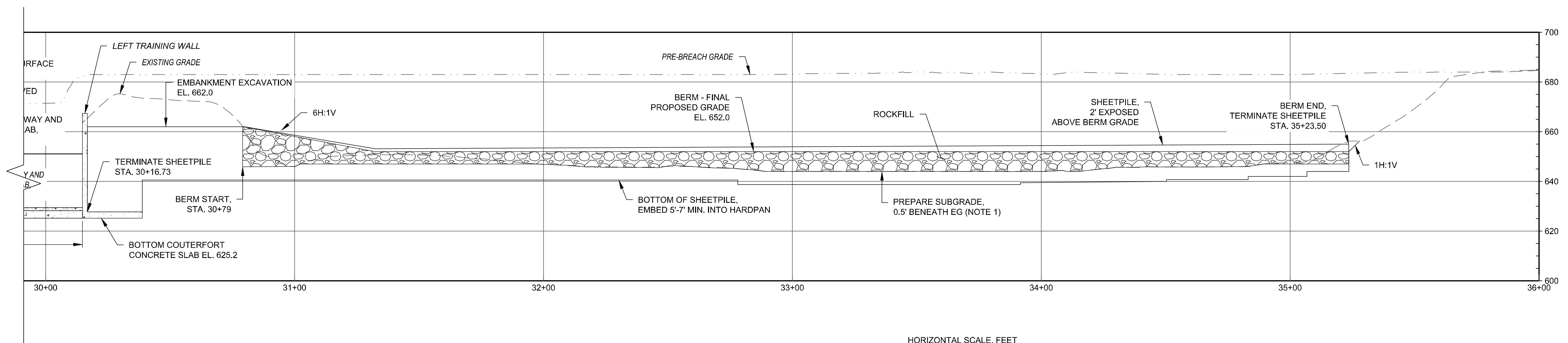
SHEET NAME: PLAN OF PROPOSED CONDITIONS - OPTION 4

SHEET NO. 18 OF 21



1 PROFILE
18 DAM ALIGNMENT

HORIZONTAL SCALE, FEET 0 20 40
0 20 40 VERTICAL SCALE, FEET
NO VERTICAL EXAGGERATION



1 PROFILE
18 DAM ALIGNMENT

HORIZONTAL SCALE, FEET 0 20 40
0 20 40 VERTICAL SCALE, FEET
NO VERTICAL EXAGGERATION

NOT FOR CONSTRUCTION

NOTES:
1. THE EXISTING GROUND BETWEEN THE LEFT ABUTMENT AND APPROXIMATELY STA. 30+75, IS ESTIMATED TO BE THE TOP OF THE HARDPAN LAYER.

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

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Checked:	AB
Approved:	WW
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SHEET NAME: DAM ALIGNMENT PROFILE - OPTION 4

SHEET NO. 19 OF 21

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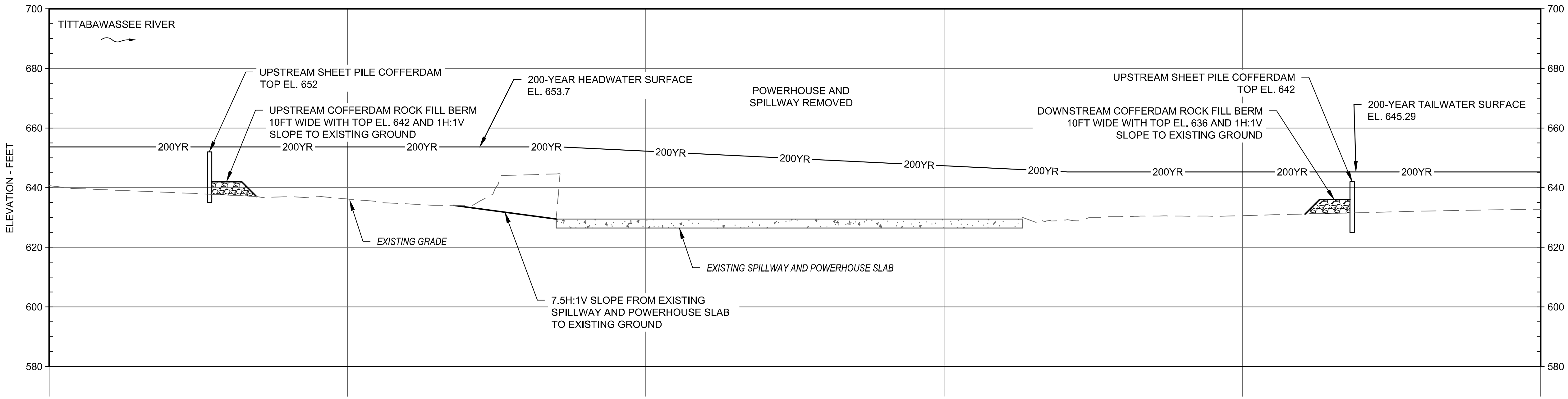

2/18 PROFILE
SPILLWAY ALIGNMENT

HORIZONTAL SCALE, FEET 0 20 40
VERTICAL SCALE, FEET 0 20 40
NO VERTICAL EXAGGERATION

NOT FOR CONSTRUCTION

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

Designed:	KP
Drawn:	TC/MS
Checked:	AB
Approved:	WW
P.E. No:	XXXXXX
GEI Project	2002879

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SHEET NAME: SPILLWAY PROFILE - OPTION 4

SHEET NO. 20 OF 21

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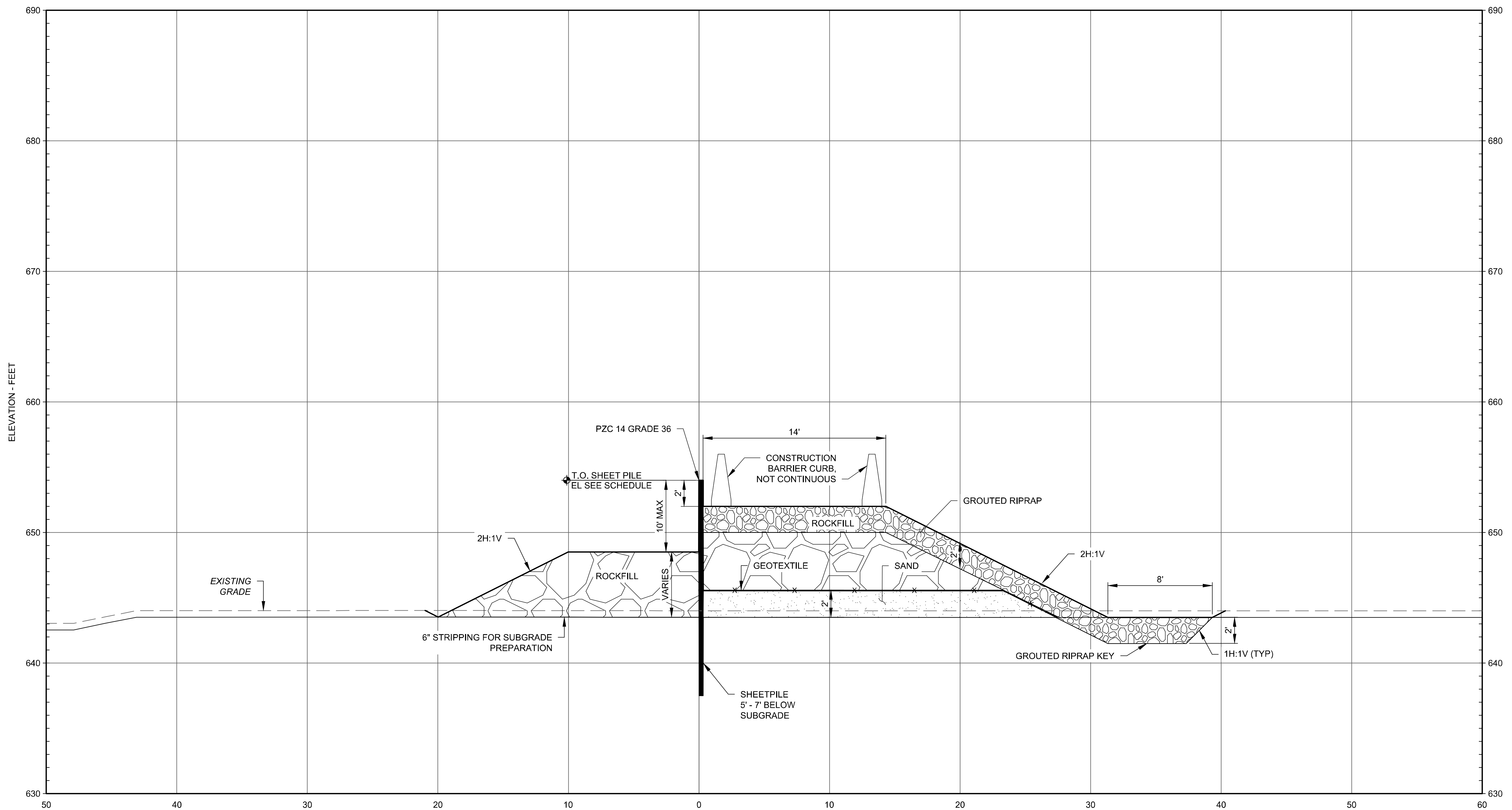

3 / 18 SECTION
BERM TYPICAL

0 4 8
SCALE, FEET

NOT FOR CONSTRUCTION

Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.	Designed: KP Drawn: TC/MS Checked: AB Approved: WW P.E. No: XXXXXX GEI Project 2002879	GEI Consultants GEI CONSULTANTS, INC. 10501 WEST RESEARCH DRIVE G100 MILWAUKEE, WI 53226 (414)930-7540	Spicer group ©2020 SAGINAW OFFICE 230 S. Washington Ave. Saginaw, MI 48607 Tel. 989-754-4717 Fax. 989-754-4440 www.SpicerGroup.com	EDENVILLE DAM PROJECT TITTABAWASSEE SPILLWAY AND BREACH TEMPORARY REPAIRS GLADWIN COUNTY, MICHIGAN	SHEET NAME: TYPICAL BERM SECTION - OPTION 4 SHEET NO.: 21 OF 21

NO	DATE	ISSUE/REVISION	APP
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Appendix C

Spillway Rating Curve Calculations

GEI Consultants

CLIENT:	Four Lakes Task Force		
PROJECT:	Edenville Dam (Tittabawassee)	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.	659.8	ft	L, Width Along Dam Axis	16.00	ft
Gate 1 Weir Crest Width, b	24.0	ft	Number of Piers, N (1,3)	1.0	-
Upstream Slope	2H:1V	Hor:Ver	Pier Contraction Coeff., Kp	0.01	-
Upstream Slope factor, Kr	Varies	-	Abutment Shape	45 Degree	-
Downstream Slope	2H:1V	Hor:Ver	Contraction Coeff., Ka (1,3)	0.1	-
Downstream Slope Factor	Varies	-			
Number of Gates	3				

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
659.8	0.0	0.0	2.89	1.00	2.89	24.0	0	0	Spillway Invert
660.0	0.2	0.0	2.89	1.00	2.89	24.0	6	19	
660.5	0.7	0.0	2.89	1.00	2.89	23.9	40	121	
661.0	1.2	0.1	2.89	1.00	2.89	23.7	90	271	
661.5	1.7	0.1	2.89	1.00	2.89	23.6	152	455	
662.0	2.2	0.1	2.90	1.00	2.90	23.5	223	668	
662.5	2.7	0.2	2.90	1.00	2.90	23.4	302	905	
663.0	3.2	0.2	2.91	1.00	2.91	23.3	389	1,166	
663.5	3.7	0.2	2.92	1.00	2.92	23.2	482	1,447	
664.0	4.2	0.3	2.93	1.00	2.93	23.1	583	1,748	
664.5	4.7	0.3	2.94	1.00	2.94	23.0	689	2,067	
665.0	5.2	0.3	2.95	1.00	2.95	22.9	802	2,405	
665.5	5.7	0.4	2.96	1.00	2.96	22.8	920	2,759	
666.0	6.2	0.4	2.98	1.00	2.98	22.7	1,043	3,130	
666.5	6.7	0.4	2.99	1.00	2.99	22.6	1,173	3,518	
667.0	7.2	0.5	3.01	1.00	3.01	22.5	1,307	3,921	
667.5	7.7	0.5	3.03	1.00	3.03	22.4	1,447	4,340	
668.0	8.2	0.5	3.04	1.00	3.04	22.3	1,592	4,775	
668.5	8.7	0.5	3.06	1.00	3.06	22.2	1,741	5,224	
669.0	9.2	0.6	3.08	1.00	3.08	22.1	1,896	5,687	
669.5	9.7	0.6	3.10	1.00	3.10	22.0	2,055	6,165	
670.0	10.2	0.6	3.12	1.00	3.12	21.9	2,219	6,657	
670.5	10.7	0.7	3.14	1.00	3.14	21.8	2,387	7,162	
671.0	11.2	0.7	3.16	1.00	3.16	21.6	2,560	7,681	
671.5	11.7	0.7	3.18	1.00	3.18	21.5	2,737	8,212	
672.0	12.2	0.8	3.19	1.00	3.19	21.4	2,919	8,756	
672.5	12.7	0.8	3.21	1.00	3.21	21.3	3,104	9,312	
673.0	13.2	0.8	3.23	1.00	3.23	21.2	3,293	9,880	
673.5	13.7	0.9	3.25	1.00	3.25	21.1	3,486	10,459	
674.0	14.2	0.9	3.27	1.00	3.27	21.0	3,683	11,049	
674.5	14.7	0.9	3.29	1.00	3.29	20.9	3,883	11,650	
675.0	15.2	1.0	3.31	1.00	3.31	20.8	4,087	12,260	
675.5	15.7	1.0	3.33	1.00	3.33	20.7	4,293	12,879	
676.0	16.2	1.0	3.35	1.00	3.35	20.6	4,503	13,508	
676.5	16.7	1.0	3.37	1.00	3.37	20.5	4,715	14,145	
677.0	17.2	1.1	3.39	1.00	3.39	20.4	4,930	14,789	
677.5	17.7	1.1	3.41	1.00	3.41	20.3	5,147	15,441	
678.0	18.2	1.1	3.43	1.00	3.43	20.2	5,366	16,099	
678.5	18.7	1.2	3.44	1.00	3.44	20.1	5,588	16,764	
679.0	19.2	1.2	3.46	1.00	3.46	20.0	5,811	17,434	
679.5	19.7	1.2	3.48	1.00	3.48	19.9	6,036	18,108	
680.0	20.2	1.3	3.49	1.00	3.49	19.8	6,262	18,787	
680.5	20.7	1.3	3.51	1.00	3.51	19.7	6,490	19,470	
681.0	21.2	1.3	3.52	1.00	3.52	19.5	6,719	20,156	
681.5	21.7	1.4	3.54	1.00	3.54	19.4	6,948	20,844	
682.0	22.2	1.4	3.55	1.00	3.55	19.3	7,178	21,533	
682.5	22.7	1.4	3.56	1.00	3.56	19.2	7,408	22,224	
683.0	23.2	1.5	3.57	1.00	3.57	19.1	7,639	22,916	
683.5	23.7	1.5	3.59	1.00	3.59	19.0	7,869	23,608	
684.0	24.2	1.5	3.60	1.00	3.60	18.9	8,100	24,299	
684.5	24.7	1.5	3.61	1.00	3.61	18.8	8,330	24,989	
685.0	25.2	1.6	3.62	1.00	3.62	18.7	8,559	25,677	
685.5	25.7	1.6	3.63	1.00	3.63	18.6	8,788	26,363	Zero-Freeboard

GEI Consultants

CLIENT:	Four Lakes Task Force		
PROJECT:	Edenville Dam (Tobacco)	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.	659.8	ft	L, Width Along Dam Axis	16.00	ft
Avg. Gate 1 Weir Crest Width, b	17.2	ft	Number of Piers, N (1,3)	1.0	-
Upstream Slope	2H:1V	Hor:Ver	Pier Contraction Coeff., Kp	0.01	-
Upstream Slope factor, Kr	Varies	-	Abutment Shape	45 Degree	-
Downstream Slope	2H:1V	Hor:Ver	Contraction Coeff., Ka (1,3)	0.1	-
Downstream Slope Factor	Varies	-			
Number of Gates	3				

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
659.8	0.0	0.0	2.89	1.00	2.89	17.2	0	0	Spillway Invert
660.0	0.2	0.0	2.89	1.00	2.89	17.1	4	13	
660.5	0.7	0.0	2.89	1.00	2.89	17.0	29	86	
661.0	1.2	0.1	2.89	1.00	2.89	16.9	64	193	
661.5	1.7	0.1	2.89	1.00	2.89	16.8	108	323	
662.0	2.2	0.1	2.90	1.00	2.90	16.7	158	474	
662.5	2.7	0.2	2.90	1.00	2.90	16.6	214	641	
663.0	3.2	0.2	2.91	1.00	2.91	16.5	275	824	
663.5	3.7	0.2	2.92	1.00	2.92	16.4	340	1,021	
664.0	4.2	0.3	2.93	1.00	2.93	16.3	410	1,231	
664.5	4.7	0.3	2.94	1.00	2.94	16.2	484	1,453	
665.0	5.2	0.3	2.95	1.00	2.95	16.1	562	1,687	
665.5	5.7	0.4	2.96	1.00	2.96	16.0	644	1,932	
666.0	6.2	0.4	2.98	1.00	2.98	15.9	729	2,188	
666.5	6.7	0.4	2.99	1.00	2.99	15.8	818	2,454	
667.0	7.2	0.5	3.01	1.00	3.01	15.7	910	2,730	
667.5	7.7	0.5	3.03	1.00	3.03	15.5	1,005	3,015	
668.0	8.2	0.5	3.04	1.00	3.04	15.4	1,103	3,310	
668.5	8.7	0.5	3.06	1.00	3.06	15.3	1,205	3,614	
669.0	9.2	0.6	3.08	1.00	3.08	15.2	1,309	3,926	
669.5	9.7	0.6	3.10	1.00	3.10	15.1	1,416	4,247	
670.0	10.2	0.6	3.12	1.00	3.12	15.0	1,525	4,576	
670.5	10.7	0.7	3.14	1.00	3.14	14.9	1,637	4,912	
671.0	11.2	0.7	3.16	1.00	3.16	14.8	1,752	5,256	
671.5	11.7	0.7	3.18	1.00	3.18	14.7	1,869	5,607	
672.0	12.2	0.8	3.19	1.00	3.19	14.6	1,988	5,965	
672.5	12.7	0.8	3.21	1.00	3.21	14.5	2,110	6,329	
673.0	13.2	0.8	3.23	1.00	3.23	14.4	2,233	6,700	
673.5	13.7	0.9	3.25	1.00	3.25	14.3	2,359	7,076	
674.0	14.2	0.9	3.27	1.00	3.27	14.2	2,486	7,457	
674.5	14.7	0.9	3.29	1.00	3.29	14.1	2,614	7,843	
675.0	15.2	1.0	3.31	1.00	3.31	14.0	2,745	8,234	
675.5	15.7	1.0	3.33	1.00	3.33	13.9	2,876	8,628	
676.0	16.2	1.0	3.35	1.00	3.35	13.8	3,009	9,027	
676.5	16.7	1.0	3.37	1.00	3.37	13.7	3,143	9,428	
677.0	17.2	1.1	3.39	1.00	3.39	13.6	3,277	9,832	
677.5	17.7	1.1	3.41	1.00	3.41	13.4	3,413	10,239	
678.0	18.2	1.1	3.43	1.00	3.43	13.3	3,549	10,647	
678.5	18.7	1.2	3.44	1.00	3.44	13.2	3,686	11,057	
679.0	19.2	1.2	3.46	1.00	3.46	13.1	3,823	11,468	
679.5	19.7	1.2	3.48	1.00	3.48	13.0	3,960	11,879	
680.0	20.2	1.3	3.49	1.00	3.49	12.9	4,097	12,290	
680.5	20.7	1.3	3.51	1.00	3.51	12.8	4,233	12,700	
681.0	21.2	1.3	3.52	1.00	3.52	12.7	4,370	13,110	
681.5	21.7	1.4	3.54	1.00	3.54	12.6	4,506	13,518	
682.0	22.2	1.4	3.55	1.00	3.55	12.5	4,641	13,924	
682.5	22.7	1.4	3.56	1.00	3.56	12.4	4,776	14,328	
683.0	23.2	1.5	3.57	1.00	3.57	12.3	4,910	14,729	
683.5	23.7	1.5	3.59	1.00	3.59	12.2	5,042	15,127	
684.0	24.2	1.5	3.60	1.00	3.60	12.1	5,174	15,522	
684.5	24.7	1.5	3.61	1.00	3.61	12.0	5,304	15,912	
685.0	25.2	1.6	3.62	1.00	3.62	11.9	5,433	16,298	
685.5	25.7	1.6	3.63	1.00	3.63	11.8	5,560	16,679	Zero-Freeboard

LABYRINTH WEIR DESIGN
No Approach Velocity

PROJECT:	Edenville Labyrinth	**TIME:**	16:42:20
PROJECT NO.	2002879	**DATE:**	17-Feb-21
FLOOD CRITERIA:	1/2 PMF +	**BY:**	PDD

USER INPUT

Max. Res	**Zr**	681.5	**ft**	**Thickness**			
Crest el.	**Zc**	678.0	**ft**	**Wall**	**Tw**	1.5	**ft**
Floor el.	**Zf**	670.0	**ft**	**Slab**	**Ts**	1.5	**ft**
Spillway width	**Ws**	250.0	**ft**	**Cutoff Depth**			
Apex Width	**2a**	3	**ft**	**Sheet Pile**	**Ds**	1	**ft**
No. of cycles	**n**	12		**Conc Wall**	**Dc**	1	**ft**
Magnification	**L/W**	3					

CHECK ON RATIOS

Lde/B =	0.34	**Ld/B RATIO IS OK**
H_o/P =	0.44	**Ho/P RATIO IS OK**
α =	15.22	**Angle IS OK**

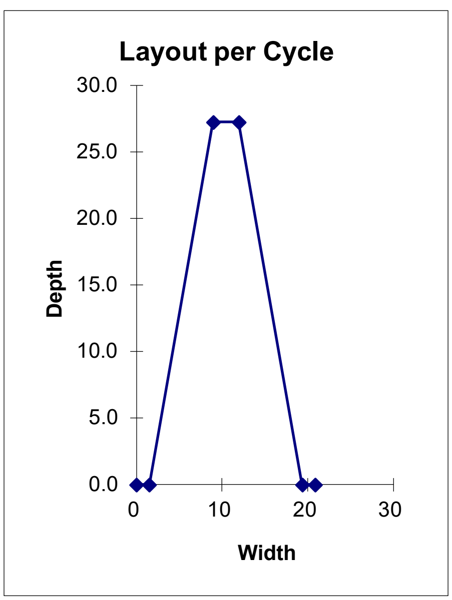
Note: L_{de}/B must be <= 0.35
Ho/P must be <= 0.9
α must be >= 6 deg

LABYRINTH DIMENSIONS (Per Cycle)

Wall Height	**P**	8	**ft**
Width	**W**	20.83	**ft**
Length	**L**	62.50	**ft**
Wall Length	**B**	28.25	**ft**
Depth	**D**	27.26	**ft**
Head max	**H**	3.50	**ft**
Wall Angle	α	15.22	**deg**
Length of Interference	L_{de}	9.71	**ft**

CREST LAYOUT
(One Cycle)

X	**Y**
0	0
1.50	0
8.92	27.26
11.92	27.26
19.33	0
20.83	0



DISCHARGE

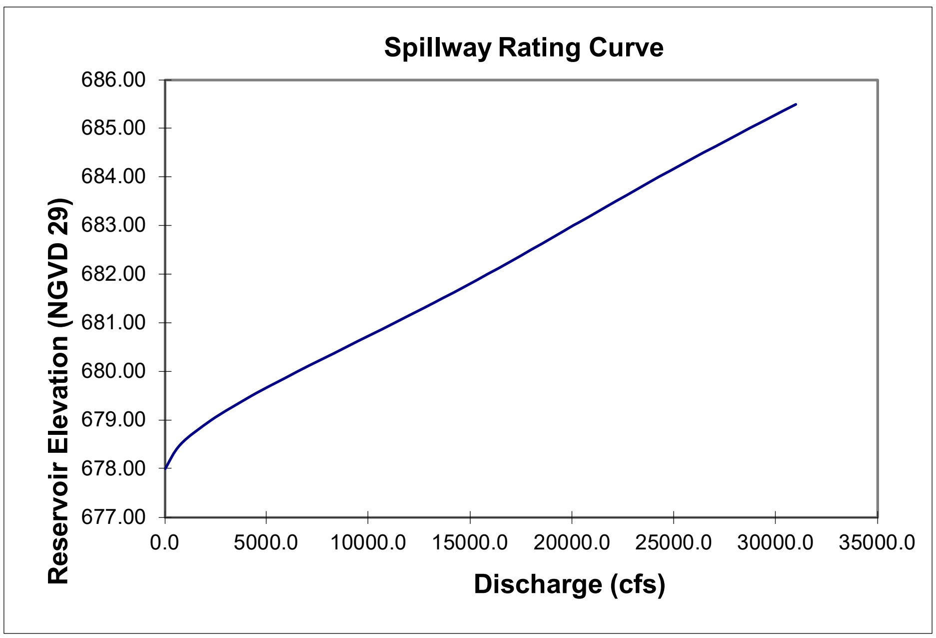
Qmax 13,614 **cfs**

COEFFICIENTS

Column	4.00
Cd lower	0.51
Cd Upper	0.58
Cd	0.52
Efficacy	2.05

RATING CURVE

HEAD	H_o/P	C_{lower}	C_{upper}	C_d	Q	RES
7.50	0.94	0.37	0.43	0.38	30977	685.50
7.00	0.88	0.38	0.44	0.39	28719	685.00
6.50	0.81	0.39	0.46	0.40	26461	684.50
6.00	0.75	0.41	0.47	0.41	24268	684.00
5.50	0.69	0.42	0.49	0.43	22147	683.50
5.00	0.63	0.44	0.51	0.45	20068	683.00
4.50	0.56	0.46	0.53	0.47	17982	682.50
4.00	0.50	0.49	0.55	0.49	15842	682.00
3.50	0.44	0.51	0.58	0.52	13614	681.50
3.00	0.38	0.54	0.60	0.54	11292	681.00
2.50	0.31	0.56	0.61	0.56	8905	680.50
2.00	0.25	0.57	0.62	0.57	6525	680.00
1.50	0.19	0.58	0.62	0.58	4265	679.50
1.00	0.13	0.57	0.60	0.57	2282	679.00
0.50	0.06	0.54	0.56	0.54	767	678.50
0.00	0.00	0.49	0.49	0.49	0	678.00



Discharge Coefficient Table Tullis et al. (1995)

Angle wall makes with centerline α

	6	8	12	15	18	25	35	90
	-------	-------	-------	-------	-------	-------	-------	-------
A0	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
A1	-0.24	1.08	1.06	1.00	1.32	1.51	1.69	1.46
A2	-1.20	-5.27	-4.43	-3.57	-4.13	-3.83	-4.05	-2.56
A3	2.17	6.79	5.18	3.82	4.24	3.40	3.62	1.44
A4	-1.03	-2.83	-1.97	-1.38	-1.50	-1.05	-1.10	

CLIENT:	Four Lakes Task Force		
PROJECT:	Edenville 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)	Tittabawassee Gated Spillway (cfs)	Tobacco Gated Spillway (cfs)	Total Gated Spillway (cfs)	Labyrinth Spillway (cfs)	Total	Comments
659.8	0	0	0		0	Spillway Invert
660.0	19	13	32		32	
660.5	121	86	208		208	
661.0	271	193	464		464	
661.5	455	323	778		778	
662.0	668	474	1,141		1,141	
662.5	905	641	1,547		1,547	
663.0	1,166	824	1,990		1,990	
663.5	1,447	1,021	2,468		2,468	
664.0	1,748	1,231	2,979		2,979	
664.5	2,067	1,453	3,521		3,521	
665.0	2,405	1,687	4,092		4,092	
665.5	2,759	1,932	4,691		4,691	
666.0	3,130	2,188	5,318		5,318	
666.5	3,518	2,454	5,972		5,972	
667.0	3,921	2,730	6,651		6,651	
667.5	4,340	3,015	7,356		7,356	
668.0	4,775	3,310	8,085		8,085	
668.5	5,224	3,614	8,837		8,837	
669.0	5,687	3,926	9,613		9,613	
669.5	6,165	4,247	10,412		10,412	
670.0	6,657	4,576	11,232		11,232	
670.5	7,162	4,912	12,074		12,074	
671.0	7,681	5,256	12,937		12,937	
671.5	8,212	5,607	13,819		13,819	
672.0	8,756	5,965	14,721		14,721	
672.5	9,312	6,329	15,641		15,641	
673.0	9,880	6,700	16,580		16,580	
673.5	10,459	7,076	17,535		17,535	
674.0	11,049	7,457	18,506		18,506	
674.5	11,650	7,843	19,493		19,493	
675.0	12,260	8,234	20,493		20,493	
675.5	12,879	8,628	21,508		21,508	
676.0	13,508	9,027	22,535		22,535	Normal Pool
676.5	14,145	9,428	23,573		23,573	
677.0	14,789	9,832	24,622		24,622	
677.5	15,441	10,239	25,680		25,680	
678.0	16,099	10,647	26,747	0	26,747	Labyrinth Spillway
678.5	16,764	11,057	27,821	767	28,588	
679.0	17,434	11,468	28,901	2,282	31,183	
679.5	18,108	11,879	29,987	4,265	34,252	
680.0	18,787	12,290	31,077	6,525	37,602	
680.5	19,470	12,700	32,170	8,905	41,076	
681.0	20,156	13,110	33,265	11,292	44,558	
681.5	20,844	13,518	34,362	13,614	47,976	
682.0	21,533	13,924	35,458	15,842	51,300	
682.5	22,224	14,328	36,553	17,982	54,535	
683.0	22,916	14,729	37,645	20,068	57,713	
683.5	23,608	15,127	38,735	22,147	60,882	
684.0	24,299	15,522	39,820	24,268	64,088	
684.5	24,989	15,912	40,901	26,461	67,362	
685.0	25,677	16,298	41,975	28,719	70,694	
685.5	26,363	16,679	43,042	30,977	74,019	Zero-Freeboard

Appendix D

Edenville Dam Conceptual Design Drawings

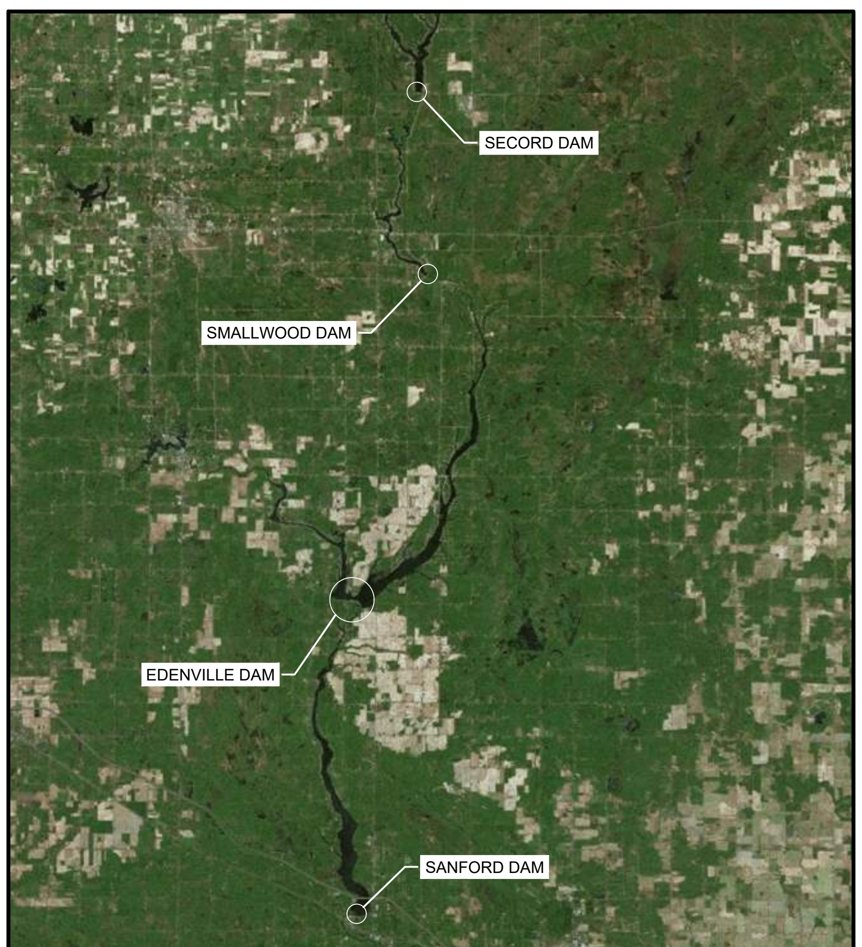
EDENVILLE DAM CONCEPTUAL DESIGN

GLADWIN COUNTY, MICHIGAN

FOUR LAKES TASK FORCE

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	TOBACCO SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"
4	C-02	EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"
5	C-03	TOBACCO - EXISTING CONDITIONS PLAN "POST AECOM STABILIZATION"
6	C-04	TOBACCO OUTLET WORKS - DEMOLITION SECTION
7	C-05	TOBACCO OUTLET WORKS - MODIFICATIONS PLAN
8	C-06	TOBACCO PRIMARY SPILLWAY - MODIFICATIONS SECTION (SHEET 1 OF 2)
9	C-07	TOBACCO PRIMARY SPILLWAY - MODIFICATIONS SECTION (SHEET 2 OF 2)
10	C-08	TOBACCO PRIMARY SPILLWAY - CREST GATE DETAILS
11	C-09	EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST GEI STABILIZATION"
12	C-10	EDENVILLE OUTLET WORKS - DEMOLITION PLAN
13	C-11	EDENVILLE OUTLET WORKS - MODIFICATIONS PLAN
14	C-12	EDENVILLE PRIMARY SPILLWAY - MODIFICATIONS SECTION
15	C-13	EDENVILLE POWERHOUSE - MODIFICATIONS SECTION
16	C-14	TOBACCO RIGHT EMBANKMENT - MODIFICATIONS
17	C-15	TOBACCO LEFT EMBANKMENT - MODIFICATIONS
18	C-16	EDENVILLE RIGHT EMBANKMENT - MODIFICATIONS SECTION
19	C-17	EDENVILLE EMBANKMENTS - MODIFICATIONS
20	C-18	EDENVILLE EMBANKMENTS - MODIFICATIONS SECTIONS & DETAILS
21	C-19	TITTABAWASSEE BREACH CHANNEL - PROPOSED LABYRINTH SPILLWAY PLAN
22	C-20	TITTABAWASSEE BREACH CHANNEL - PROPOSED LABYRINTH SPILLWAY SECTION & DETAILS

PREPARED FOR:

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

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
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FAX. (989) 754-4440

GEI PROJECT NO. 2002879

NO.	DATE	ISSUE/REVISION	APP
0	X/X/2021	CONCEPTUAL DESIGN SUBMITTAL	XXX

DRAFT

DWG. NO. G-01

SHEET NO. 1

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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 670.0' AND AT NGVD29 DATUM IS 675.8').
- A CONVERSION OF -0.558' 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 675.8' (+0.3' / -0.4')
- WINTER RESERVOIR OPERATIONS: MINIMUM 672.8' (+0.7')

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)

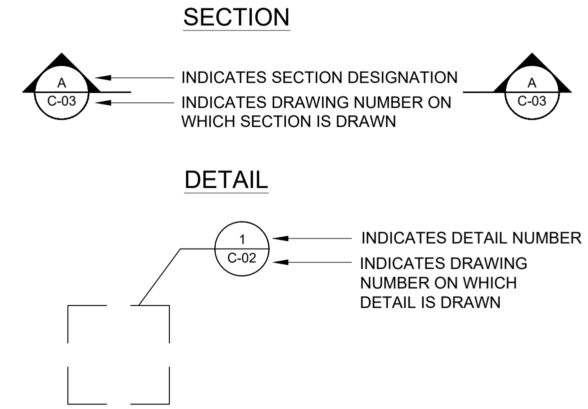
ABBREVIATIONS

BO = BOTTOM OF
C = CENTER LINE
MM = MOVEMENT MONUMENT
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

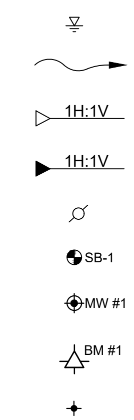
SECTION AND DETAIL LEGEND

SECTION

DETAIL

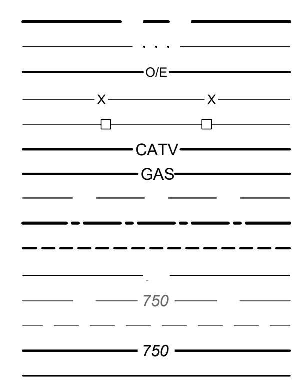


SYMBOLS LEGEND



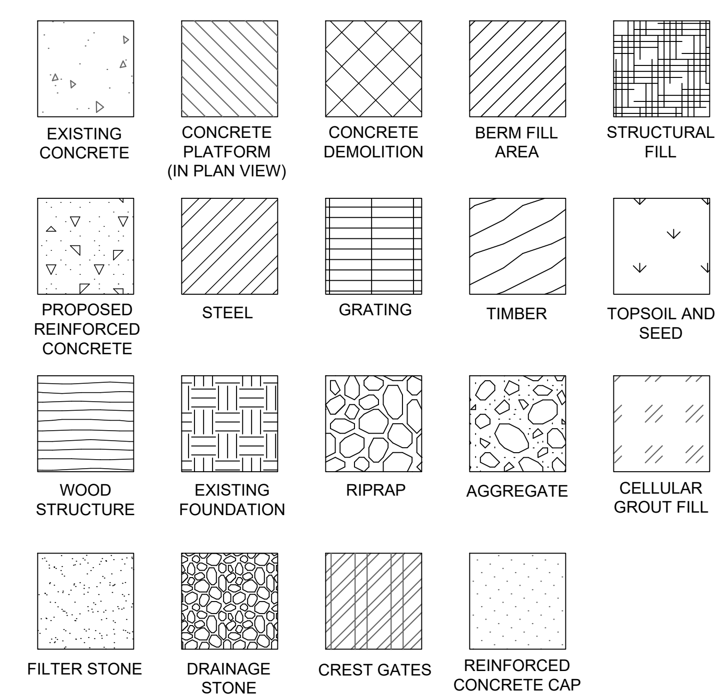
- WATER ELEVATION
- FLOW DIRECTION
- CUT SLOPE
- FILL SLOPE
- POWER POLE
- SOIL BORING
- MONITORING WELL
- SURVEY REFERENCE MONUMENT (CONTORL POINT / BENCHMARK)
- SURVEY MOVEMENT MONUMENT

LINETYPE LEGEND



- CENTERLINE
- WATER ELEVATION
- OVERHEAD ELECTRIC LINES
- FENCE LINE (STEEL)
- FENCE LINE (WOOD)
- UNDERGROUND CABLE
- GAS LINE
- EDGE OF ROADWAY (UNPAVED)
- ROADWAY CENTERLINE
- BURIED PIPING
- SILT FENCE
- EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- DESIGN MAJOR CONTOURS
- DESIGN MINOR CONTOURS

HATCH LEGEND



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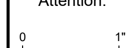

If this scale bar does not measure 1" then drawing is not original scale.

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

DRAFT

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

Four Lakes Task Force

GEI Project 2002879

Edenville Dam
Conceptual Design
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)
- FENCE LINE (WOOD)
- EDGE OF ROADWAY (UNPAVED)
- BURIED PIPING
- EXISTING MAJOR CONTOURS (750)
- EXISTING MINOR CONTOURS
- SHEETPILE

SYMBOLS LEGEND

- SB-3 SOIL BORING
- FLOW DIRECTION
- BM #200 SURVEY REFERENCE MONUMENT
- POWER POLE

TOBACCO SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"

0 100 200
SCALE, FEET

NOTES:

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

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

Four Lakes Task Force

GEI Project 2002879

Edenville Dam
Conceptual Design
Gladwin County, Michigan

TOBACCO SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"

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
- FLOW DIRECTION
- BM #200 SURVEY REFERENCE MONUMENT
- POWER POLE

EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"

0 100 200
SCALE, FEET

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

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

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GEI Project 2002879

Edenville Dam
Conceptual Design
Gladwin County, Michigan

EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST EDENVILLE DAM FAILURE"

DWG. NO. C-02

SHEET NO. 4

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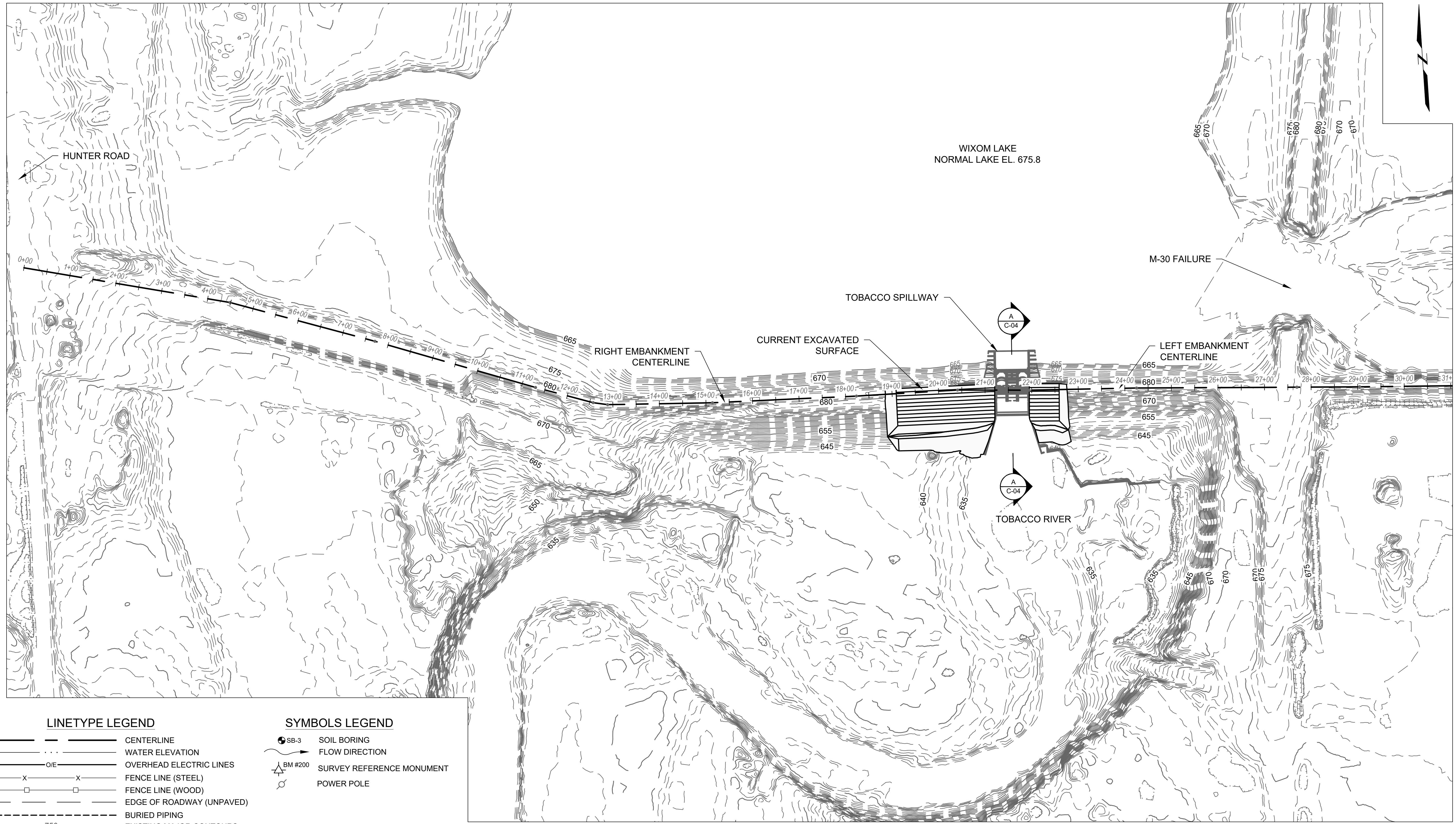

TOBACCO - EXISTING CONDITIONS PLAN "POST AECOM STABILIZATION"

0 100 200
SCALE, FEET

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
- SHEETPILE

SYMBOLS LEGEND

- SB-3 SOIL BORING
- FLOW DIRECTION
- BM #200 SURVEY REFERENCE MONUMENT
- POWER POLE

NOTES:

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

Attention:
0 1"
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Gladwin County, Michigan

TOBACCO - EXISTING CONDITIONS PLAN "POST AECOM STABILIZATION"

DWG. NO.
C-03

SHEET NO.
5

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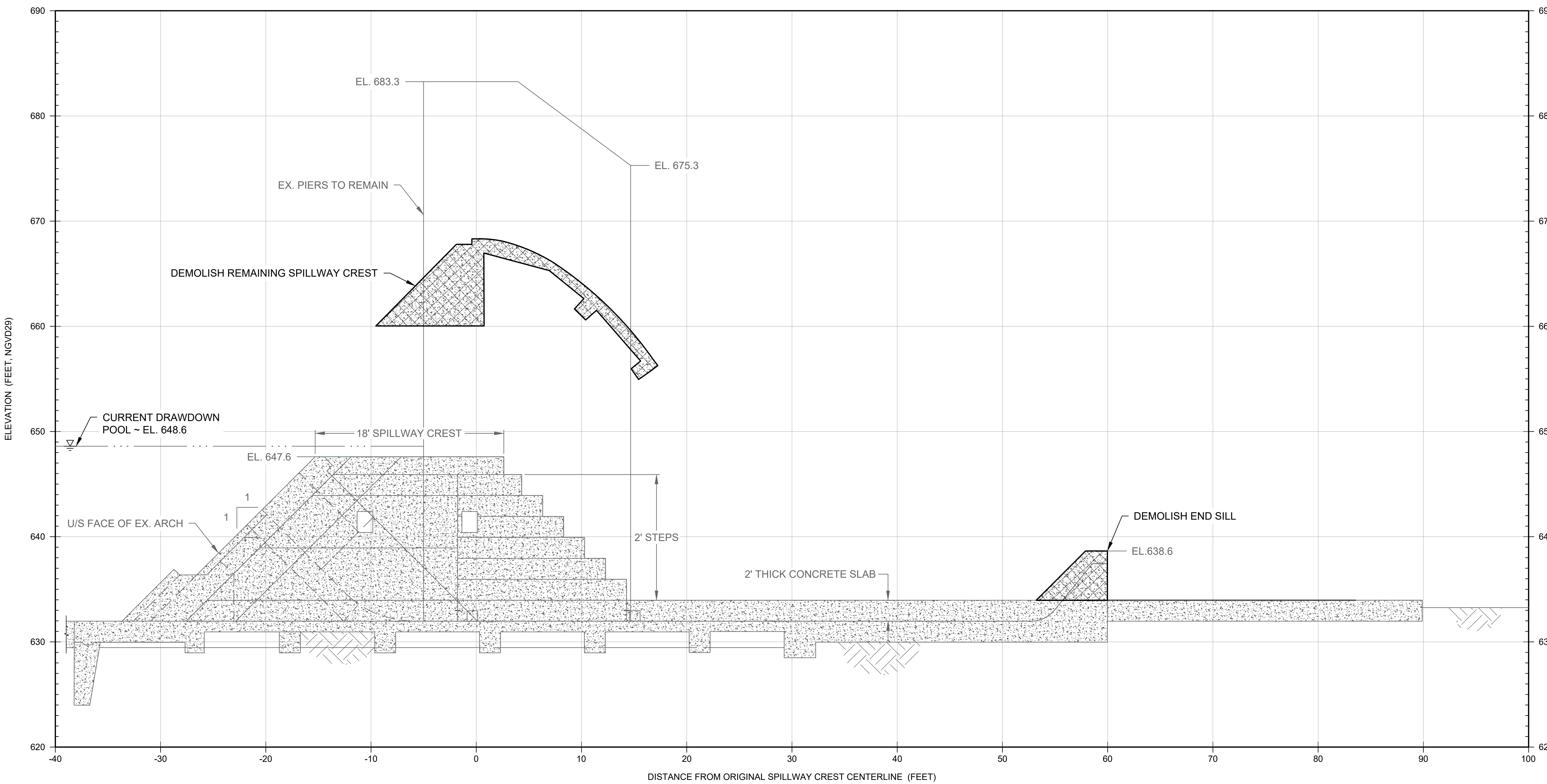
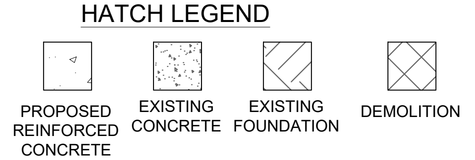


A
C-03
SECTION
SPILLWAY BAY 2

0 5 10
SCALE, FT

HATCH LEGEND



Attention:

0 1"

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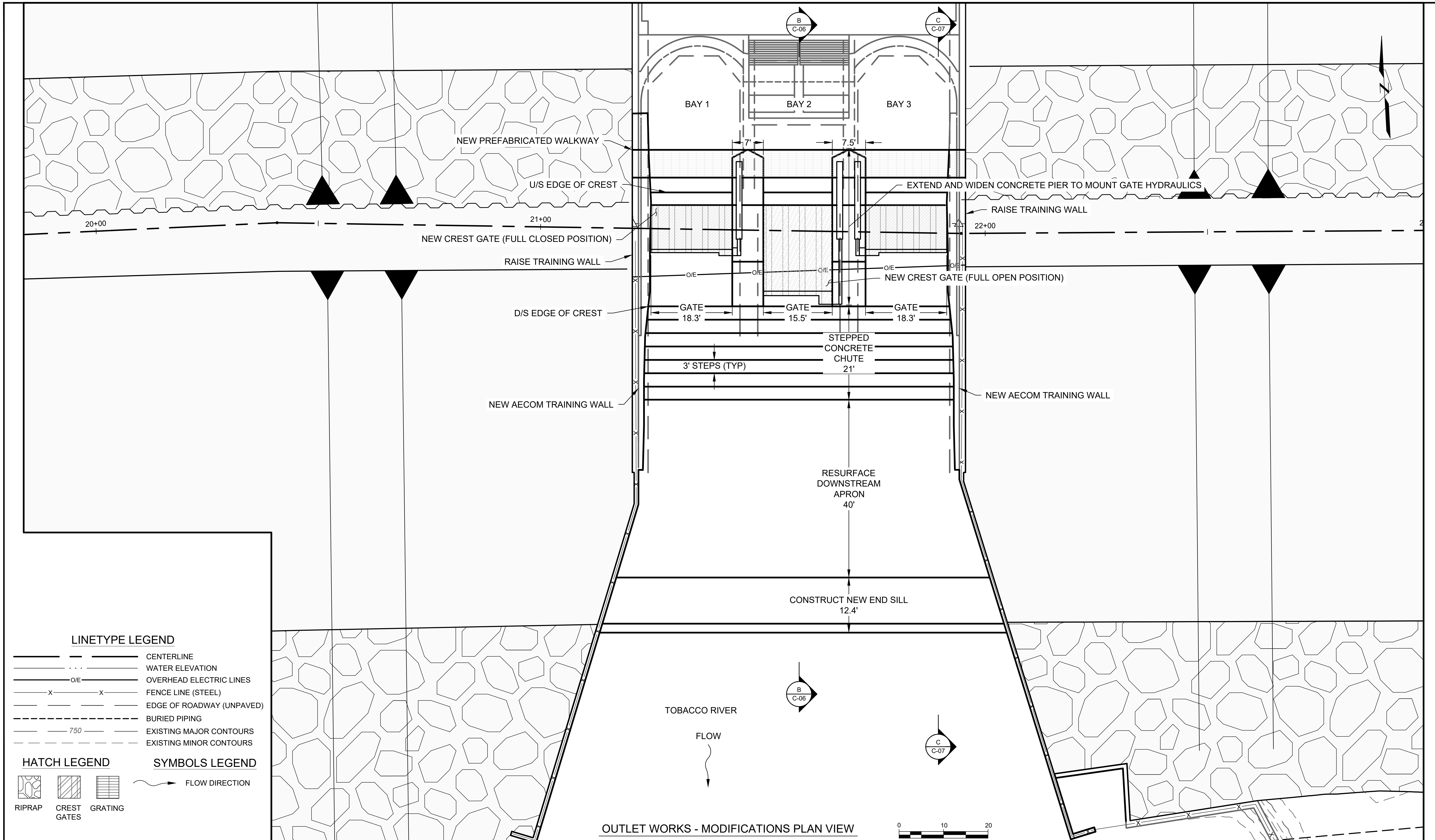
Edenville Dam
Conceptual Design
Gladwin County, Michigan

TOBACCO OUTLET WORKS - DEMOLITION SECTION

DWG. NO.
C-04

SHEET NO.
6



OUTLET WORKS - MODIFICATIONS PLAN VIEW

Attention:

0 1"

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

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Gladwin County, Michigan

TOBACCO OUTLET WORKS - MODIFICATIONS PLAN

DWG. NO. C-05

SHEET NO. 7

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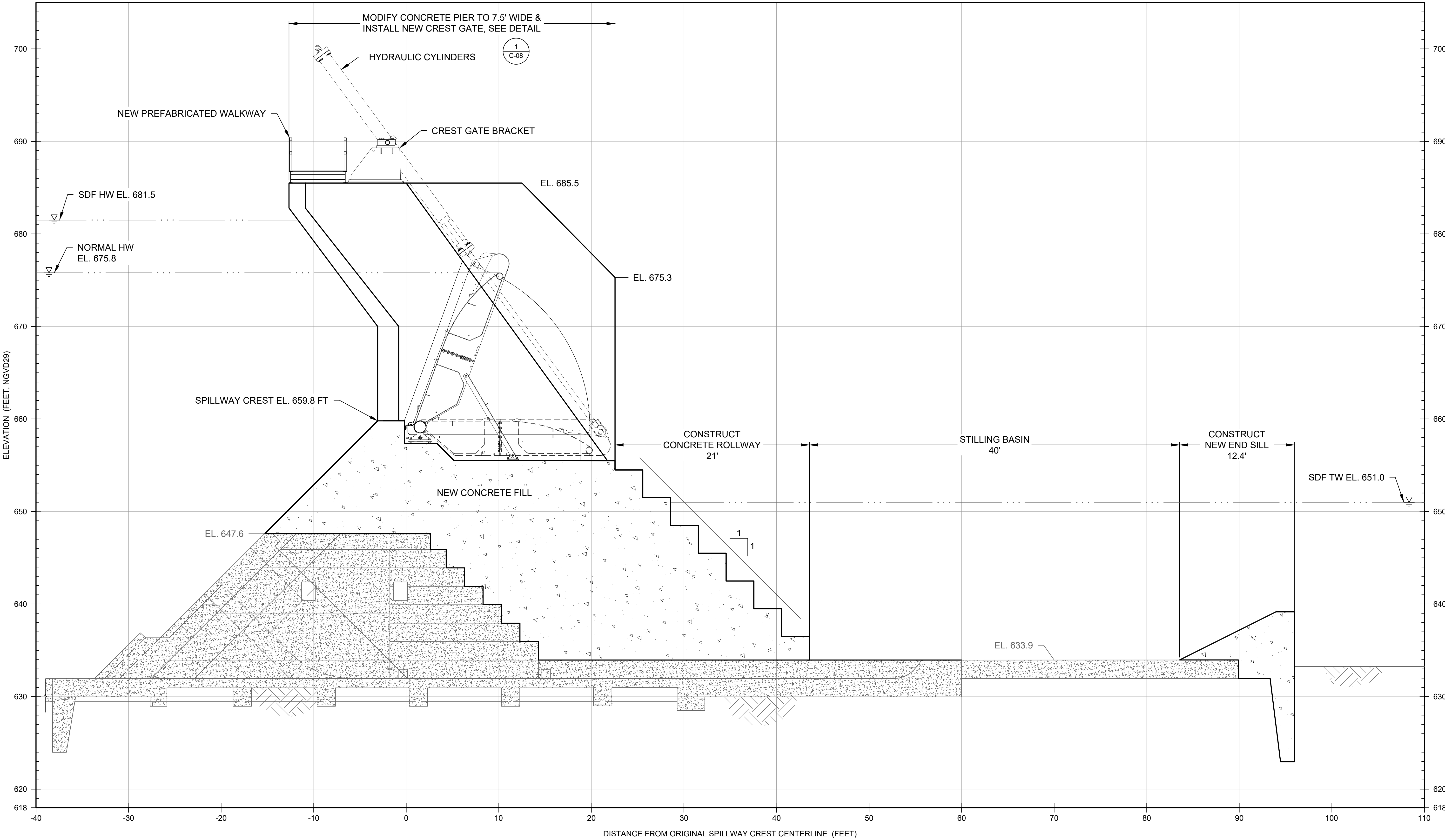

B
C-05
SECTION
SPILLWAY BAY 2

0 5 10
SCALE, FT

HATCH LEGEND

PROPOSED REINFORCED CONCRETE
EXISTING CONCRETE
EXISTING FOUNDATION

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

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Gladwin County, Michigan

TOBACCO PRIMARY SPILLWAY - MODIFICATIONS SECTION (SHEET 1 OF 2)

DWG. NO. C-06

SHEET NO. 8

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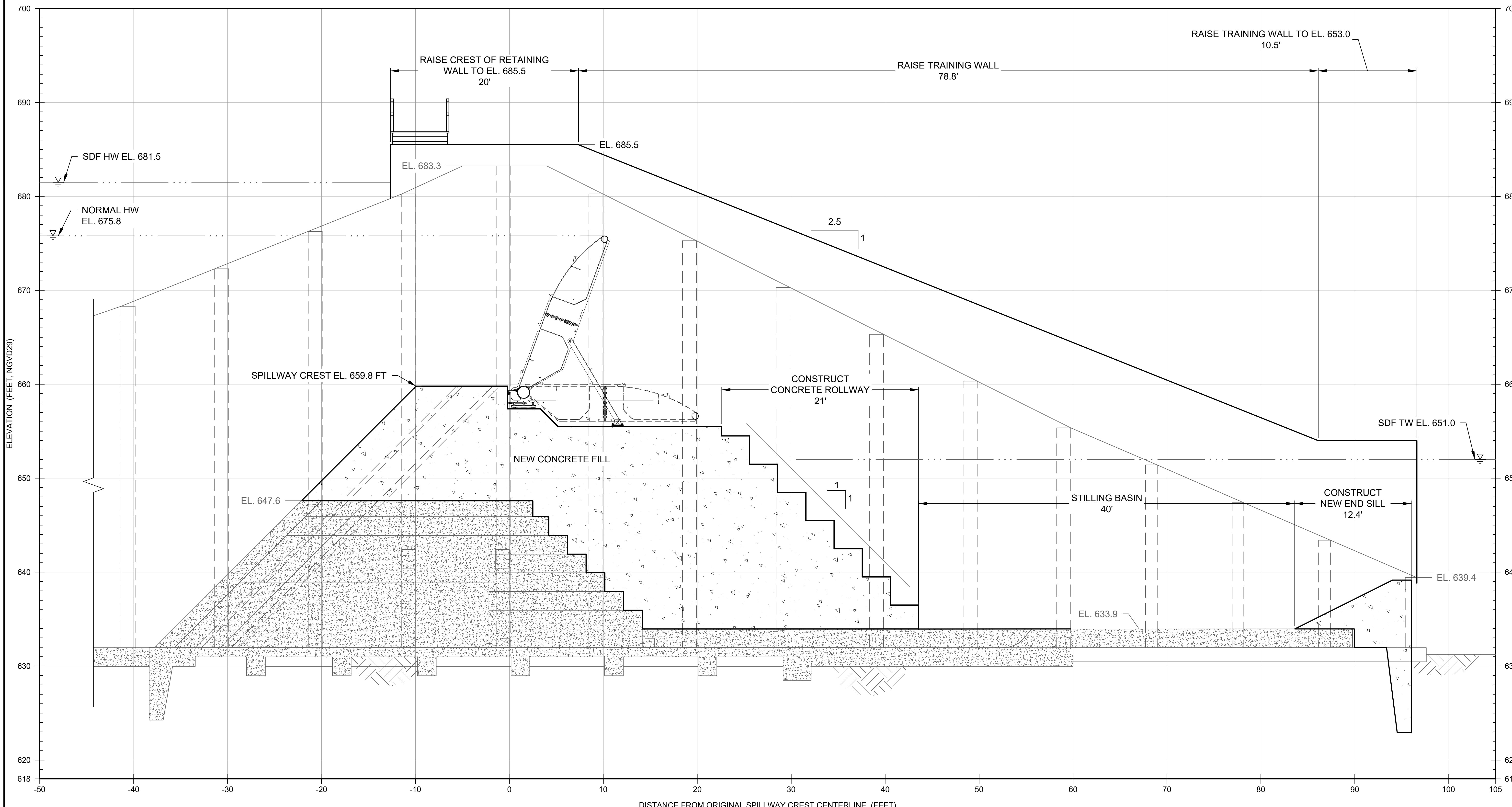

C
C-05

SECTION
SPILLWAY& LEFT TRAINING WALL

0 5 10
SCALE, FT

HATCH LEGEND

PROPOSED REINFORCED CONCRETE
EXISTING CONCRETE
EXISTING FOUNDATION

Attention:
0 1"
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Edenville Dam
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TOBACCO PRIMARY SPILLWAY - MODIFICATIONS SECTION (SHEET 2 OF 2)

DWG. NO.
C-07

SHEET NO.
9

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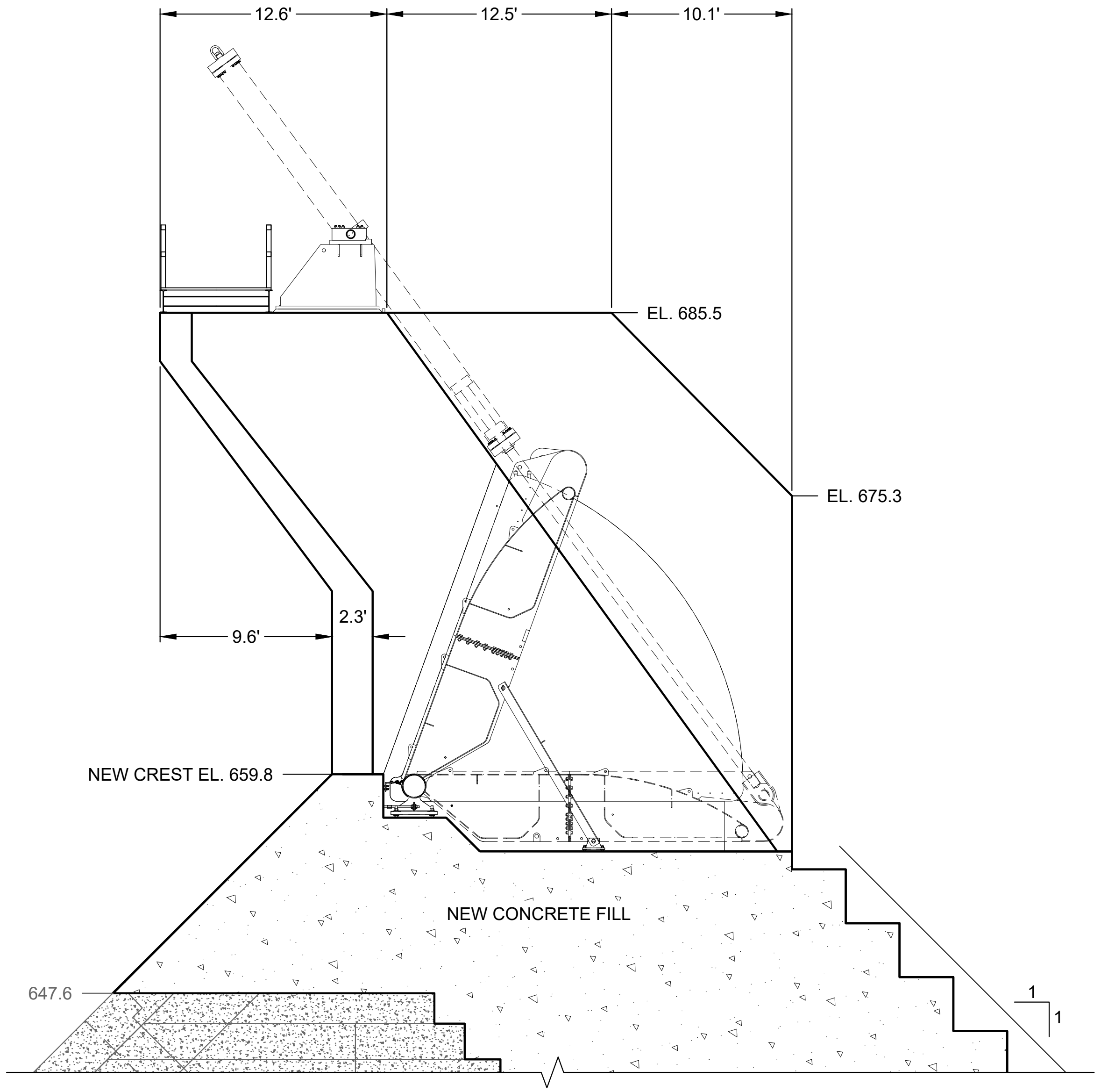

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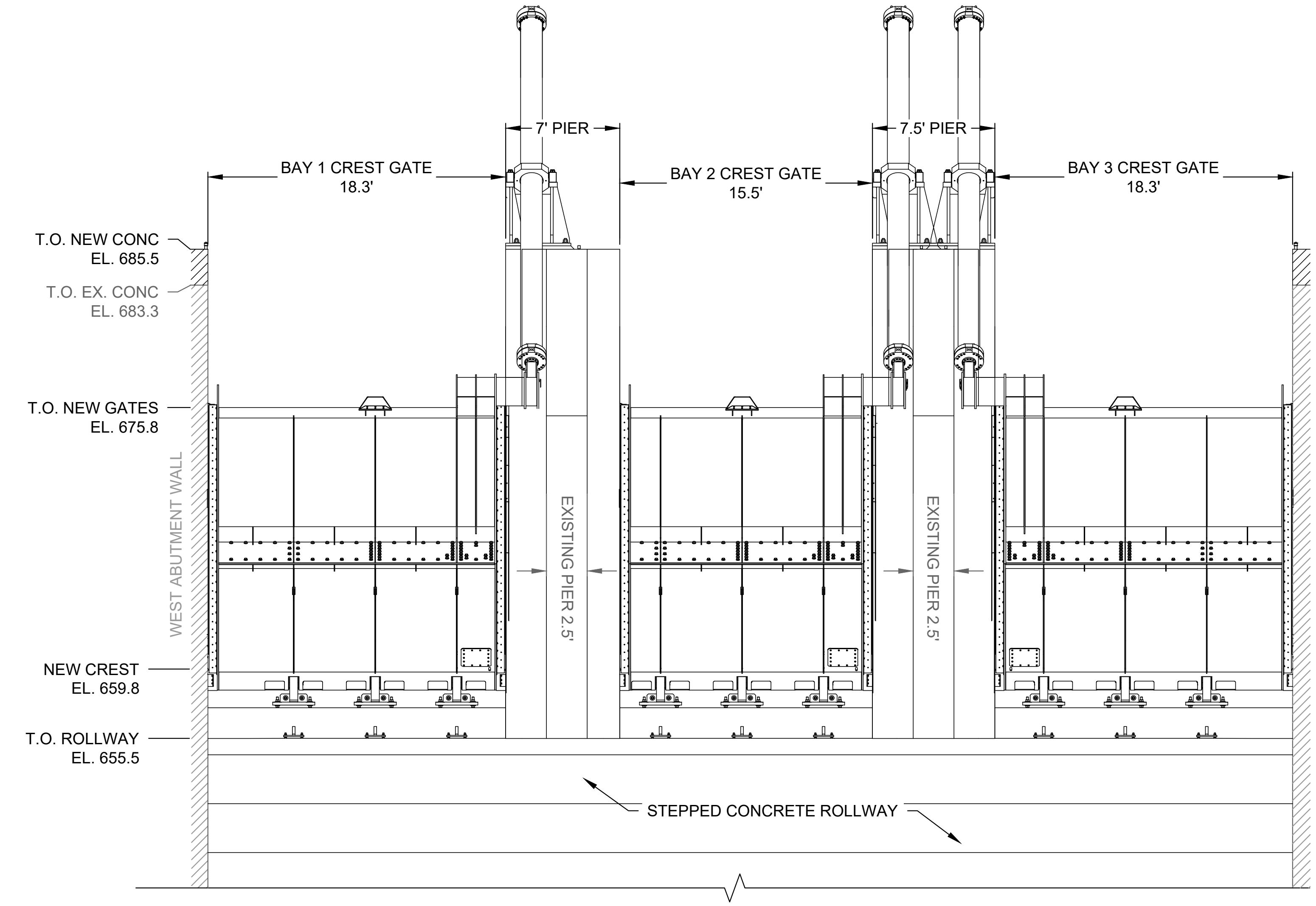

DOWNSTREAM ELEVATION

(LOOKING UPSTREAM)

1
C-06

DETAIL

PIER-MOUNTED CREST GATE

0 5 10
SCALE, FT

HATCH LEGEND

PROPOSED REINFORCED CONCRETE

EXISTING CONCRETE

Attention:

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Approved By: B. WALTON

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TOBACCO PRIMARY SPILLWAY - CREST GATE DETAILS

DWG. NO. C-08

SHEET NO. 10

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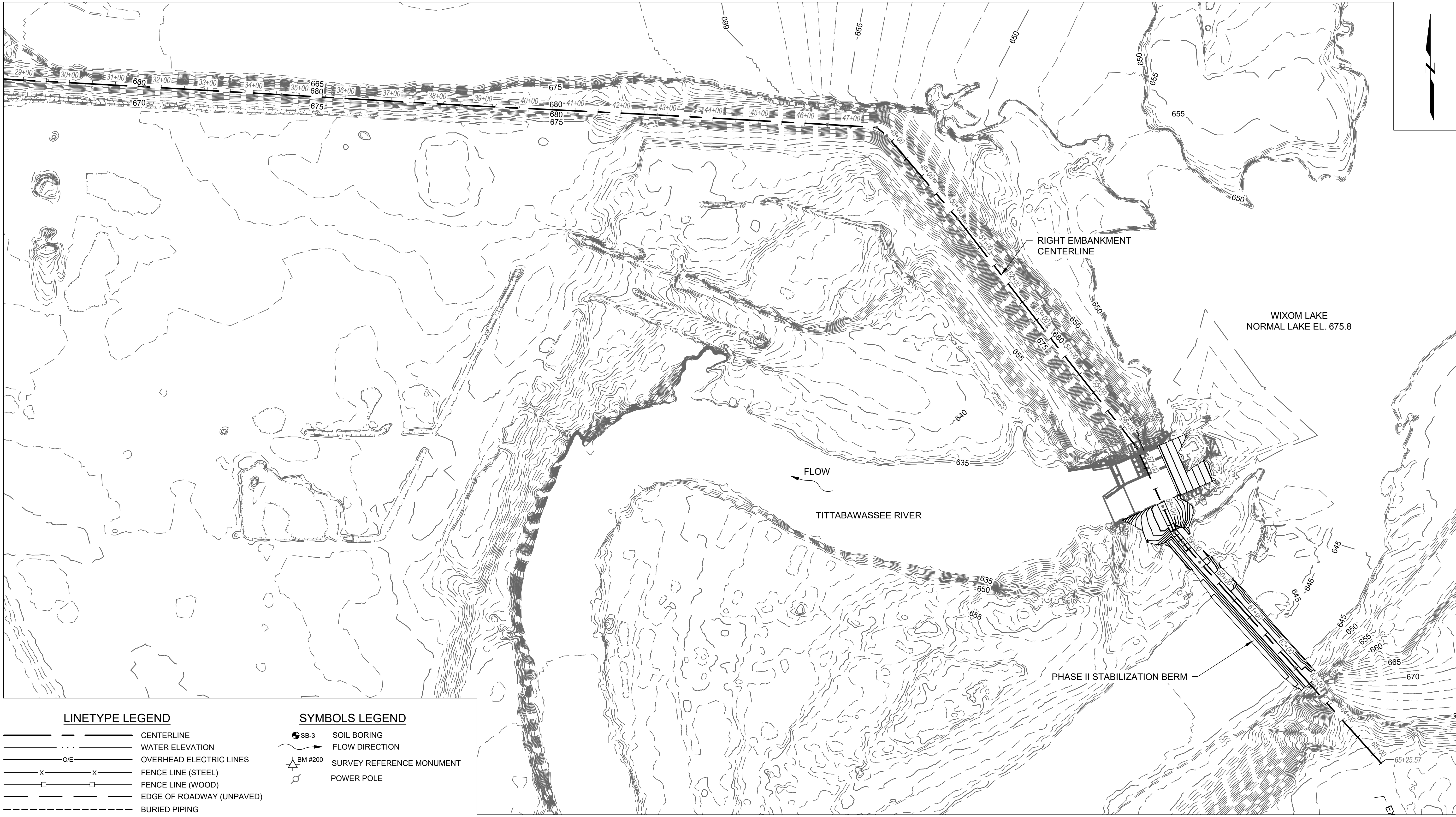

LINETYPE LEGEND

- 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
- FLOW DIRECTION
- BM #200 SURVEY REFERENCE MONUMENT
- POWER POLE

EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST GEI STABILIZATION"

SCALE, FEET: 0 100 200

NOTES:

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

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

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Gladwin County, Michigan

EDENVILLE SITE PLAN - EXISTING CONDITIONS "POST GEI STABILIZATION"

DWG. NO. C-09

SHEET NO. 11

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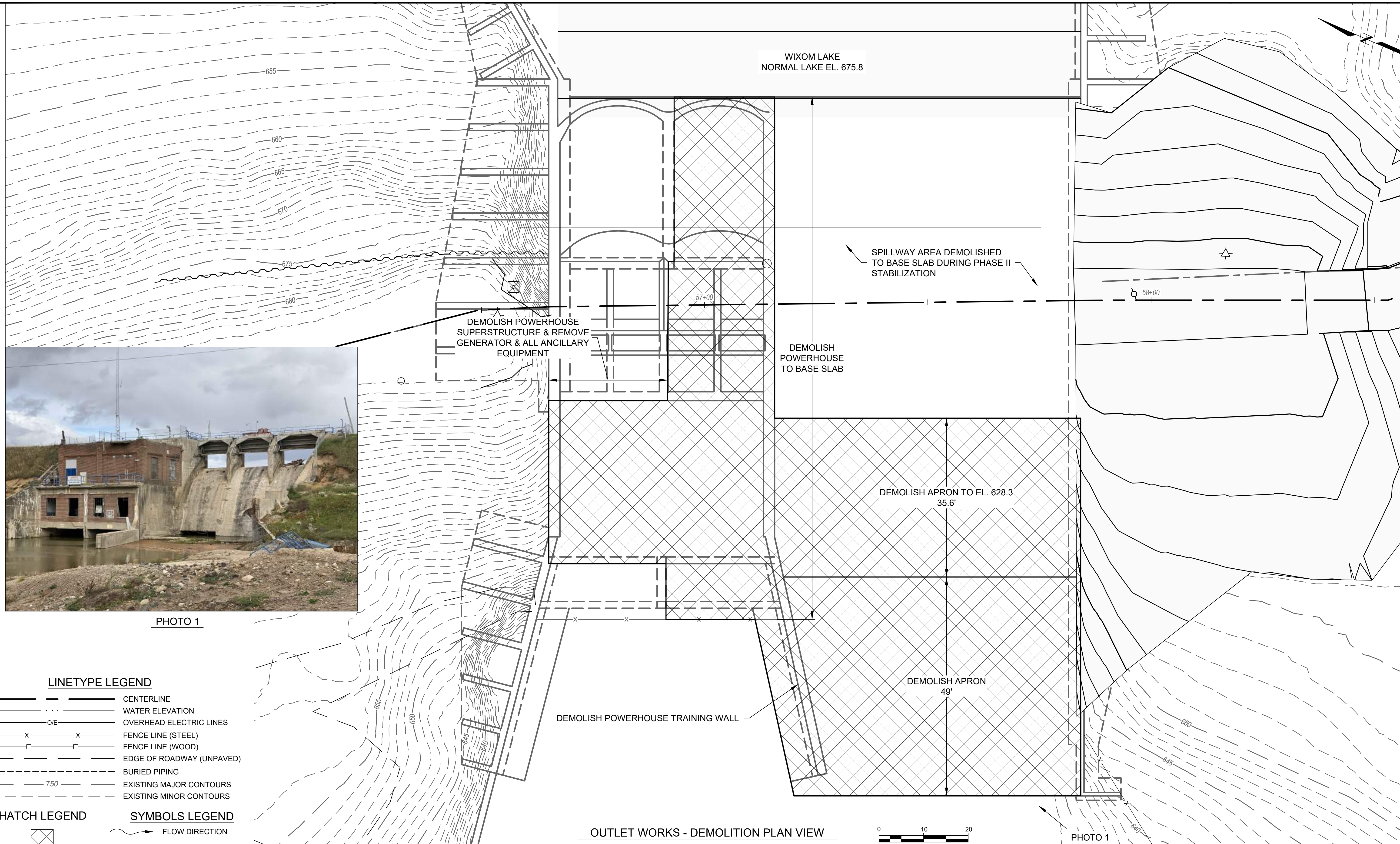

OUTLET WORKS - DEMOLITION PLAN VIEW

PHOTO 1

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

HATCH LEGEND

DEMOLITION

SYMBOLS LEGEND

FLOW DIRECTION

Attention:

0 1"

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Conceptual Design
Gladwin County, Michigan

EDENVILLE OUTLET WORKS - DEMOLITION PLAN

DWG. NO.
C-10

SHEET NO.
12

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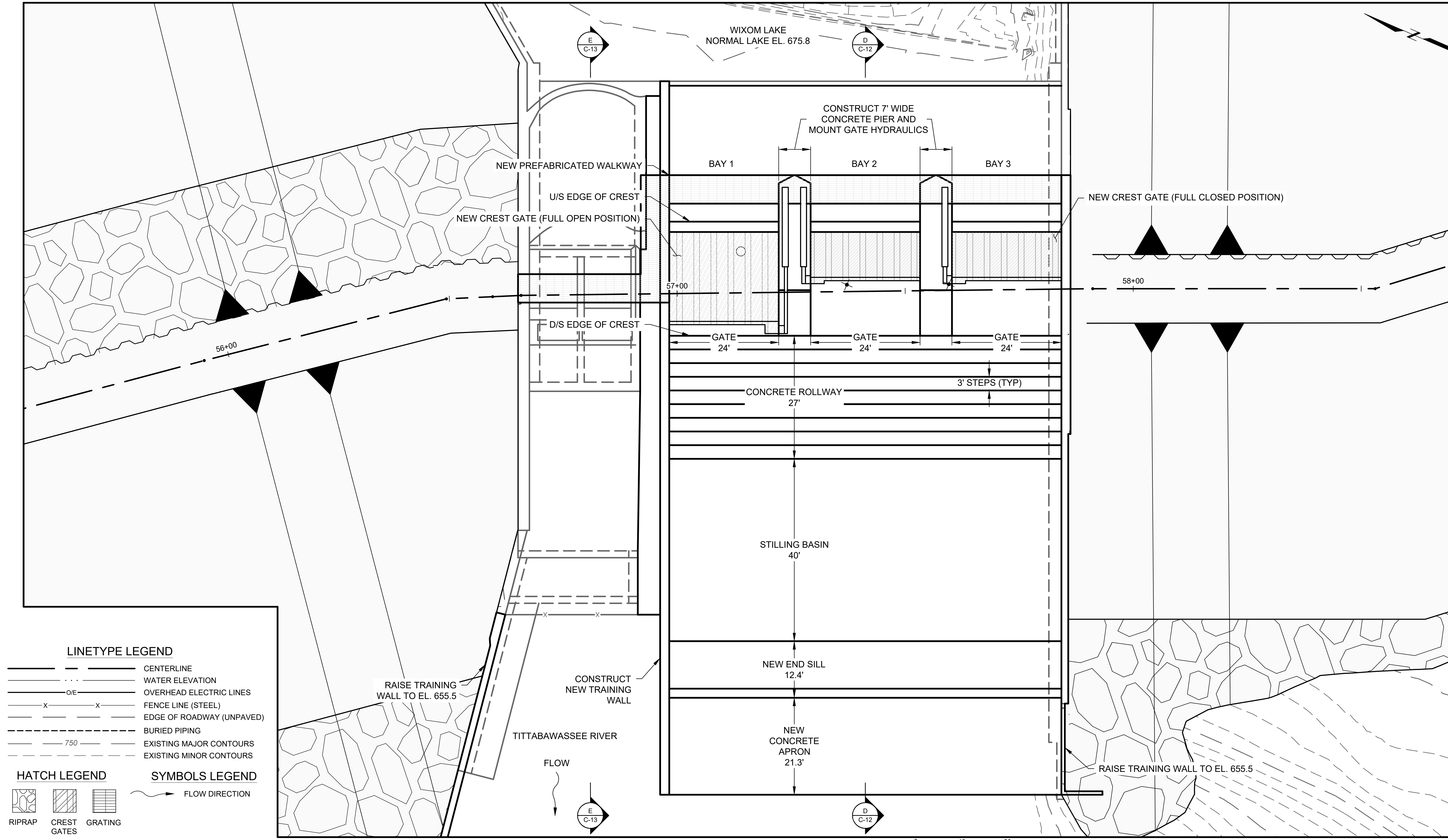

OUTLET WORKS - MODIFICATIONS PLAN VIEW

0 10 20
SCALE, FT

Attention:

0 1"

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Four Lakes Task Force

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Conceptual Design
Gladwin County, Michigan

EDENVILLE OUTLET WORKS - MODIFICATIONS PLAN

DWG. NO.
C-11

SHEET NO.
13

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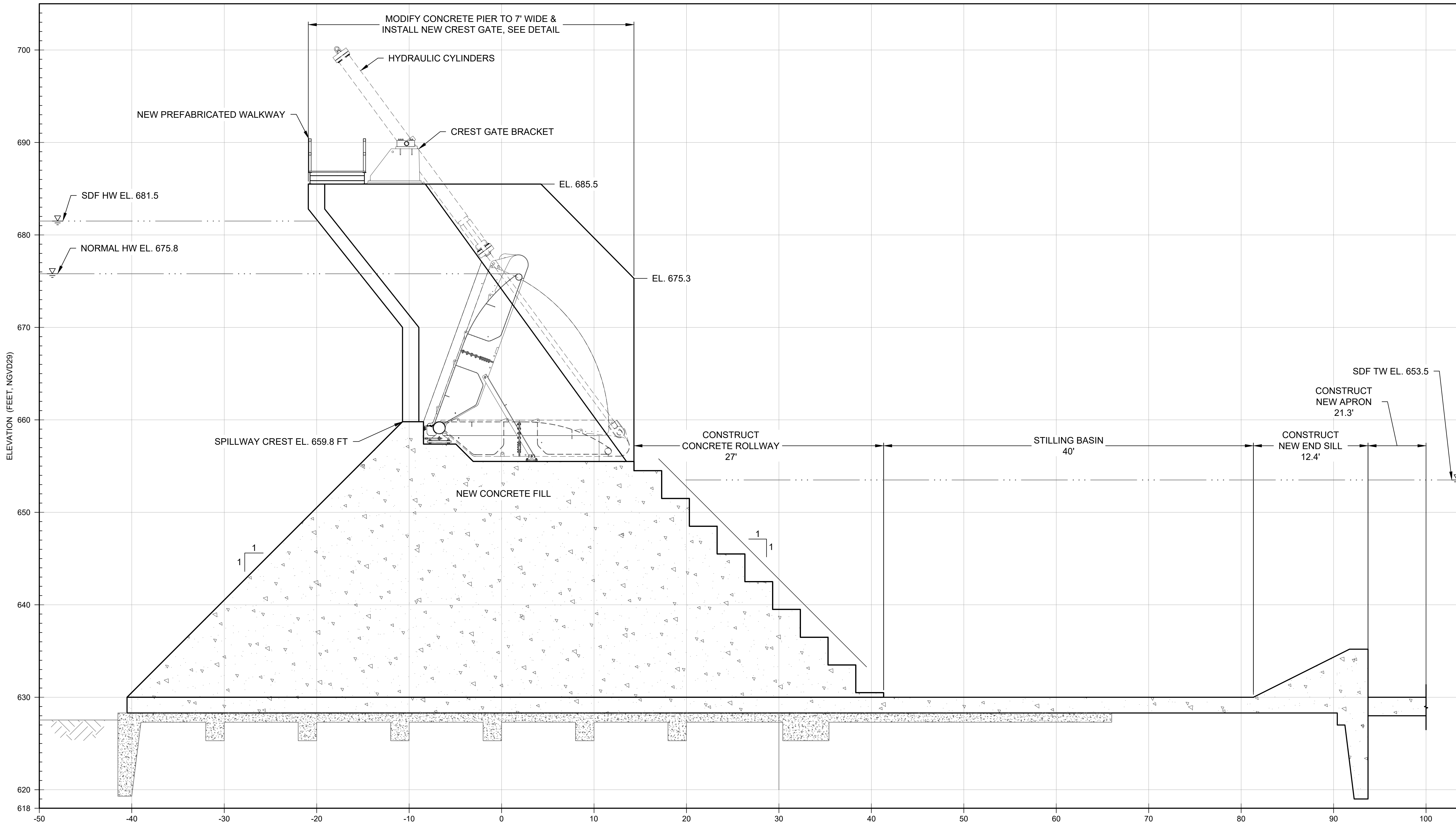

D
C-11

SECTION
SPILLWAY

0 5 10
SCALE, FT

HATCH LEGEND

EXISTING CONCRETE | EXISTING FOUNDATION | PROPOSED REINFORCED CONCRETE

Attention:				
0 1"				
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Edenville Dam
Conceptual Design
Gladwin County, Michigan

EDENVILLE PRIMARY SPILLWAY - MODIFICATIONS SECTION

DWG. NO.
C-12

SHEET NO.
14

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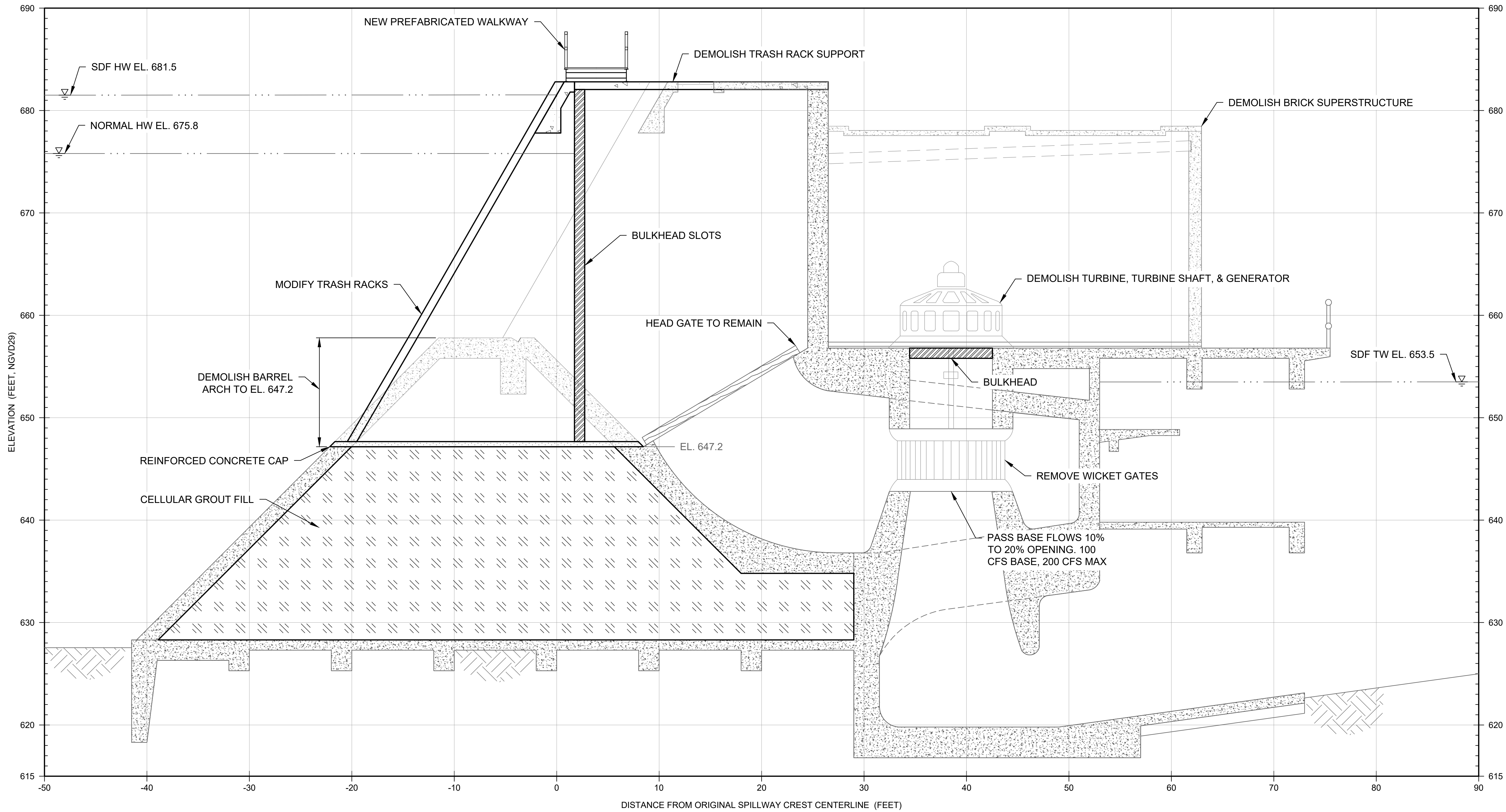

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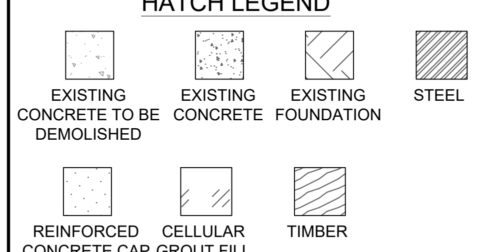

E / C-11 SECTION POWERHOUSE

0 5 10 SCALE, FT

Attention:				
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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Gladwin County, Michigan

EDENVILLE POWERHOUSE - MODIFICATIONS SECTION

DWG. NO. C-13

SHEET NO. 15

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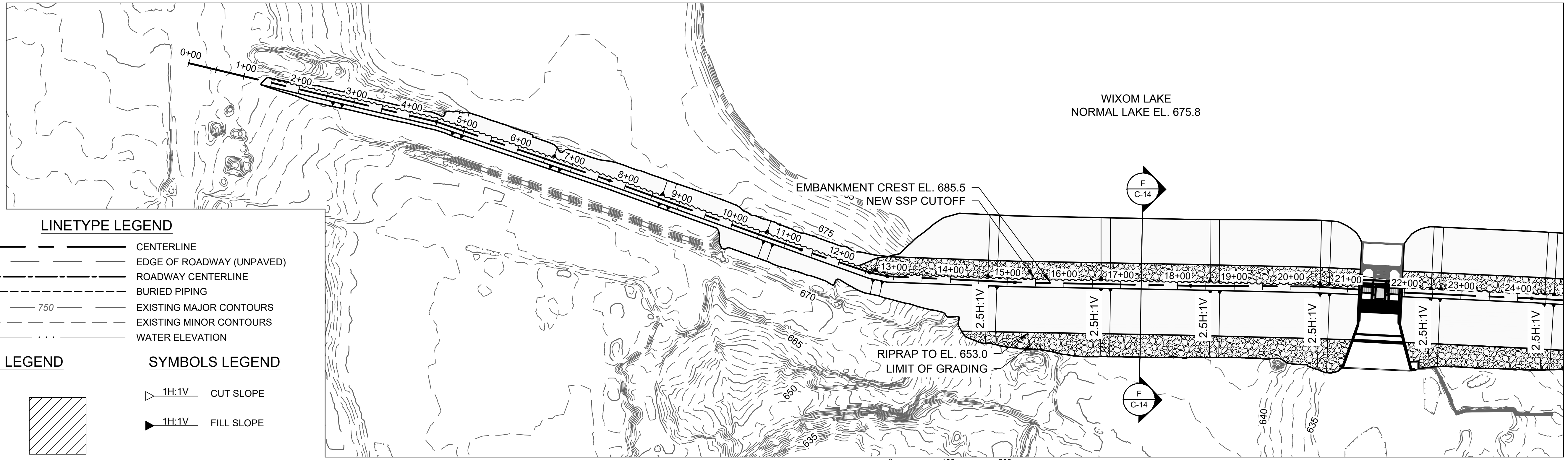


LINETYPE LEGEND

- CENTERLINE
- EDGE OF ROADWAY (UNPAVED)
- ROADWAY CENTERLINE
- BURIED PIPING
- 750 EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- WATER ELEVATION

HATCH LEGEND

- RIPRAP
- BERM FILL AREA

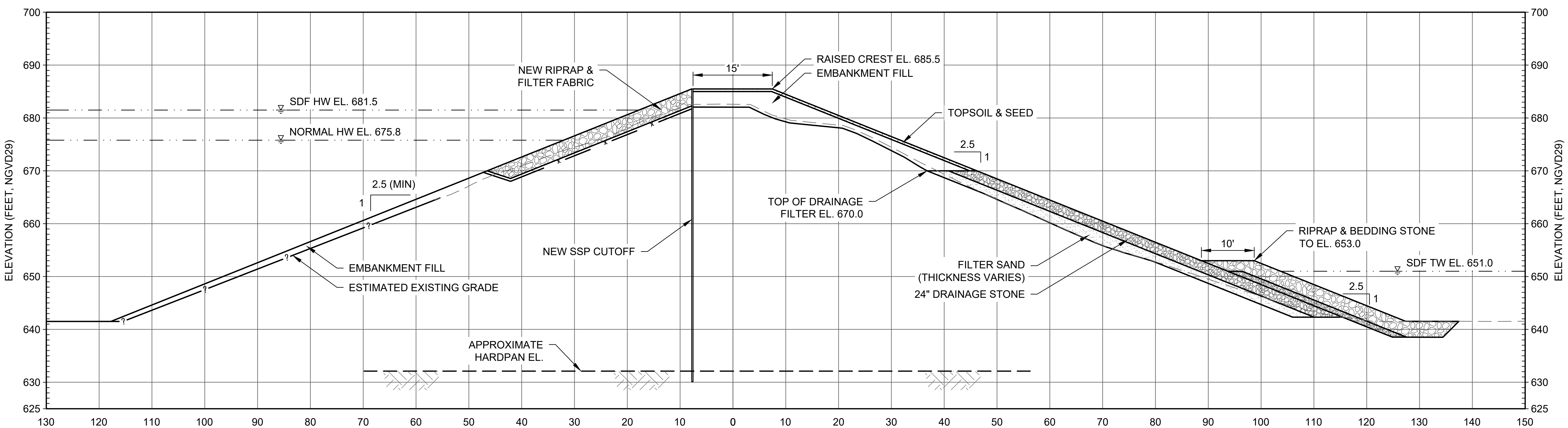
SYMBOLS LEGEND

- 1H:1V CUT SLOPE
- 1H:1V FILL SLOPE

SITE PLAN - PROPOSED MODIFICATIONS

TOBACCO - RIGHT EMBANKMENT

0 100 200 SCALE, FEET



F / C-14 SECTION

TOBACCO - RIGHT 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.

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Gladwin County, Michigan

TOBACCO RIGHT EMBANKMENT - MODIFICATIONS

DWG. NO. C-14

SHEET NO. 16

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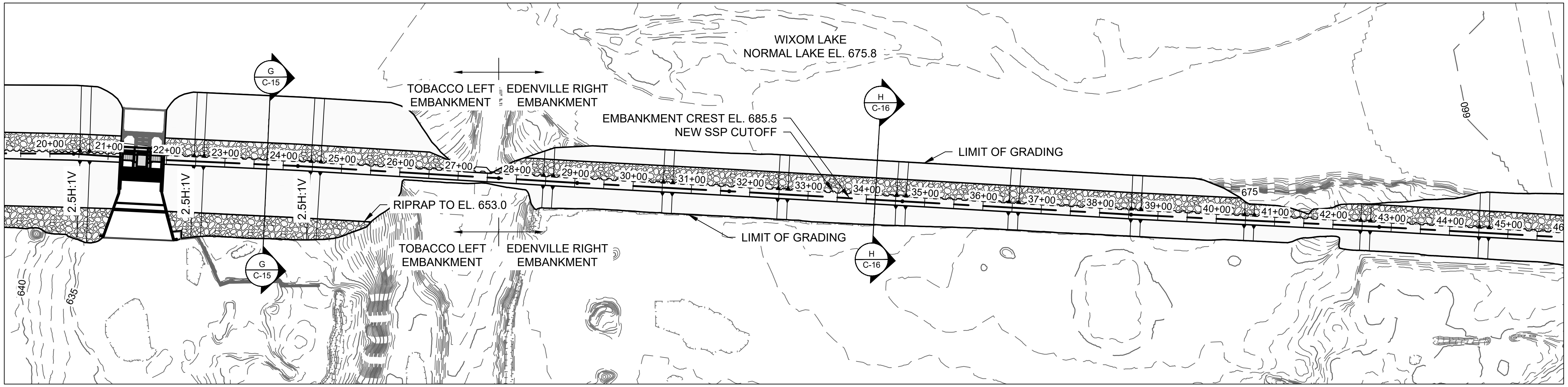
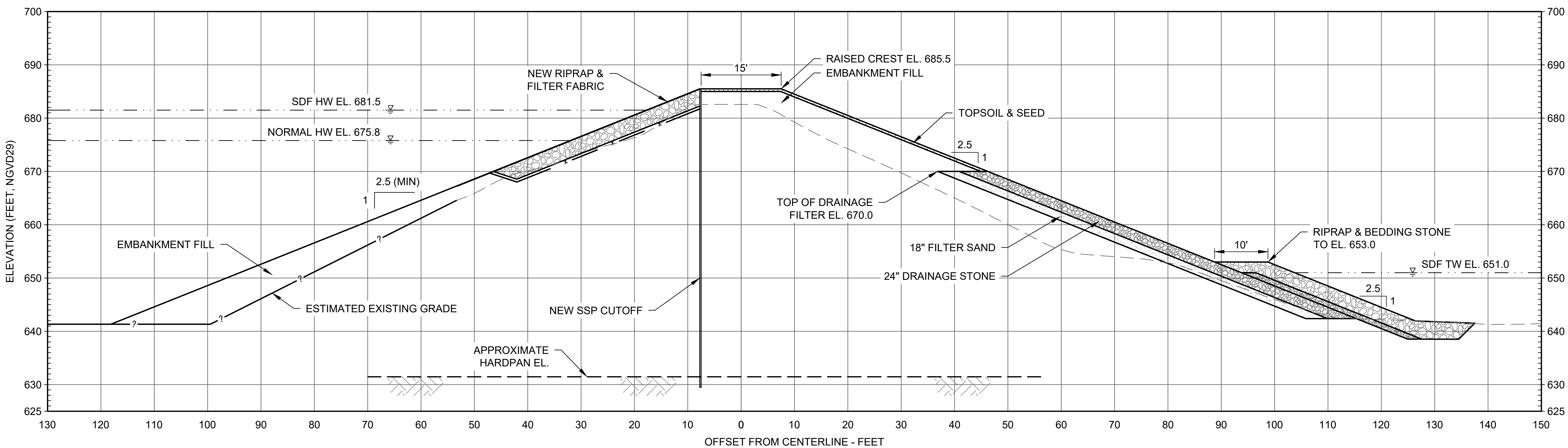


SITE PLAN - PROPOSED MODIFICATIONS
TOBACCO LEFT & TITTABAWASSEE RIGHT EMBANKMENTS

SCALE, FEET 0 100 200



G C-15 SECTION
TOBACCO LEFT EMBANKMENT

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

Attention: 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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G100
MILWAUKEE, WI 53226
(414)930-7540

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

Four Lakes Task Force

GEI Project 2002879

Edenville Dam
Conceptual Design
Gladwin County, Michigan

TOBACCO LEFT EMBANKMENT - MODIFICATIONS

DWG. NO. C-15

SHEET NO. 17

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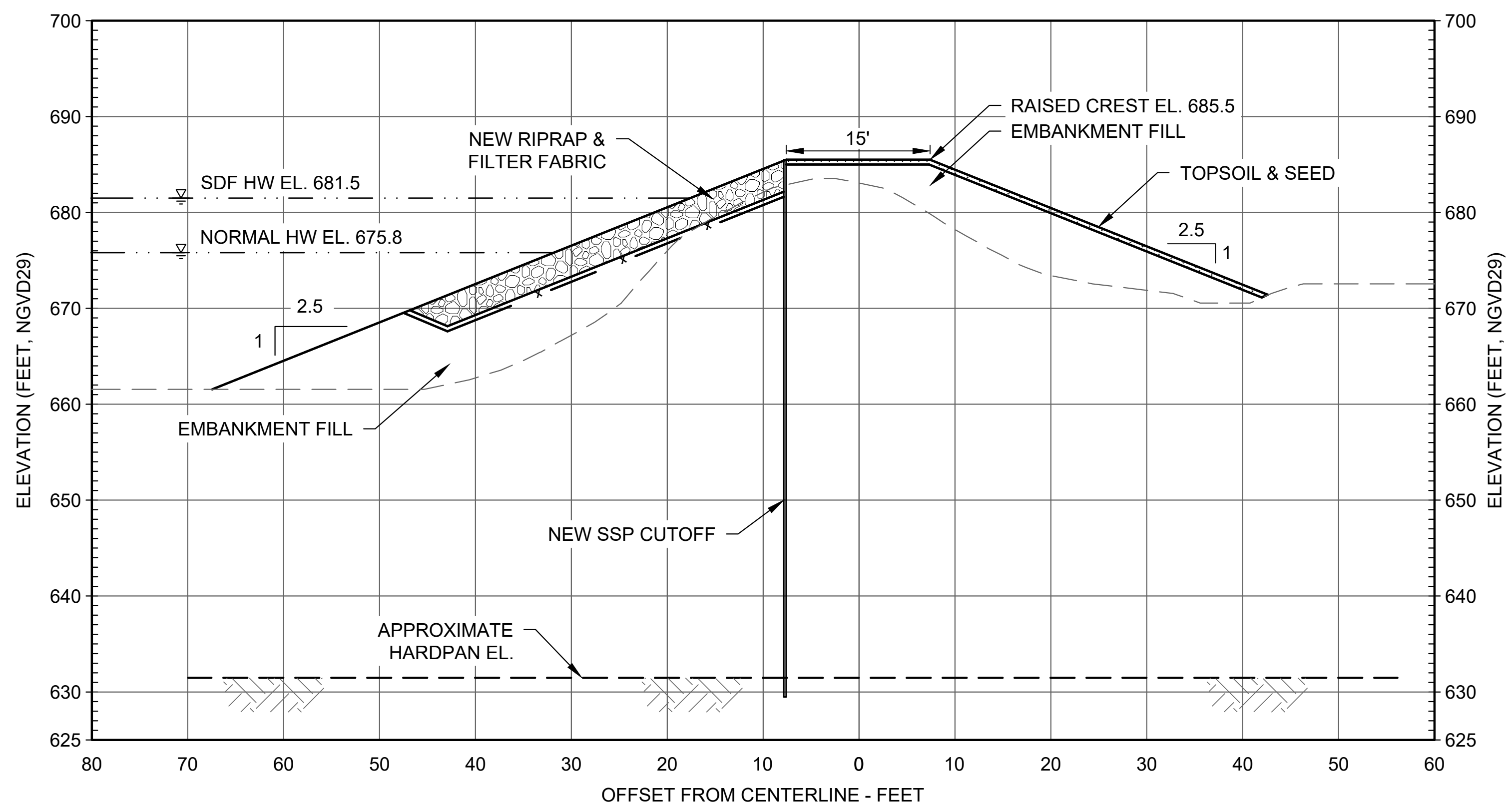
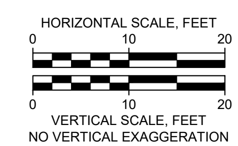


H
C-15
SECTION
EDENVILLE RIGHT EMBANKMENT



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EDENVILLE RIGHT EMBANKMENT - MODIFICATIONS SECTION

DWG. NO. C-16

SHEET NO. 18

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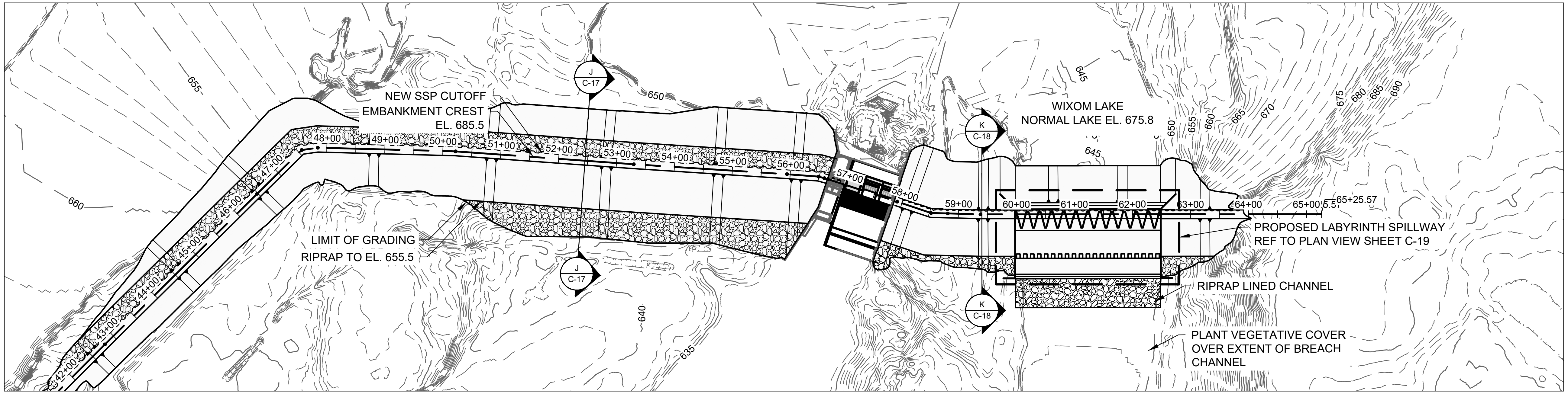
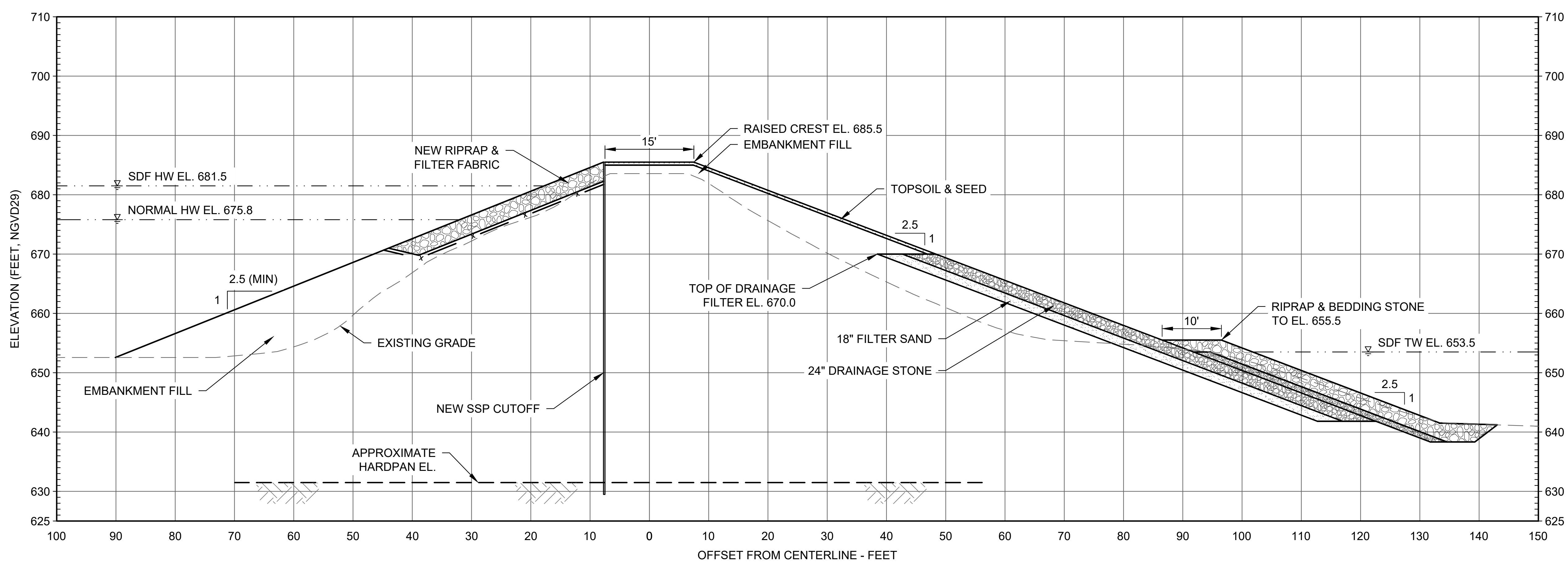


SITE PLAN - PROPOSED MODIFICATIONS

EDENVILLE RIGHT & LEFT EMBANKMENTS

0 100 200
SCALE, FEET



J / C-17 SECTION

EDENVILLE RIGHT EMBANKMENT

HORIZONTAL SCALE, FEET 0 10 20

VERTICAL SCALE, FEET 0 10 20

NO VERTICAL EXAGGERATION

Attention:

0 1"

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Drawn: A. SAMPSON

Approved By: B. WALTON

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Gladwin County, Michigan

EDENVILLE EMBANKMENTS - MODIFICATIONS

DWG. NO. C-17

SHEET NO. 19

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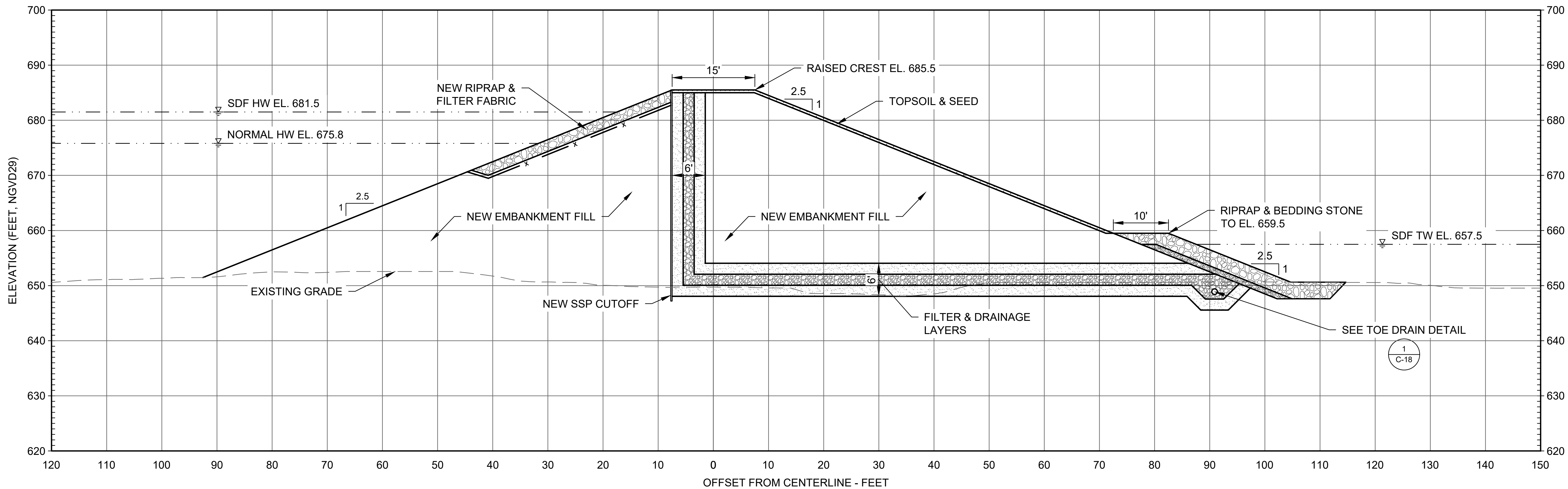
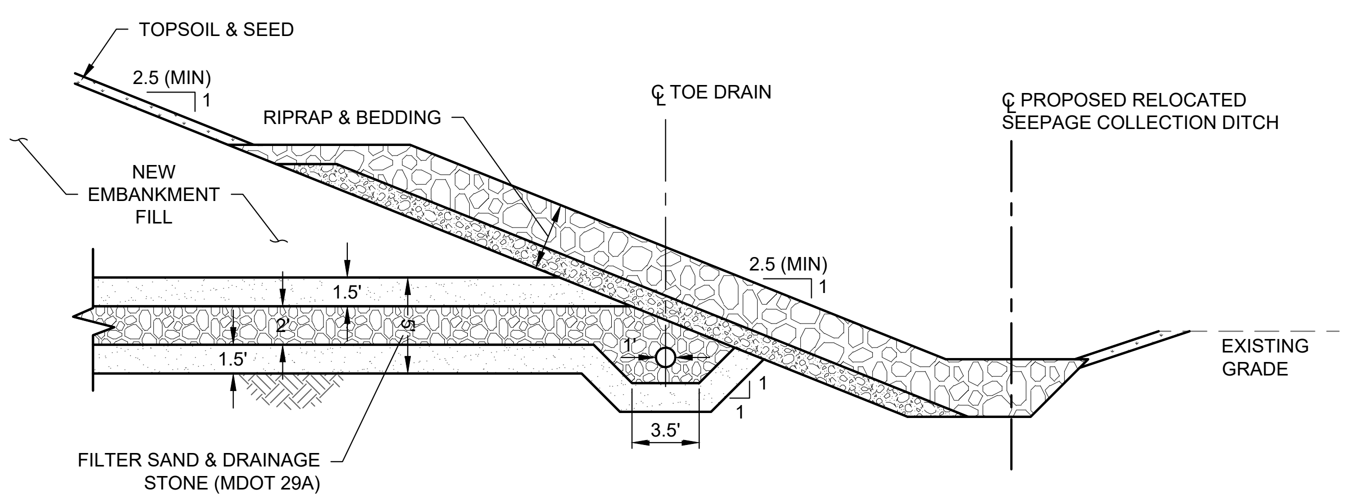


K
C-17
SECTION
EDENVILLE LEFT EMBANKMENT

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



1
C-18
DETAIL
TOE DRAIN

0 5 10
SCALE, FEET

Attention:				
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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GEI Project 2002879

Edenville Dam
Conceptual Design
Gladwin County, Michigan

EDENVILLE EMBANKMENTS - MODIFICATIONS SECTIONS & DETAILS

DWG. NO.
C-18

SHEET NO.
20

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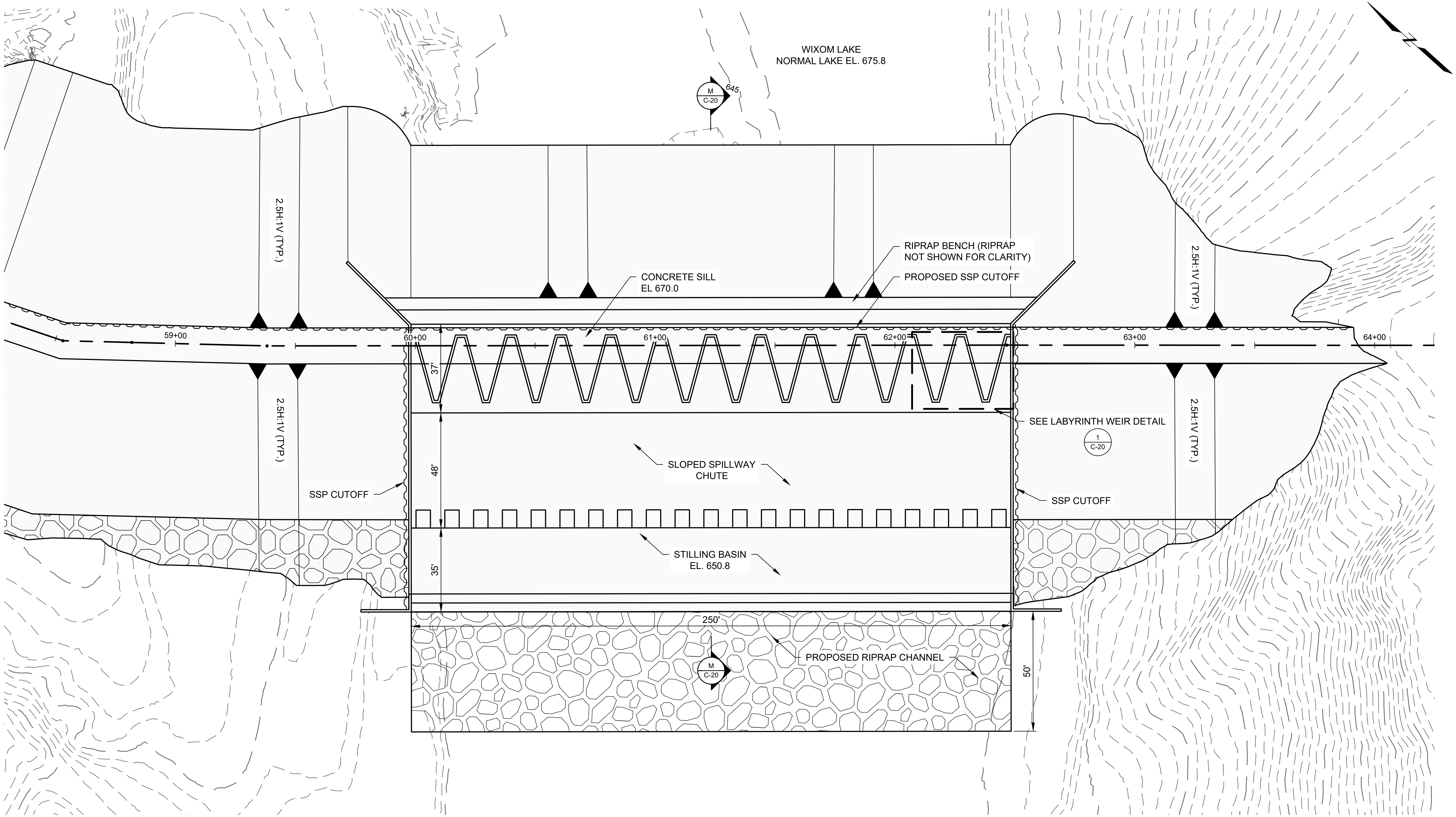

PLAN VIEW

PROPOSED LABYRINTH SPILLWAY

0 20 40

SCALE, FEET

Attention:

0 1"

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Edenville Dam
Conceptual Design
Gladwin County, Michigan

TITTABAWASSEE BREACH CHANNEL - PROPOSED LABYRINTH SPILLWAY PLAN

DWG. NO.
C-19

SHEET NO.
21

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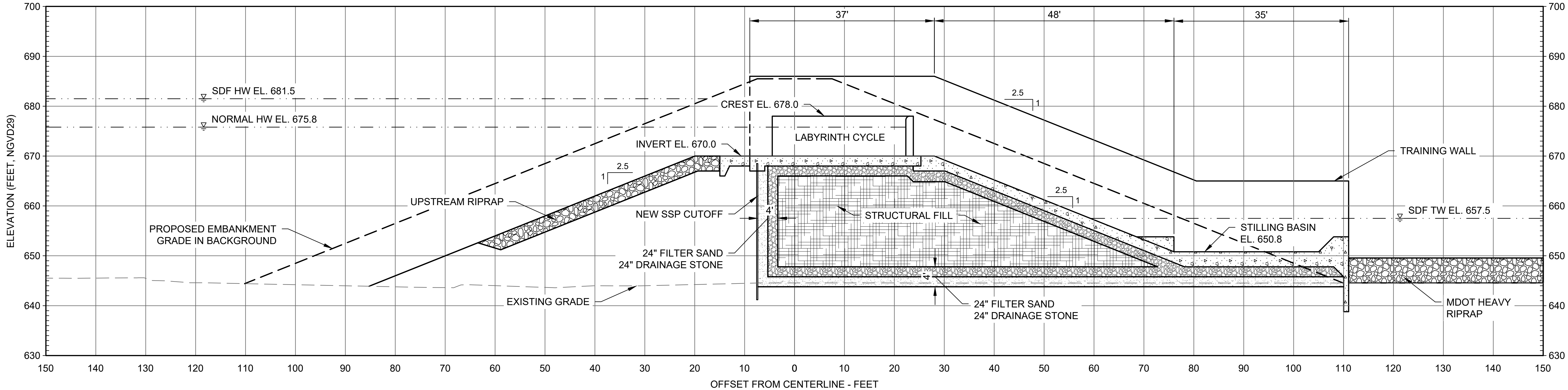
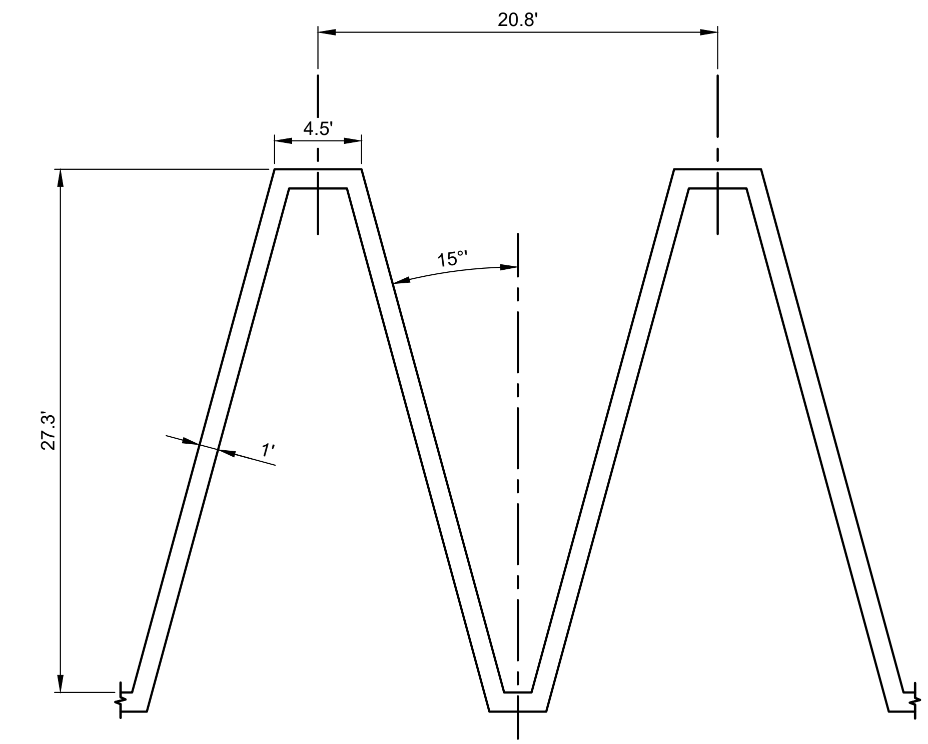


M C-19 SECTION
PROPOSED SPILLWAY

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



1 C-19 DETAIL
LABYRINTH WEIR CYCLE

SCALE, FEET 0 5 10

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Four Lakes Task Force

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Edenville Dam
Conceptual Design
Gladwin County, Michigan

TITTABAWASSEE BREACH CHANNEL - PROPOSED LABYRINTH SPILLWAY SECTION & DETAILS

DWG. NO. C-20

SHEET NO. 22

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Appendix E

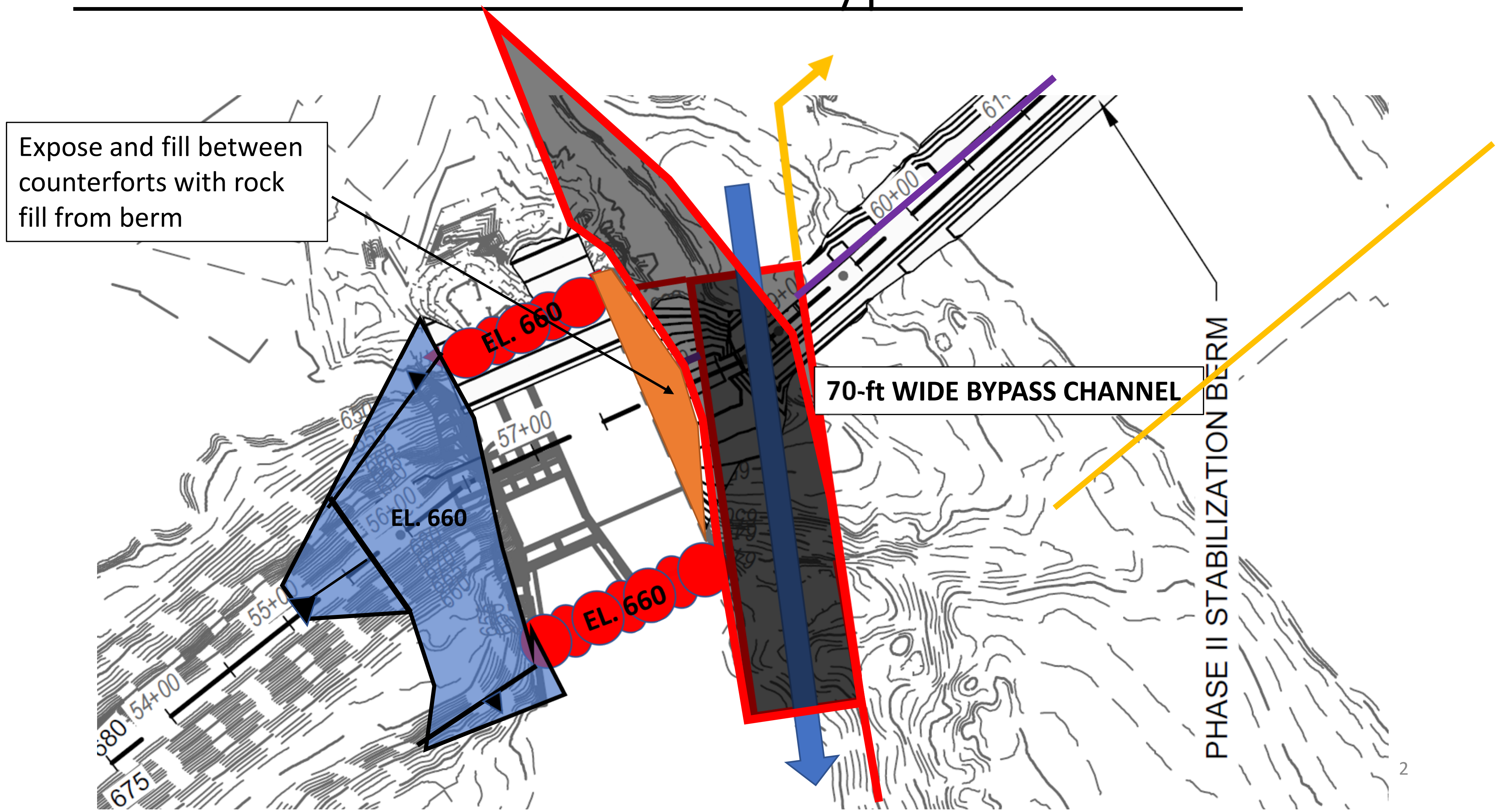
Conceptual Cofferdam Designs

Four Lakes Task Force Concept for Edenville and Tobacco Cofferdams and River Control

Bill Walton, P.E., S.E.

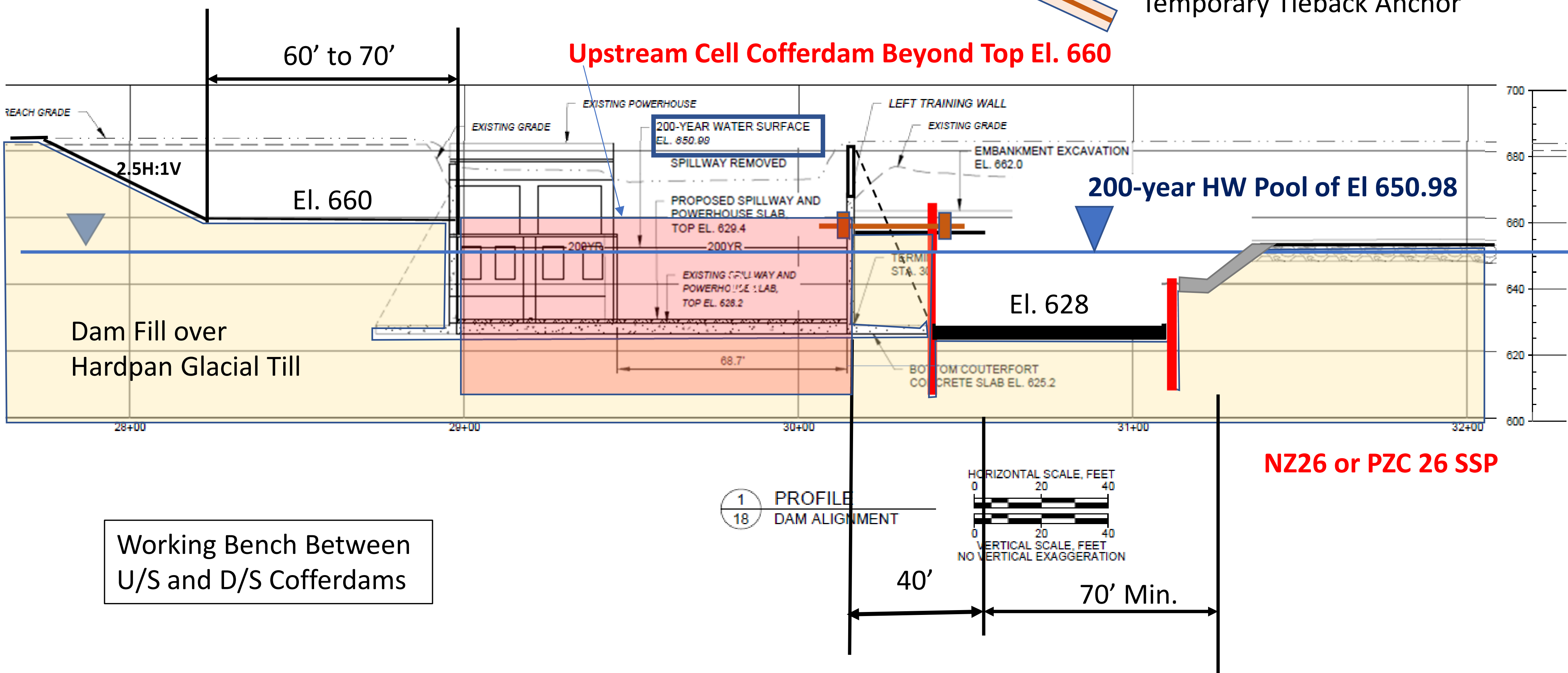
March 9, 2021

Edenville Cofferdam and Bypass Channel

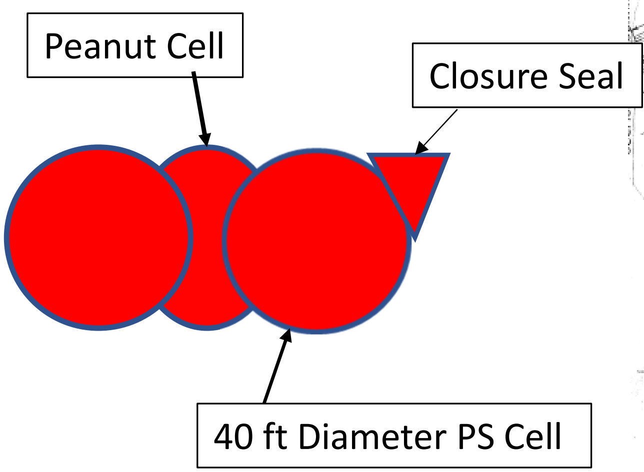


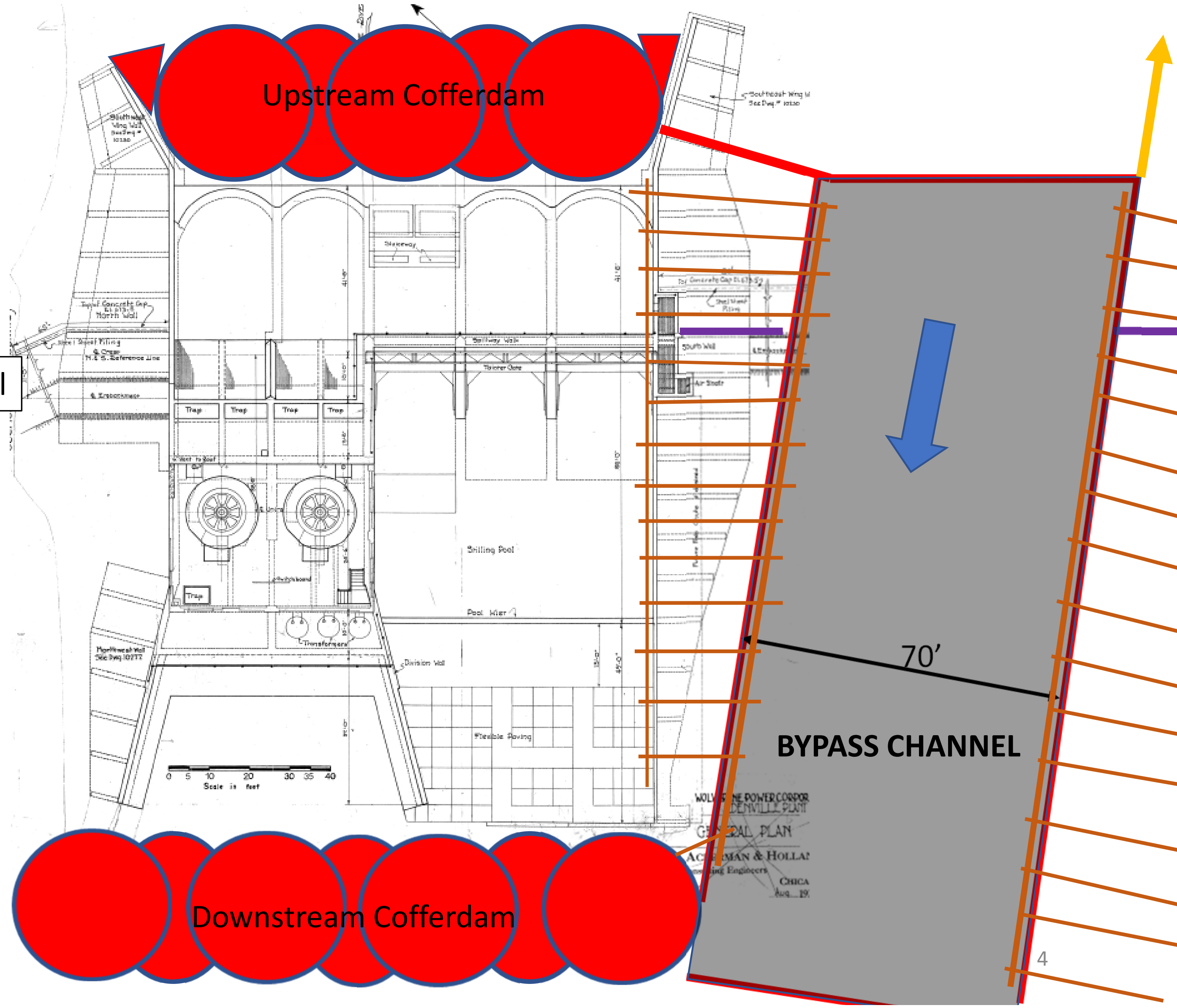
Section Looking Upstream Diversion Channel

- Temporary Concrete Spillway Apron
- Threaded Tie Rod
- Anchor Head and Waler
- Temporary Tieback Anchor



Cofferdam and Bypass Channel





USACE EM 1110-2-2503 Cell Design (GEI has Calibrated Software Reviewed by USACE at Soo Looks for LC

838 FOUNDATION ANALYSIS AND DESIGN

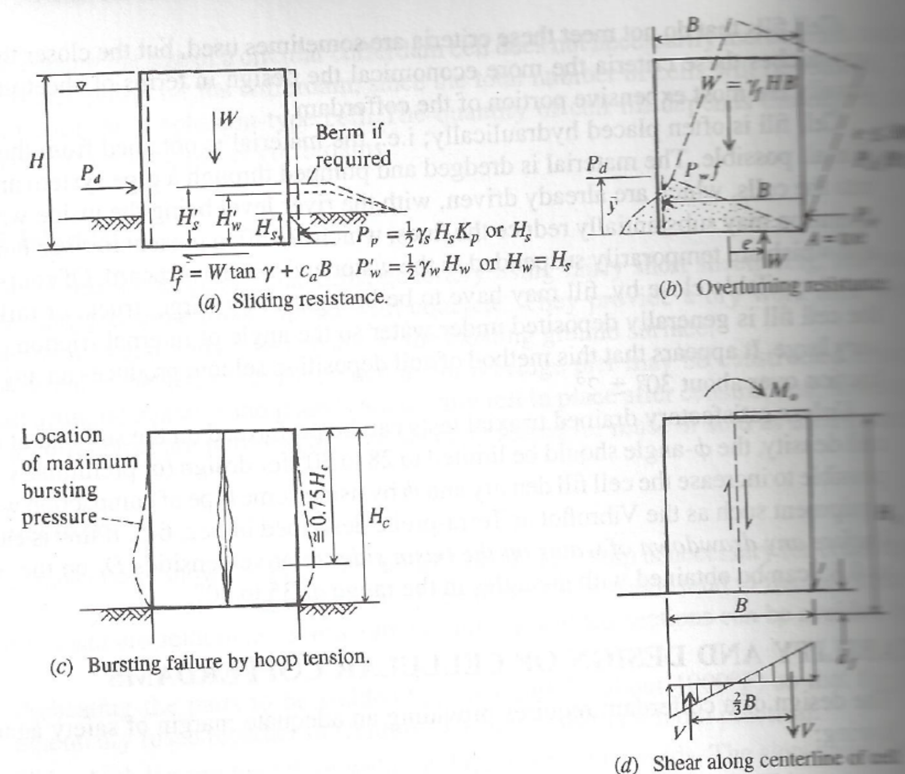


Figure 15-5 Stability of cofferdams.

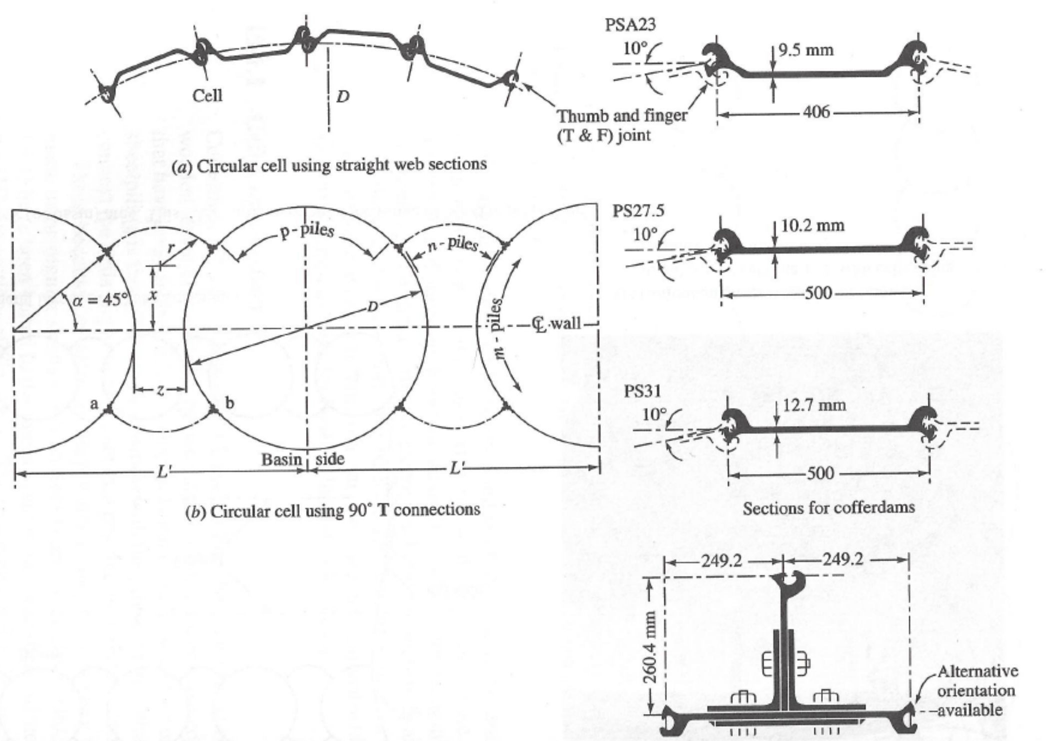
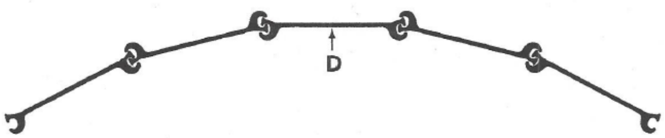


Figure 15-4 Sheetpiling and connections used in cellular cofferdam construction. Bolts are A325 with washers (usually 22-mm diam) at 115-mm spacing except 600-mm end zones where spacing is 75 mm. (Figure is a composite from Bethlehem Steel Corporation booklet No. 2001).

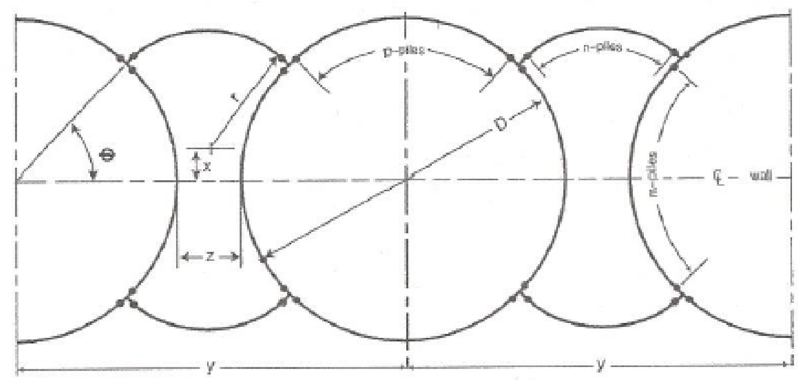
Hot Rolled Gerdau SSP 40 ft PS 27.5 Cellular Cells

GERDAU SHEET PILING

DIAMETERS AND AREAS OF CIRCULAR CELLS USING PS 27.5 AND PS 31



PS FLAT SHEET PILING 90° EXTRUDED TEE LAYOUT



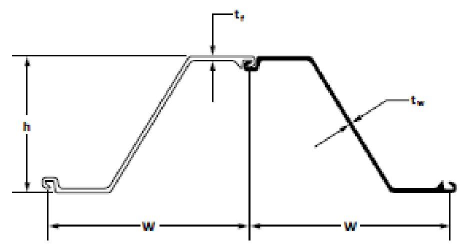
θ is measured to the center of the 90° connection

Number of Piles in Cell†	D ft (m)	z ft (m)	y ft (m)	r ft (m)	X ft (m)	θ deg	Number of Piles m	n	p	Area Within Circle sq ft (sq m)	Area Between Circles sq ft (sq m)	Average Width ft (m)	Layout Number (see Website)
44	21.20 *6.46*	7.53 *2.30*	28.73 *8.76*	9.72 *2.96*	0.68 *0.21*	45.3	10	9	10	353 *32.8*	197 *18.3*	19.2 *5.9*	4
48	23.29 *7.10*	6.84 *2.08*	30.13 *9.18*	9.67 *2.95*	1.45 *0.44*	45.2	11	9	11	426 *39.6*	203 *18.9*	20.9 *6.4*	6
52	25.38 *7.74*	6.31 *1.92*	31.69 *9.66*	9.73 *2.97*	2.15 *0.66*	45.2	12	9	12	506 *47.0*	210 *19.5*	22.6 *6.9*	4
56	27.47 *8.37*	5.62 *1.71*	33.09 *10.09*	9.68 *2.95*	2.92 *0.89*	45.2	13	9	13	593 *55.1*	213 *19.8*	24.3 *7.4*	6
60	29.56 *9.01*	5.09 *1.55*	34.64 *10.56*	9.73 *2.97*	3.62 *1.10*	45.2	14	9	14	686 *63.7*	218 *20.3*	26.1 *8.0*	4
64	31.65 *9.65*	5.95 *1.81*	37.60 *11.46*	10.76 *3.28*	3.58 *1.09*	45	15	10	15	787 *73.1*	264 *24.5*	27.9 *8.5*	3
68	33.73 *10.28*	5.42 *1.65*	39.15 *11.93*	10.82 *3.30*	4.28 *1.30*	45	16	10	16	894 *83.1*	269 *25.0*	29.7 *9.1*	5
72	35.82 *10.92*	4.73 *1.44*	40.55 *12.36*	10.76 *3.28*	5.05 *1.54*	45.2	17	10	17	1008 *93.6*	269 *25.0*	31.5 *9.6*	3
76	37.91 *11.55*	5.59 *1.70*	43.51 *13.26*	11.83 *3.61*	5.09 *1.55*	45.1	18	11	18	1129 *104.9*	324 *30.1*	33.4 *10.2*	4
80	40.00 *12.19*	4.91 *1.50*	44.91 *13.69*	11.77 *3.59*	5.87 *1.79*	45.1	19	11	19	1257 *116.8*	323 *30.0*	35.2 *10.7*	6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.78	45	20	12	20	1391	[illegible]	[illegible]	[illegible]

All dimensions given are nominal.

Hot Rolled Nucor NZ 26 SSP

NZ Hot Rolled Steel Sheet Pile



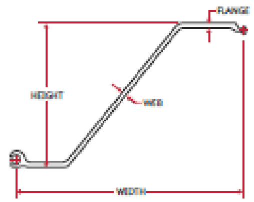
NZ

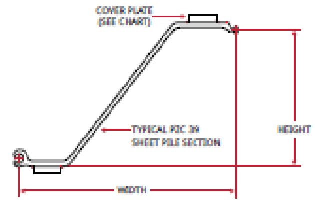
SECTION	Width (w)	Height (h)	THICKNESS		Cross Sectional Area	WEIGHT		SECTION MODULUS		Moment of Inertia	COATING AREA	
	in mm	in mm	Flange (t_f) in mm	Web (t_w) in mm	in²/ft cm²/m	Pile lb/ft kg/m	Wall lb/ft² kg/m²	Elastic in³/ft cm³/m	Plastic in³/ft cm³/m	in⁴/ft cm⁴/m	Both Sides ft²/ft of single m²/m	Wall Surface ft²/ft² m²/m²
NZ 14	30.31 770	13.39 340	0.375 9.5	0.375 9.5	6.40 135.4	55 81.26	21.77 106.30	25.65 1379	30.50 1640	171.7 23447	6.10 1.86	1.20 1.20
NZ 19	27.56 700	16.14 410	0.375 9.5	0.375 9.5	7.07 149.6	55 81.85	24.05 117.40	35.08 1886	41.33 2222	283.1 38659	6.18 1.88	1.35 1.35
NZ 20	27.56 700	16.16 411	0.394 10.0	0.394 10.0	7.34 155.4	57 85.37	24.82 122.00	36.24 1948	42.80 2301	292.8 39984	6.18 1.88	1.35 1.35
NZ 21	27.56 700	16.20 412	0.433 11.0	0.433 11.0	7.80 165.2	61 90.78	26.56 129.70	38.69 2080	45.85 2465	313.4 42797	6.18 1.88	1.35 1.35
NZ 22	27.56 700.0	16.25 413.0	0.480 12.20	0.480 12.20	8.57 181.4	67 99.71	29.20 142.44	41.47 2230	49.34 2653	336.9 46006	6.18 1.88	1.35 1.35
NZ 26	27.56 700	17.32 440	0.500 12.7	0.500 12.7	9.08 192.2	71 105.66	30.99 151.30	48.50 2608	57.01 3065	419.9 57340	6.49 1.98	1.41 1.41
NZ 28	27.56 700	17.38 441	0.560 14.2	0.560 14.2	9.98 211.2	78 116.08	33.96 165.82	52.62 2829	62.16 3342	457.4 62461	6.49 1.98	1.41 1.41
NZ 38	27.56 700	19.69 500	0.689 17.5	0.500 12.7	11.00 232.9	86 127.99	37.45 182.83	70.84 3809	81.57 4386	697.3 95214	6.58 2.01	1.43 1.43
NZ 40	27.56 700.0	19.73 501.0	0.735 18.70	0.551 14.00	11.77 249.1	92 136.91	40.06 195.59	74.97 4031	86.75 4664	739.6 100997	6.58 2.01	1.43 1.43
NZ 42	27.56 700.0	19.77 502.0	0.769 19.50	0.589 15.0	12.41 262.7	97 144.36	42.24 206.23	78.17 4203	90.80 4881	772.5 105490	6.58 2.01	1.43 1.43

Hot Rolled Foster PZC 26SSP

LBFoster Piling

Z Pile Profile





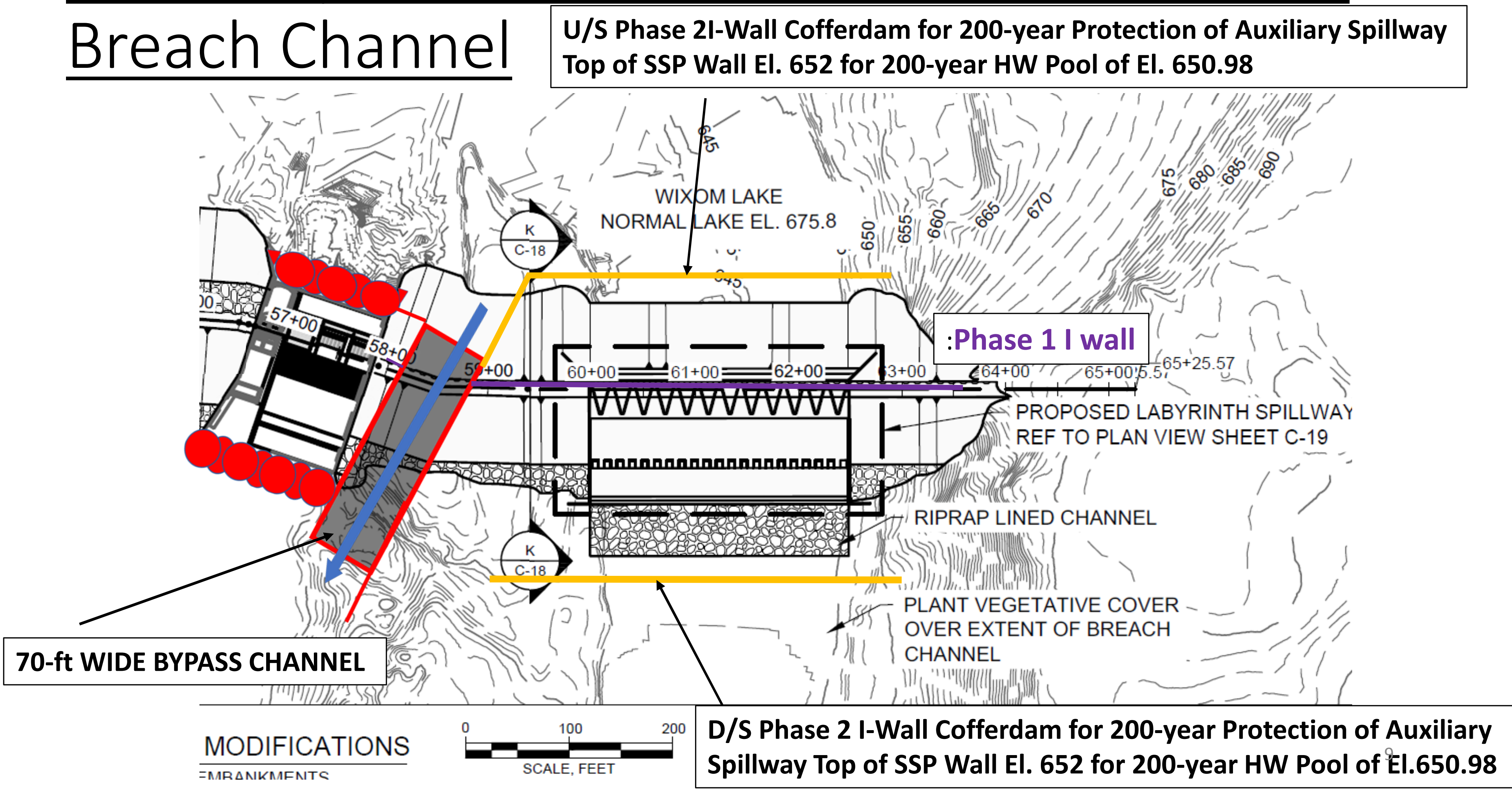
Cover Plated Z Profile

Section	Width+	Height+	Web Thickness+	Flange Thickness+	Weight		Moment of Inertia		Section Modulus		Nominal Coating Area*
	in	in	in	in	lb / lft	lb / ft²	in⁴	in⁴ / wft	in³	in³ / wft	ft² / lft
	mm	mm	mm	mm	kg / lm	kg / m²	cm⁴	cm⁴ / wm	cm³	cm³ / wm	m² / lm
PZC 13	**27.88**	**12.56**	**0.375**	**0.375**	**50.4**	**21.7**	**353.0**	**152.0**	**56.2**	**24.2**	**5.60**
	708	**319**	**9.5**	**9.5**	**75.1**	**106.0**	**14,690**	**20,760**	**920**	**1,300**	**1.71**
PZC 14	27.88	12.60	0.420	0.420	55.0	23.7	381.6	164.3	60.5	26.0	5.60
	708	320	10.7	10.7	81.8	115.5	15,890	22,440	990	1,400	1.71
PZC 18	**25.00**	**15.25**	**0.375**	**0.375**	**50.4**	**24.2**	**532.2**	**255.5**	**69.8**	**33.5**	**5.60**
	635	**387**	**9.5**	**9.5**	**75.1**	**118.2**	**22,150**	**34,890**	**1,145**	**1,800**	**1.71**
PZC 19	25.00	15.30	0.420	0.420	55.0	26.4	576.3	276.6	75.3	36.1	5.60
	635	388	10.7	10.7	81.8	128.8	23,990	37,780	1,235	1,945	1.71
PZC 25	27.88	17.66	0.485	0.560	69.4	29.9	938.7	404.1	106.3	45.7	6.15
	708	449	12.3	14.2	103.3	145.9	39,070	55,190	1,740	2,455	1.87
PZC 26	**27.88**	**17.70**	**0.525**	**0.600**	**73.9**	**31.8**	**994.3**	**428.1**	**112.4**	**48.4**	**6.15**
	708	**450**	**13.3**	**15.2**	**110.0**	**155.4**	**41,390**	**58,460**	**1,840**	**2,600**	**1.87**
PZC 28	27.88	17.75	0.570	0.645	79.0	34.0	1,057	455.1	119.1	51.3	6.15
	708	451	14.5	16.4	117.6	166.1	44,000	62,150	1,950	2,755	1.87
PZC 37	22.50	21.02	0.488	0.563	69.6	37.1	1,349	719.6	128.4	68.5	6.15
	572	534	12.4	14.3	103.6	181.2	56,160	98,270	2,100	3,680	1.87
PZC 39	**22.50**	**21.05**	**0.525**	**0.600**	**74.0**	**39.5**	**1,429**	**762.1**	**135.6**	**72.3**	**6.15**
	572	**535**	**13.3**	**15.2**	**110.2**	**192.8**	**59,480**	**104,100**	**2,220**	**3,890**	**1.87**
PZC 41	22.50	21.09	0.561	0.636	78.4	41.8	1,507	803.6	142.7	76.1	6.15
	572	536	14.2	16.2	116.6	204.1	62,720	109,700	2,340	4,090	1.87

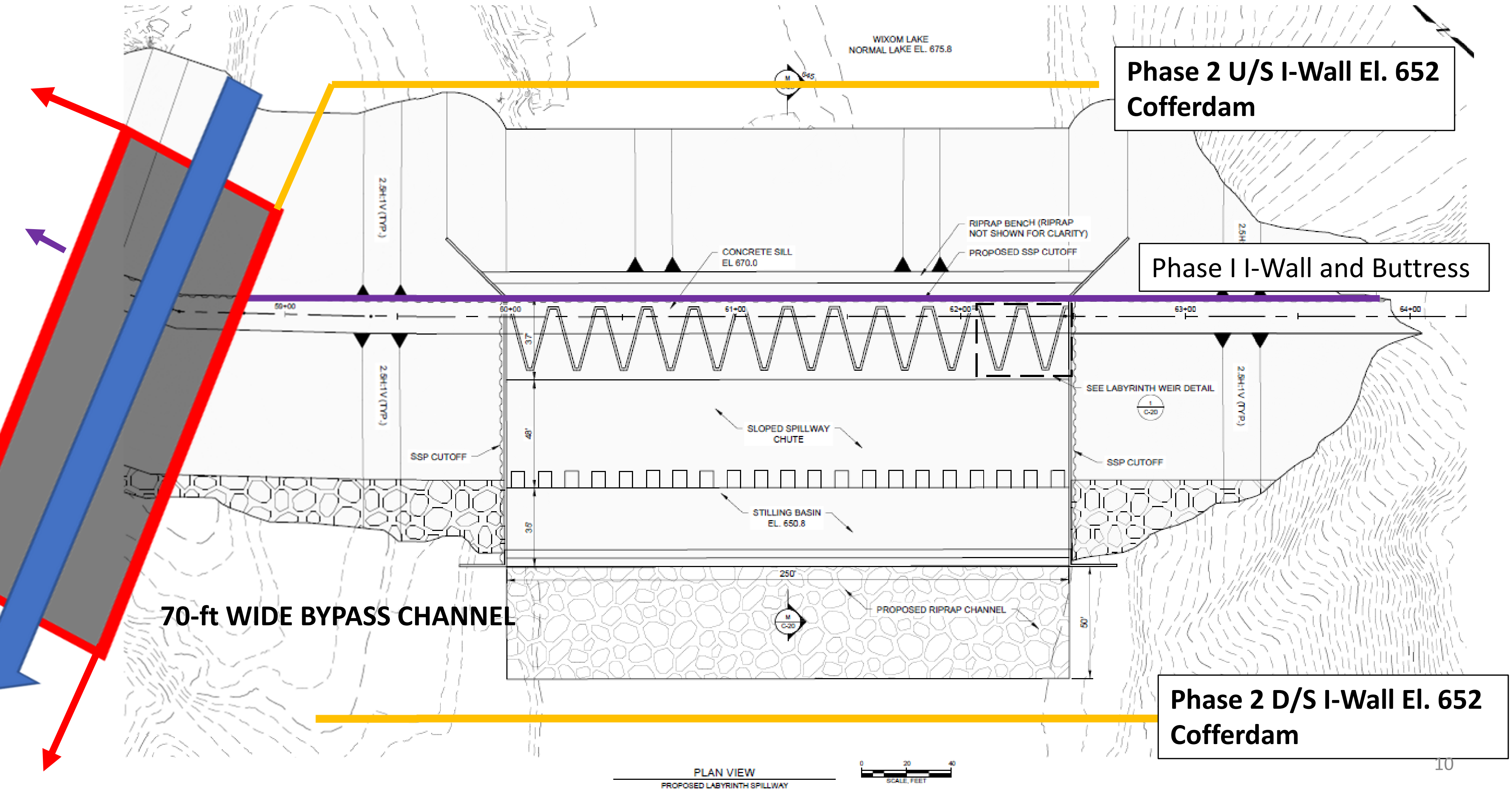
Available Grades: ASTM A572 Gr. 50 and 60, A588 and A690
+Values stated are nominal
*Both sides of sheet excludes socket interior and ball interlock

PZC™ is a trademark of Gerdau

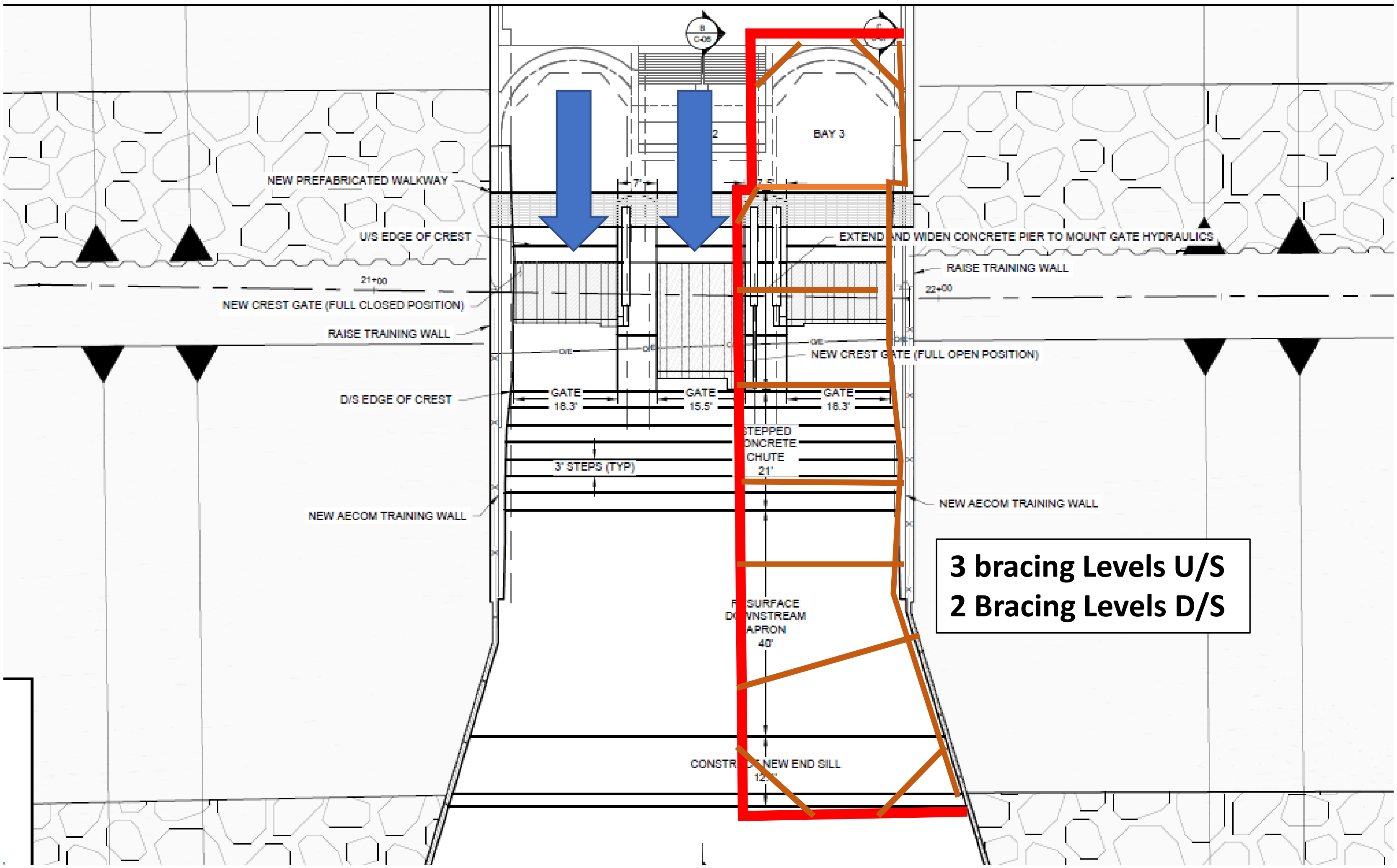
New Labyrinth and Embankment Dam Across Breach Channel



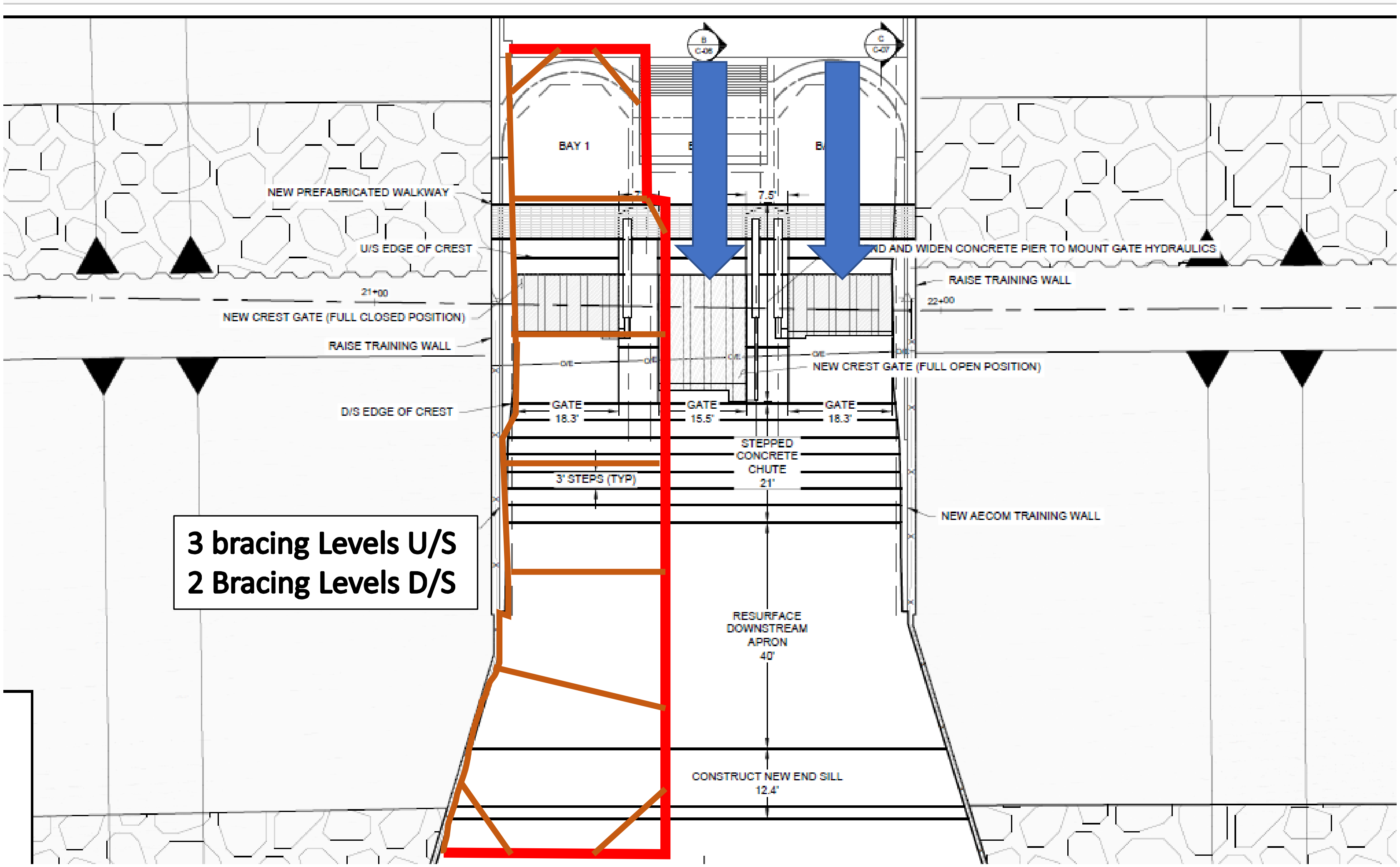
Edenville Auxiliary Spillway Cofferdam



Tobacco Spillway Cofferdam Sequence Phase 1

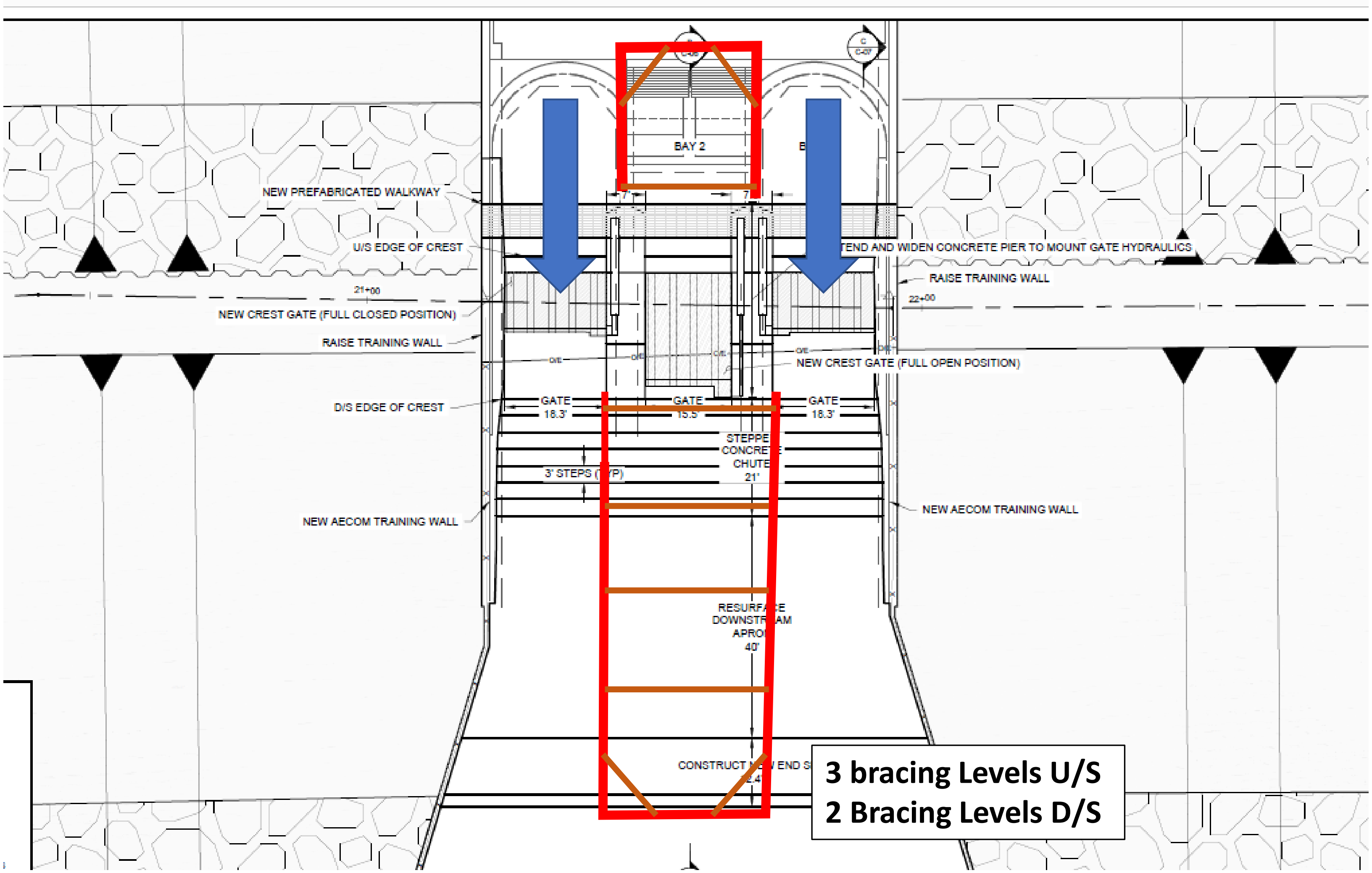


Tobacco Spillway Cofferdam Sequence - Phase 2



3 bracing Levels U/S
2 Bracing Levels D/S

Tobacco Spillway Cofferdam Sequence - Phase 3



Appendix F

Opinions of Probable Construction Costs (OPCC) Worksheets

OPINION OF PROBABLE COST - CONCEPTUAL

Project: Edenville Dam
Client: Four Lakes Task Force (FLTF)

Project No.: 2002879
Date: 3/5/2021
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	$ 4,331,000	$ 4,331,000	5% of Other Costs
0.02	Bonds and Insurance	1	LS	$ 1,732,000	$ 1,732,000	2% of Other Costs
0.03	Construction Permits	1	LS	$ 100,000	$ 100,000	
				Subtotal	**$ 6,163,000**	
1.00	**Site Preparation**					
1.01	Erosion and Sediment Control	1	LS	$ 50,000	$ 50,000	
1.02	Temporary Access Roads, Facilities and Laydown Areas	1	LS	$ 500,000	$ 500,000	
1.03	Phase I Cofferdams - Edenville Spillway, PH and Breach Area	1	LS	$ 23,000,000	$ 23,000,000	
1.04	Phase II Cofferdam - Tobacco Spillway Area	1	LS	$ 3,000,000	$ 3,000,000	
1.05	Construction Dewatering	1	LS	$ 200,000	$ 200,000	
1.06	Sediment Removal and Dredging	1	LS	$ 1,500,000	$ 1,500,000	
1.07	River Diversion	1	LS	$ 5,000,000	$ 5,000,000	
				Subtotal	**$ 33,250,000**	
2.00	**Demolition / Abandonment**					
2.01	Edenville Powerhouse Decommissioning, Demolition and Disposal	1	LS	$ 2,500,000	$ 2,500,000	
2.02	Edenville Downstream Apron Concrete Demolition	301	CY	$ 100	$ 30,083	
2.03	Edenville Powerhouse Concrete Demolition	972	CY	$ 100	$ 97,213	
2.04	Cellular Grout Within Sluiceway	759	CY	$ 700	$ 531,300	
2.05	Reinforced Concrete Cap Above Cellular Grout	13	CY	$ 700	$ 9,004	
2.06	Mechanical and Electrical Equipment Demolition and Disposal	1	LS	$ 250,000	$ 250,000	
				Subtotal	**$ 3,417,601**	
3.00	**Edenville Embankments - Reconstruct Breached Section (L = 740 feet)**					
3.01	Sheet Pile Cutoffs	12,780	SF	$ 65	$ 830,700	Assumes top of stabilization SSP at elev. 652. This quantity only accounts for SSP extension.
3.02	Excavation	5,806	CY	$ 20	$ 116,117	Assumes stabilization berm already removed.Excavation of berm material not included in this quantity.
3.03	Embankment Fill	42,643	CY	$ 30	$ 1,279,283	Includes excavation and soil quantities beneath new labyrinth spillway
3.04	Filter Sand	8,573	CY	$ 40	$ 342,937	
3.05	Drainage Stone	7,189	CY	$ 40	$ 287,547	
3.06	Upstream Riprap Protection	2,241	CY	$ 125	$ 280,097	
3.07	Downstream Riprap Protection	1,522	CY	$ 125	$ 190,210	
3.08	Geotextile	49,165	SF	$ 2	$ 98,330	
3.09	Bedding Stone	422	CY	$ 45	$ 18,994	
3.10	Crest Gravel	100	CY	$ 35	$ 3,500	
3.11	Topsoil, Seed and Temporary Erosion Protection	910	CY	$ 45	$ 40,966	
				Subtotal	**$ 3,488,683**	
4.00	**Edenville Embankments - Repaired and Stabilized Section (Unbreached - L = 2,915 feet)**					
4.01	Sheet Pile Cutoffs	160,325	SF	$ 65	$ 10,421,125	Assumes SSP length of 55 ft
4.02	Excavation	5,119	CY	$ 20	$ 102,378	
4.03	Embankment Fill	45,874	CY	$ 30	$ 1,376,207	
4.04	Filter Sand	2,381	CY	$ 40	$ 95,247	
4.05	Drainage Stone	3,177	CY	$ 40	$ 127,088	
4.06	Upstream Riprap Protection	11,984	CY	$ 125	$ 1,497,966	
4.07	Downstream Riprap Protection	3,192	CY	$ 125	$ 399,051	
4.08	Geotextile	121,593	SF	$ 2	$ 243,187	
4.09	Bedding Stone	1,021	CY	$ 45	$ 45,939	
4.10	Crest Gravel	810	CY	$ 35	$ 28,340	
4.11	Topsoil, Seed and Temporary Erosion Protection	4,412	CY	$ 45	$ 198,545	
				Subtotal	**$ 14,535,072**	
5.00	**Tobacco Embankments - Repaired and Stabilized Section (L=2,540 feet)**					
5.01	Sheet Pile Cutoffs	139,700	SF	$ 65	$ 9,080,500	Assumes SSP length of 55 ft
5.02	Excavation	3,529	CY	$ 20	$ 70,572	
5.03	Embankment Fill	30,373	CY	$ 30	$ 911,189	
5.04	Filter Sand	4,683	CY	$ 40	$ 187,316	
5.05	Drainage Stone	5,926	CY	$ 40	$ 237,023	
5.06	Upstream Riprap Protection	5,203	CY	$ 125	$ 650,326	
5.07	Downstream Riprap Protection	4,623	CY	$ 125	$ 577,904	
5.08	Geotextile	83,748	SF	$ 2	$ 167,495	
5.09	Bedding Stone	1,227	CY	$ 45	$ 55,217	
5.10	Crest Gravel	706	CY	$ 35	$ 24,694	
5.11	Topsoil, Seed and Temporary Erosion Protection	3,875	CY	$ 45	$ 174,366	
				Subtotal	**$ 12,136,603**	
6.00	**New Gated Spillways and Outlet Works - Edenville**					
6.01	Mass Concrete	4,793	CY	$ 700	$ 3,355,152	
6.02	Reinforced Concrete Downstream Apron	795	CY	$ 700	$ 556,526	
6.03	Reinforced Concrete End Sill	252	CY	$ 700	$ 176,141	
6.04	Reinforced Concrete Structure Piers	319	CY	$ 900	$ 286,667	
6.05	Crest Gates - Installed with Hoists and Controls	3	EA	$ 750,000	$ 2,250,000	
6.06	Steel Frame Operators Deck	1	LS	$ 750,000	$ 750,000	
6.07	Reinforced Concrete - Left and Right Training Wall Extensions	648	CY	$ 900	$ 583,516	
				Subtotal	**$ 7,958,001**	
7.00	**New Gated Spillways and Outlet Works - Tobacco**					
7.01	Mass Concrete	1,802	CY	$ 700	$ 1,261,348	
7.02	Reinforced Concrete End Sill	222	CY	$ 700	$ 155,141	
7.03	Reinforced Concrete Structure Piers	251	CY	$ 900	$ 225,583	
7.04	Crest Gates (Shallow) Installed with Hoists and Controls	3	EA	$ 750,000	$ 2,250,000	
7.05	Steel Frame Operators Deck	1	LS	$ 750,000	$ 750,000	
7.06	Reinforced Concrete - Left and Right Training Wall Extensions	58	CY	$ 900	$ 52,533	
				Subtotal	**$ 4,694,605**	
8.00	**Powerhouse Rehabilitation**					
8.01	Misc surface concrete and masonry repairs	1	EA	$ 750,000	$ 750,000	
8.02	Convert water passages to low level outlet	1	EA	$ 1,000,000	$ 1,000,000	
8.03	Head Gate and Hoist	1	EA	$ 500,000	$ 500,000	
				Subtotal	**$ 2,250,000**	
9.00	**New Labyrinth Spillway Structure - Edenville**					
9.01	Reinforced Concrete Labyrinth Weir	222	CY	$ 900	$ 199,872	
9.02	Reinforced Concrete Sill Slab	811	CY	$ 700	$ 568,032	
9.03	Reinforced Concrete Chute Slab	1,061	CY	$ 700	$ 742,508	
9.04	Reinforced Concrete Stilling Basin Floor Slab	814	CY	$ 700	$ 570,065	
9.05	Reinforced Concrete Energy Dissipators	53	CY	$ 700	$ 36,750	
9.06	Reinforced Concrete End Sill	398	CY	$ 700	$ 278,769	
9.07	Reinforced Concrete Spilllway and Stilling Basin Walls	213	CY	$ 900	$ 191,533	
9.08	Steel Sheet Pile Cutoffs	9,521	SF	$ 65	$ 618,833	Assumes top of stabilization SSP at elev. 652. This quantity only accounts for extension of SSP.
9.09	Drain Pipe (Solid and Slotted)	270	LF	$ 25	$ 6,750	
				Subtotal	**$ 3,213,112**	
10.00	**New Discharge Channel for Labyrinth Spillway**					
10.01	Downstream Heavy Riprap (Riprap Lined Channel)	1,157	CY	$ 125	$ 144,676	Assumed W=250', L=50', thickness=2.5'
10.02	Geotextile	12,500	SF	$ 2	$ 25,000	
				Subtotal	**$ 169,676**	
11.00	**Site Restoration**					
11.01	Place Overburden, Seed, Fertilize, and Mulch Slopes	1	LS	$ 1,000,000	$ 1,000,000	
11.02	Dam Safety Monitoring Instrumentation	1	LS	$ 500,000	$ 500,000	
				Subtotal	**$ 1,500,000**	
	Subtotal				$ 92,776,352	
	Contingency			25%	$ 23,194,000	
	Construction Subtotal				**$ 115,970,352**	
	Engineering Investigations, Design and Construction Engineering	-	-		**$ 5,000,000**	
	Total Estimated Cost				**$ 120,970,352**	
				say	**$ 120,970,000**	

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.