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Conceptual Design Basis Report
Rehabilitation of Sanford Dam

Midland County, Michigan

Submitted to:
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Submitted by:
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GEI Project No. 2002879, Task 4

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1. Introduction

1.1 Background

Following the May 19, 2020, storm event that resulted in a catastrophic failure of the Edenville and Sanford Dams, severe downstream erosion damage to the Smallwood Dam, and minor downstream erosion damage to 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 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 cost estimates assuming repair or reconstruction of the dams without hydropower generation and increasing spillway capacity to pass the ½ Probable Maximum Flood (PMF) in accordance with the Michigan Department of Environment, Great Lakes and Energy (EGLE) requirement for high hazard dams. The FLTF also requested that GEI develop cost estimates to pass the full PMF in the event the State of Michigan EGLE, at a future date, increases the high hazard dam minimum spillway capacity requirement above the ½ PMF, or if the probable maximum precipitation (PMP) estimates for a Michigan site-specific region increase. These high-level cost estimates were used to begin budgetary planning for the reconstruction / rehabilitation of the four projects.

As follow-up to our Post Failure Reconstruction Cost Study, the FLTF requested two additional engineering studies be undertaken. The first (Task Order No. 3) is a Tobacco and Tittabawassee River watershed 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 Sanford 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 flooding, the initial results of GEI’s Task 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 Sanford dam failure, the six (6) gate Tainter gate spillway could pass approximately 29,690 cubic feet per second (cfs) of flow with an additional 6,485 cfs through the fuse plug spillway for a total (zero-freeboard) spillway capacity of 36,175 cfs before water begins spilling and overtopping the embankments. According to the latest flood analysis, a total spillway capacity of approximately 35,500 cfs (with residual freeboard) is needed to safely pass the ½ PMF as currently required by the Michigan EGLE without overtopping the dam structures or the abutments.
- The gated spillways and integral three-unit powerhouse reinforced concrete hollow, buttress-type structures constructed on glacial till soil foundations that were more common pre-1940s when materials were expensive, and labor was 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 water lines, 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 hydropower operation, there is no low-level outlet to draw down or drain the impoundment below the invert of the spillway sill.
- The downstream riprap erosion protection is inadequate to prevent erosion during high flows.
- The former fuse plug spillway was ineffective and did not breach as designed under a rising impoundment. Both the left and right embankment structures were overtopped and breached. A new passive auxiliary spillway, along with increased gated primary spillway capacity, is needed to safely pass the design flood. Both the right and left embankments also need to be reconstructed.

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

- Provide improved 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 six (6) Tainter gate spillways and two of the three powerhouse units (left two units razed) and convert to eight (8) 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 (left 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 400 cfs base flows during low flow winter months.

1.2 Project Purpose

The purposes of this Design Basis Report are to provide 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 hydrology and geology, 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.
- Develop design drawings for dam reconstruction to an approximate 30% level of development and prepare an engineer's opinions of probable construction cost.

1.3 Authorization

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

1.4 Project Personnel

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

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

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

1.5 Elevation Datum

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

Table 1: Vertical Datum Conversions

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

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

1.6 Limitation of Liability

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

2. Description of Project Structures

2.1 General Project Descriptions

The Sanford Dam is located on the Tittabawassee River, a tributary to the Saginaw River, and is approximately 11 river miles upstream of the City of Midland in Midland County, Michigan (see **Figure 1**). The facility is owned and operated by the FLTF and the FERC license is currently maintained by Boyce. Construction of the dam was completed in 1925 to provide storage and headwater level control for the purpose of hydroelectric power generation. From left to right and prior to the 2020 breach, the Project consisted of a 175-foot-long left embankment, a 71-foot-long powerhouse containing three generating units with an operating head of 27.8 feet, a 148.2-foot-wide gated spillway with six Tainter gates, a 320-foot-long saddle dike, a 190-foot-wide fuse plug spillway and a 680 foot-long-right embankment with a minimum dam crest at elevation (El.) 636.8 feet. The pre-failure normal headwater and tailwater pools at the dam are El. 630.8 and El. 603.0, respectively. The Exhibit F Drawings from the FERC license, illustrating the typical plan and sections for each of the existing project structures, are included in **Appendix A**. The Sanford Hydroelectric Project is classified as having a high hazard potential based on estimated downstream impacts in the event of failure.

The reinforced concrete spillway is a hollow reinforced concrete barrel arch and ogee shaped rollway structure spanning to buttress piers and the left powerhouse wall and right spillway training walls with six (6) Tainter gate bays. The left gate (Bay 1) is 25.4-feet-wide by 10-feet-high, the center gates (Bays 2 through 5) are 22-feet-wide by 10-feet-high, and the right gate (Bay 6) is 25.4-feet-wide by 10-feet-high. The spillway ogee sill crest is at El. 622.3 feet [1]. The gates are operated by hydraulic hoist with the operators located directly adjacent to the hoist above each gate on an elevated platform. The hydraulic gate chain and single cable hoist and reel system were installed in 2019, replacing the original electric hoist and trolley system.

The powerhouse consists of a reinforced concrete substructure and brick superstructure with one vertical Francis shaft unit. Both spillway and powerhouse structures are reportedly constructed on dense glacial till. The base slabs for both contain shear keys and an upstream concrete cutoff into the till. The existing powerhouse and Tainter gate spillway are illustrated in **Appendix A**.

The fuse plug auxiliary spillway was constructed in the early 2000s on the right embankment. The auxiliary spillway consisted of a sloping reinforced concrete base slab and vertical side walls within which an “erodible” sandy fill and a sloping clay core wall was placed to create a continuous water retaining structure. The auxiliary spillway was 190-feet long with a concrete sill at El. 631.8 feet. The top of the fuse plug was designed to initiate under flood pool

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

conditions when the headwater level rose above starter notch El. 634.8 feet. The downstream toe of the fuse plug was armored with riprap for a downstream distance of 40 feet to protect against erosion and undermining during either high tailwater events or during operation.

The left embankment is approximately 175-feet long, with maximum height of 18 feet near the spillway. The embankment was constructed of native silt, sand, and clay from on-site sources. The embankment slopes are 2.5H:1V on the upstream slope and 2H:1V on the downstream slope. There are no available construction records of the steel sheet pile cutoff walls constructed upstream and downstream of the left embankment.

The former right embankment, which breached during the 2020 flood event, was approximately 1,200-feet long (minus the 190-foot-long fuse plug spillway), approximately 30-feet tall and reportedly constructed of on-site silt, sand, and clay. The embankment slopes were 2.5H:1V on the upstream slope and 2H:1V on the downstream slope with clay tile finger drains laid into gravel ditches at the embankment foundation contact under the downstream shell. As a result of worsening seepage conditions observed in 2008 along the right embankment (right of the fuse plug), a reverse filter was constructed along the downstream embankment toe that extended from the fuse plug to the right abutment.

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

Table 2: Key Existing Project Data

Parameter	Sanford Project
Min. Dam Crest El. (feet)	636.8
Normal Headwater Operating Pool El. (feet)	630.8
Normal Tailwater Operating Pool El. (feet)	603.0
Spillway Invert El. (feet)	622.3
# Tainter Gates	6
Gate Numbering (left to right looking downstream)	1 to 6
Gate 1 Width (feet)	25.4
Gate 1 Max Opening (feet)	10.0
Gate 2 Width (feet)	22.0
Gate 2 Max Opening (feet)	10.0
Gate 3 Width (feet)	22.0
Gate 3 Max Opening (feet)	10.0
Gate 4 Width (feet)	22.0
Gate 4 Max Opening (feet)	10.0
Gate 5 Width (feet)	22.0
Gate 5 Max Opening (feet)	10.0
Gate 6 Width (feet)	25.4

Parameter	Sanford Project
Gate 6 Max Opening (feet)	10.0
Auxiliary Spillway Type	Fuse Plug
Auxiliary Spillway Sill El. (ft)	631.8
Auxiliary Spillway Length (feet) (Left Embankment Overflow)	190.0
Left Embankment Length (feet)	125.0
Left Embankment Dam Crest El. (feet)	636.8
Left Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1
Right Embankment Length (feet)	1,200
Right Embankment Dam Crest El. (feet)	636.8
Right Embankment Upstream / Downstream Slopes (H:V)	2.5:1 / 2:1

2.2 Sanford Dam Failure

During the May 19, 2020, flood event, all six (6) Tainter gates were fully opened (10 feet to 11 feet) in attempt to safely discharge the flood flows of the Tittabawassee River. At approximately 5:30 p.m. Eastern Standard Time (EST), the upstream Edenville Dam breached, resulting in the Sanford Dam headwater rising to 12.5-inches above the powerhouse floor to approximate El. 638.8 feet. With headwater rising rapidly, the fuse plug section of the embankment did not breach as designed. The right embankment adjacent to the left fuse plug training wall to the right was overtopped by approximately 2 feet and eventually breached at approximately 7:30 p.m. EST, resulting in the catastrophic failure of the Sanford Dam. Embankment overtopping prior to the embankment failure is illustrated in **Exhibit 2-1**.

The left embankment was overtopped by approximately 2 feet during the flood event, causing head cutting erosion of the right and left embankments and access road. The switchyard, which is located just downstream of the left embankment toe, was saturated (muddy) and covered in silt and sandy sediment deposits from the embankment overtopping and high tailwater during the May 2020 storm event.

Exhibit 2-1 Sanford Dam Embankment Overtopping

The fuse plug spillway failed to initiate prior to the right embankment overtopping. The overtopping of the right embankment and undermining of the foundation soils led to the catastrophic failure of the fuse plug spillway, resulting in the concrete chute detaching from the training walls and migrating approximately 50 feet downstream. The remaining fuse plug spillway is damaged beyond repair and will be demolished and hauled offsite as part of the Sanford Dam interim stabilization construction planned for 2021. A view of the former fuse plug spillway is provided in **Exhibit 2-2**. A drone aerial image illustrating the existing project structures following the dam failure is included in **Exhibit 2-3**.

Exhibit 2-2 Former Fuse Plug Spillway

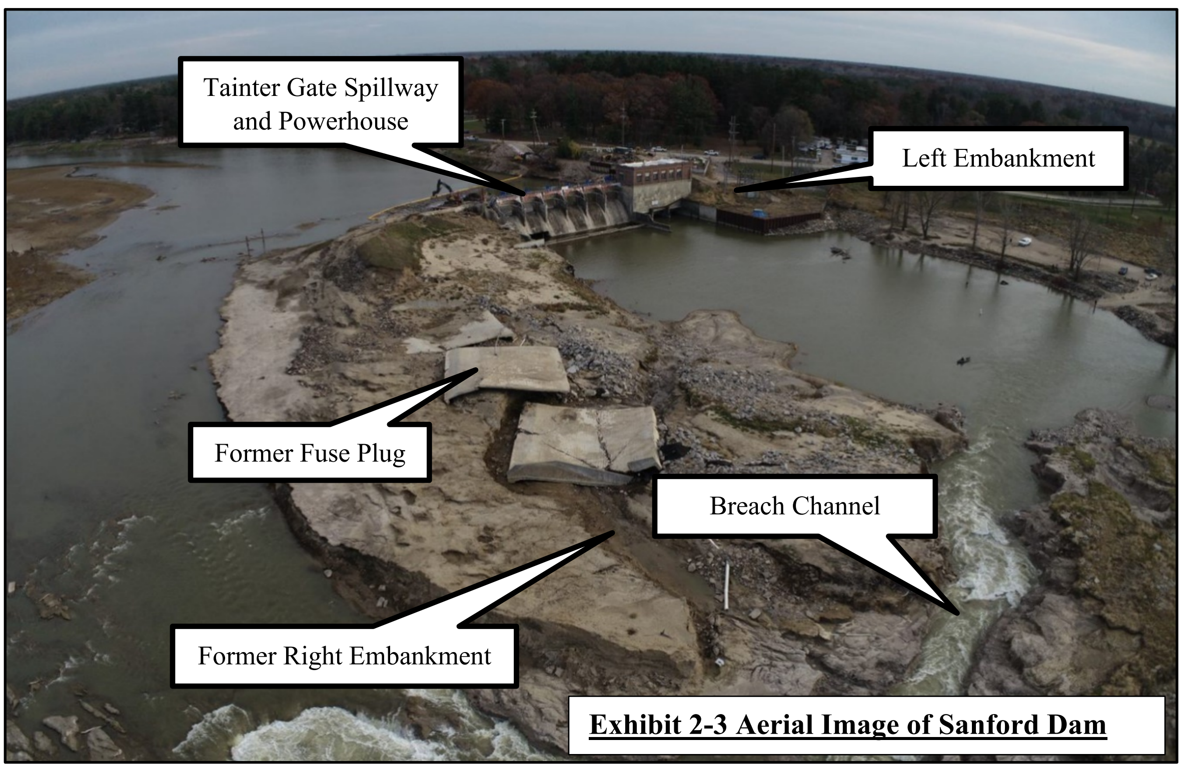


Exhibit 2-3 Aerial Image of Sanford Dam

2.3 Reservoir Operations

Prior to the failure, the project was operated as a "run-of-river." Per the FERC license, the reservoir is to be operated at a summer and winter elevation. The summer headwater level is maintained between elevation 631.1 and 630.4 feet with the normal summer level at elevation 630.8 feet. The winter headwater level is maintained with the normal winter level at elevation 627.8 feet. Currently, the Tainter gates are in the fully open position (10-feet) and the Tittabawassee River bypasses the Tainter gate spillway through the breach channel at approximate Sanford Lake El. of 613.0 ±.

2.4 Sanford Dam Temporary Breach Stabilization

The Natural Resource Conservation Service (NRCS) has identified that the Sanford Dam interim stabilization and sediment removal project may be eligible for the NRCS Emergency Watershed Protection (EWP) Program funding. The EWP Program will contribute up to 75 percent of the engineering and construction costs for eligible emergency projects. During the GEI October 2020 inspection, we shared and discussed a conceptual level design to achieve the following goals of the Sanford Dam interim stabilization project with Mr. Dan Vasher (NRCS):

1. Stabilize the existing breach channel.

2. Provide an armored channel right (west) of the existing breach channel to convey base river flows and flood flows up to the 200-year event to prevent further head cutting, erosion and transport of riverbed materials and sediments downstream. Steel sheet piling will be driven to glacial till at three transverse sections across the flow channel to allow the channel to be stepped in profile to minimize gradients and protect against head cutting.

3. Provide a new, water-retaining flood control structure consisting of a steel sheet pile cutoff founded in the clayey glacial till and driven along the alignment of the proposed right embankment cutoff wall extending from the existing spillway structure up to the right abutment. It will be embedded into the clayey glacial till and buttressed with large rockfill to convey flows around the dam and into the new 200-year flood channel to provide protection against embankment overtopping and erosion.

Following the inspection, GEI developed conceptual design drawings and cost estimates for the interim stabilization of the Sanford Dam embankment and breach channel to initiate the NRCS EWP funding request. The general construction sequence includes the following:

1. Construct temporary access road causeway in the tailrace upstream of the breach channel.

2. Drive steel sheet piling and place rock to stabilize the existing breach channel.

3. Drive I-Wall style steel sheet piling and buttress on right embankment to the left of the existing breach channel.

4. Drive I-Wall style steel sheet piling and buttress on the right embankment to the right of the existing breach channel.

5. Construct the new 200-year flow discharge channel.

6. Cut down the steel sheet piles in front of the 200-year flow channel and divert base flow from the existing breach channel to the new 200-year flow channel.

The Sanford Dam temporary breach stabilization is currently planned for 2021 to 2022. The preliminary Sanford Dam stabilization drawings are included in **Appendix B**.

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 Sanford Dam project:

- Sanford Hydropower Plant Design Drawings, 1923
- Supporting Technical Information Document (STID), Rev. 2017
- Secord Gate Test Notes, Spicer Group Inc., December 2019
- PMF Report by Ayres Associates, Inc., May 2020
- GEI Flood Study of the Tittabawassee River from Secord to Sanford Dam, March 2021

3.2 Hydrology

GEI has reviewed the May 2020, PMF Report by Ayres Associates, Inc. (Ref. Ayres, 2020) prepared for Secord, Smallwood, Edenville and Sanford Dams. This report was prepared before the May 2020 flood and 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 3** and represent the results of the most recent provisional model, as revised to account for observations noted during the May 2020 flood. Note also that the "½ PMF" is not half of the PMF value. Verbal consultation with EGLE personnel clarified that "½ PMF" in the context of State of Michigan EGLE standards refers to the flood calculated to result from one-half of the Probable Maximum Precipitation (PMP).

Table 3: Sanford Dam Flood Routing Results – Existing Conditions

Parameter or Modeling Result	½ PMF	PMF
Peak Inflow (cfs)	37,695	116,065
Peak Outflow (cfs)	35,480	112,295
Maximum Reservoir El. (feet)	637.2	644.3
Freeboard (Dam Crest El. 636.8)	-0.4	-7.5

As indicated in **Table 3**, the Sanford Dam ½ PMF results in a peak inflow of 37,695 cfs, a maximum reservoir elevation of 637.2, a peak discharge of 35,480 cfs, and 0.4 feet of dam crest overtopping. The overtopping duration is estimated to be 14 hours. The PMF results in a peak inflow of 116,065 cfs, a maximum reservoir elevation of 644.3, a peak discharge of 112,295 cfs and an overtopping depth of 7.5 feet. The overtopping duration is estimated to be 48 hours.

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

Table 4: Summary of Previous PMF Studies

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

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

Considering the significant increase in the PMF, the FLTF currently has Applied Weather Associates (AWA) under contract to compute a site-specific PMP and probability assessment of various rainfall depths for the Tittabawassee River Basin. The FLTF recognizes that PMP and PMF studies typically 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 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, GEI understands that the FLTF projects will be classified as high hazard dams, and shall be capable of passing the ½ PMF.

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

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

1. Providing acceptable safety to the public;
2. Effectively applying the resources of the dam owner;
3. Maintaining the credibility of the regulator in representing the interest of the public; and
4. Assessing the desire of the public for the benefits of a dam in exchange for the inherent risks that come from living downstream of a dam.

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

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

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

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

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

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

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

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

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

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

Table 5: 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 +

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 analyses 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 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 analyses 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. 635.5 with 2.5 feet of freeboard below the dam crest.
- Reconstruct the right embankment to crest El. 638.0 and repair the left embankment.
- The structural integrity of the earthen dam and foundation should not be jeopardized by auxiliary spillway operations.
- Operation of the new 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 levels (see **Table 1** in Section 1.4) to minimize static ice loading on the auxiliary concrete labyrinth weir spillway.

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.

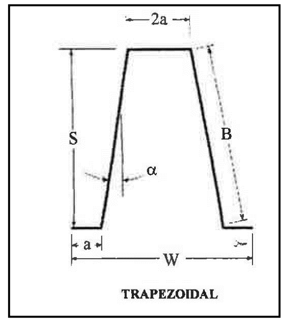
The effective length **L** of a spillway crest used in spillway discharge computations is expressed by the equation: $\mathbf{L = L' - 2(NK_p + K_a)\,H_e}$, where:

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 *f*
- Magnification, M = L/W



The discharge can be expressed as Q = *f* (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 Sanford Dam Flood Routing Results

The proposed spillway rating curves developed using the 2D HEC-RAS model were then input into the HEC-HMS model as the primary spillway to determine the final routing results. Based on the new spillway configuration for the Sanford Dam, the ½ PMF + design storm results in a peak inflow of 47,300 cfs, a maximum reservoir water surface at El. 635.0, a peak discharge of 46,000 cfs, and a minimum of 3.0-feet of dam crest freeboard. The Sanford Dam ½ PMF + design storm inflow, outflow, and stage hydrographs are shown on **Figure 2**. Based on the configuration described above, the proposed Sanford Dam spillway configuration would have sufficient discharge capacity to safely pass the ½ PMF + design storm with over 3.0 feet of freeboard.

Prior to the May 2020 breach of the right embankment, the tailwater increased and completely submerged the switchyard immediately downstream of the right embankment. The elevation of the switchyard ranges from El. 618.0 to El. 620.0 feet and the flood levels completely submerged the chain link fence surrounding the switchyard. Exact tailwater elevations are not available from Boyce records; however, this anecdotal evidence suggests that the tailwater increased approximately 8 to 10 feet prior to the failure, resulting in a tailwater elevation ranging from El. 626.0 to El. 628.0 feet. The downstream tailwater is impacted by a number of factors. The Sanford Road Bridge and Pere-Marquette Trail Bridge, located approximately 0.5 miles downstream, constrict the cross-sectional area of the Tittabawassee River. Approximately 0.5 feet further downstream, the confluence with the Salt River contributes additional flood flow from the Salt River watershed. Furthermore, the left floodplain located immediately downstream consists of a public park and ball fields that are low (El. 613.0 ±) relative to the ½ PMF + design storm tailwater of El. 632.1 feet, and a significant amount of flood flow is conveyed around the bridges in the low-lying floodplain. The Salt River is not included in the Tittabawassee River watershed at Sanford Dam, so we added the DEQ estimated 100-year flood flow rate of 16,000 cfs concurrent with the ½ PMF + design storm. During the ½ PMF + design storm, the downstream tailwater rises to El. 632.1 feet, which is approximately 17.3 feet higher than the spillway crest El. 614.8 feet. In general, tailwater submergence begins to reduce spillway capacity when the tailwater depth divided by the headwater energy depth above the spillway is greater than 0.67; therefore, the tailwater submergence ratio of 0.82 is high enough to cause a 0.5 feet of increase in the upstream headwater elevation during the ½ PMF + design storm. When the Salt River contributing flow is removed, the tailwater reduces to El. 630.6 feet, illustrating that the variability in the Salt River has an appreciable impact on the tailwater elevation downstream of Sanford Dam.

The proposed Sanford 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 is slightly offset with the rating curves calculated by the 2D model up to the ½ PMF + design storm headwater El. 635.1, meaning that downstream submergence has a minor impact on the discharge capacity of the spillway. Output data from the HEC-HMS model are summarized in **Table 6**.

Table 6: Sanford Dam Flood Routing Results – Proposed Conditions

Parameter or Modeling Result	½ PMF + design storm
Initial Water Surface El. (feet)	630.8
Peak Inflow (cfs)	47,300
Peak Outflow (cfs)	46,000
Maximum Reservoir El. (feet)	635.0
Freeboard (Dam Crest El. 638.0)	3.0

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

4. Summary of Dam Repairs and Flood Capacity Upgrades

4.1 Primary Spillway Modifications

The existing Tainter gate spillway and powerhouse will be partially demolished and the six (6) Tainter gates will be replaced with eight (8) hydraulically operated crest gates at sill El. 614.8 to increase the spillway capacity. The crest gates would range from 16.5-feet-wide to 23-feet-wide by 16-feet-high. The hydraulic gate operators will be supported on new, reinforced concrete piers. The upstream portions of the barrel arches below El. 614.8 will remain and the crest gates and their anchorage embedment will be founded on new mass concrete. The gates will discharge onto a short section of concrete rollway and into a new reinforced concrete stilling basin. The two rightmost powerhouse bays will be converted into an additional crest gate bay and the leftmost 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**.

4.2 Auxiliary Spillway

A new 250-foot-wide 12-cycle auxiliary spillway will be constructed at weir El. 632.5 within the former right embankment of the Sanford 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 would vary from about 18-feet-high downstream of the labyrinth spillway to about 15-feet-high in the steep portion of the chute. The new chute slab would be a minimum of 2-feet-thick and would include an appropriate underdrainage system to prevent hydrostatic uplift. Beneath the concrete auxiliary spillway will be a new hot-rolled SSP wall with interlock sealants. This sheeting will be connected to centerline sheeting left and right of the auxiliary spillway to reduce under seepage and allow construction of the spillway with reduced seepage inflow. An additional seepage 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 350 feet downstream to the confluence with the Tittabawassee River through the former Sanford 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 Sanford Dam to minimize active daily ice management. For the long-term reconstruction, we are proposing to retrofit the existing powerhouse to pass base flows (200-400 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 two rightmost turbine bays.
- Fill the abandoned sluice bay below the intake with either cellular grout or mass concrete. The total impoundment drawdown potential is from El. 630.8 to El. 612.0 ±.
- Construct new vertical slide gates with integrated bulkhead slots upstream of existing head gate.
- Remove the generator, turbine shaft, and wicket gates.
- Keep existing trash racks.
- Construct a new steel bulkhead over the runner pit in the powerhouse floor slab.
- Affix (weld) the runner in place to the new bulkhead.
- Remove the existing timber headgates.
- The upstream slide gates will be used to throttle base flows to pass the 200 to 400 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 the powerhouse modifications is illustrated on Drawing C-6 included in **Appendix D.**

4.4 Embankment Modifications

The left embankment slopes will be flattened to provide adequate stability in accordance with EGLE stability requirements under normal and flood pool loading criteria. The former right embankment will be re-constructed with a minimum 15-foot-crest width at El. 638.0 and minimum 2.5H:1V upstream and downstream slopes. A steel sheet pile cutoff will be provided along the upstream edge of the right embankment crest and be founded in the clay glacial till to provide a continuous seepage cutoff. A vertical chimney drain 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 will also be provided along the upstream and downstream slopes to protect against wave-induced erosion and high tailwater, respectively. General site plans and cross sections for the Sanford Dam embankment reconstruction are provided in **Appendix D**.

4.4.1 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 4 inches in diameter 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.

4.4.2 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 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.

4.4.3 Riprap and Bedding

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

5. Structural Design Criteria

5.1 General

The existing and proposed concrete spillways, water retaining structures and conveyance channels described in this Report are the primary gated spillway (comprised of side walls, center piers, rollway, stilling basin and crest gates), powerhouse (side walls, intake, scroll case, draft bay, stilling basin), and auxiliary spillway (side walls, base slab, 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 Sanford Dam structures to quantify bearing capacity, subgrade moduli and estimate glacial till foundation settlement under new dam loads to assess dam performance when the hollow sections of the existing spillway and powerhouse dam are filled in with concrete, steel crest gates, 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 new 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 supports 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 walls (due to a buried fish passage structure that has truncated counterfort walls). Concrete wall overlays and counterfort extensions and use of lightweight fill may be required on the right downstream embankment side of the existing training walls to reduce lateral earth pressures.

5.1.1 Stability Analyses

Stability analyses of the spillway training wall, spillway overflow section, pier and powerhouse concrete structures will be based on FERC Dam Safety Guidelines Chapter 3 *Gravity Dams* and Chapter 10 *Other Dams* and USACE EM-1110-2-2100 – *Stability Analysis of Concrete Structures* (Ref. USACE, 2005).

5.1.2 Reinforced Concrete Design

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

5.2 Material Properties

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

Compressive Strength:

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

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

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

5.2.1 Load Cases and Required Factors of Safety Against Sliding

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

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

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

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

5.2.2 Limits on Resultant Force Location

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

Table 8: Requirements for Loading of Resultant – All Structures

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

5.2.3 Factors of Safety versus Floatation

The required factors of safety for uplift (flotation) stability (FERC Load Case 1A) in accordance with FERC Engineering Guidelines Chapter 10 are shown in **Table 9**.

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

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

6. Embankment Design Criteria

6.1 Existing Subsurface Information

Limited subsurface explorations and investigations were completed for the project. The results of four soil borings are presented on Figure 7 included in the STID. A note on Figure 7 states, "information taken from Drawing No. 10111, by Holland, Ackerman and Holland, No Date." Exact information about when the borings were performed was not found. The borings were performed on the upstream side of the embankments. The results of the borings indicated the site soils generally consisted of clay loam, red clay and blue clay. Some layers of yellow, white and blue sand were also noted. The method of drilling and sampling was not stated, and no strength testing was performed.

In 2001, three (3) soil borings were completed by RC & Associates, Inc. (Ref. RC, 2001) for a liquefaction analysis performed as part of the 2001 Consultants Safety Inspection Report (Ref. Barr, 2002). Boring No. 1 was performed from the left embankment crest approximate 50 feet left of the powerhouse. Boring Nos. 2 and 3 were performed on the right embankment crest approximately 60 feet and 200 feet to the right of the spillway, respectively. The results of Boring No. 1 indicated alternating layers of very loose to loose sand and silty sand and soft to stiff silty and sandy clay to a depth of 31 feet, where stiff to hard clay and dense to extremely dense sands were encountered. At Boring Nos. 2 and 3, primarily soft to stiff silty clay with isolated layers of loose to medium dense silty and clayey sand were encountered to 38 feet. Hard silty clay and extremely dense silty sand were encountered below this depth.

Note that the right embankment fill material and most of the native upper foundation soils were lost downstream during the 2020 breach.

6.2 Existing Stability Analyses

The stability of the embankments was evaluated as part of the 1989 Consultant's Safety Inspection report (Ref. Blystra, 1989). The embankment section was evaluated for the following loading conditions:

- normal pool headwater,
- normal pool + seismic,
- flood (surcharge) headwater,
- sudden drawdown from top of gates, and
- sudden drawdown from maximum pool levels.

The section was analyzed using the computer program TSTAB for circular arc failure surfaces using the Bishop's Simplified Method. The results indicated that Factors of Safety met or exceeded the FERC minimum required results for the analyzed load cases. The analyses show factors of safety summarized in **Table 10**.

Table 10: Summary of Embankment Stability

Loading Condition	Computed FS	FERC Required FS
Downstream Normal Pool	1.53	1.5
Downstream Earthquake at Normal Pool	1.32	1.0
Downstream Maximum Pool	1.46	1.5
Upstream Rapid Drawdown	7.30	1.2

6.3 Review of Existing Subsurface Information and Future Explorations and Stability Analyses

Overall, the subsurface information is limited for the size and length of the embankment structures. The right embankment no longer exists after the 2020 breach and will need to be completely reconstructed except for the existing sheet pile wall located to the right of the existing Tainter gate spillway.

The existing record stability analysis only evaluated one section of the embankment. The geometry of the slope and actual location of the analyzed embankment section is not known. Modifications to the embankment were made since 1989, and the record analysis may not be representative. The results meet the FERC minimum required Factor of Safety; however, the analysis uses old and outdated methods.

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

Given the limited information available and that both structures 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 seepage and embankment stability should be performed using more current software (i.e., GeoStudio's SEEP/W and SLOPE/W) and utilize moment and force equilibrium method of analysis (i.e., Spencer or Morgenstern Price) to model seepage through the foundation and new embankment and quantify global stability. We recommend the final scope for additional subsurface explorations be developed at a later date and be based on the proposed repairs.

6.4 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 use as 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.

6.5 Loading Conditions

The following FERC-required loading conditions will be evaluated:

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

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

6.6 Material Properties

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

6.7 Phreatic Surface Assumptions

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

6.8 Results

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

7. Construction Considerations

7.1 Erosion Control

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

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

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

7.2 Upstream and Downstream Cofferdams

The proposed upstream and downstream cofferdam design may consist of steel sheet pile (SSP) walls or cells, rockfill and stacked supersacks (filled with concrete sand to function as a seepage cutoff) constructed in two (II) Phases at the Tainter gate spillway and former right embankment breach channel. Phase I will be constructed at the powerhouse and Tainter gate spillway to allow construction of the low-level outlet and new crest gate spillway while the stabilized breach channel remains open to pass base river flow. Phase II will be constructed once the new crest gate and low-level outlet is constructed, and flow diverted back into the original river channel. The Phase II cofferdam will allow construction of the new labyrinth spillway, concrete chute, and Type III stilling basin in the dry. The conceptual design for the Phase I and II cofferdams is illustrated in **Exhibit 7-1** and **Exhibit 7-2** and included in **Appendix D**.

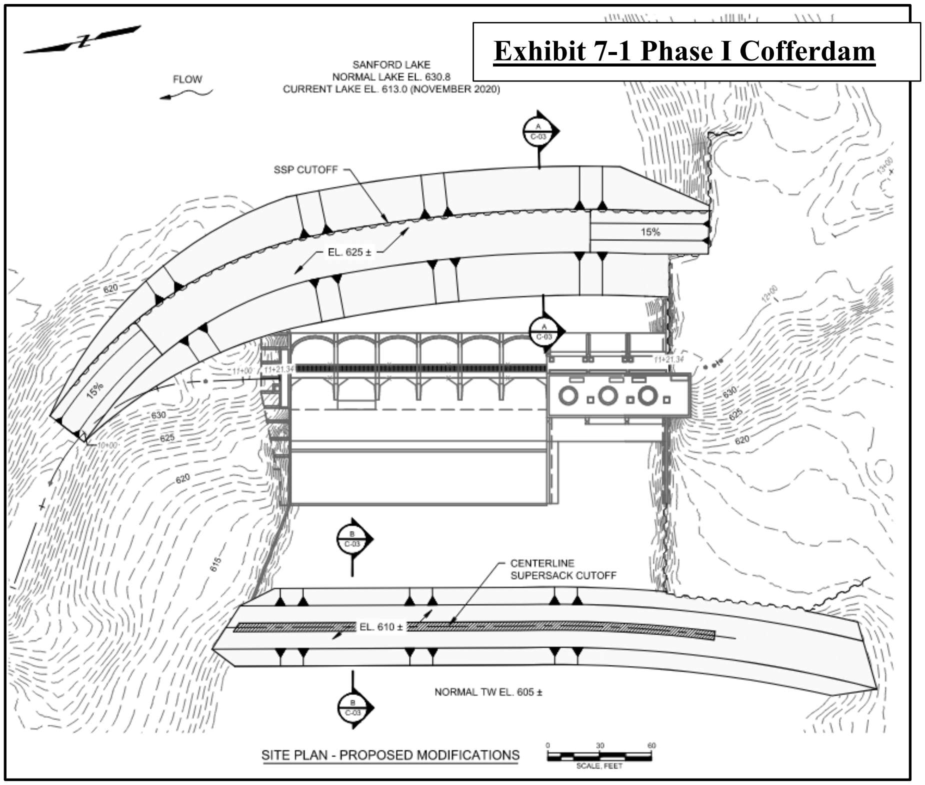


Exhibit 7-1 Phase I Cofferdam

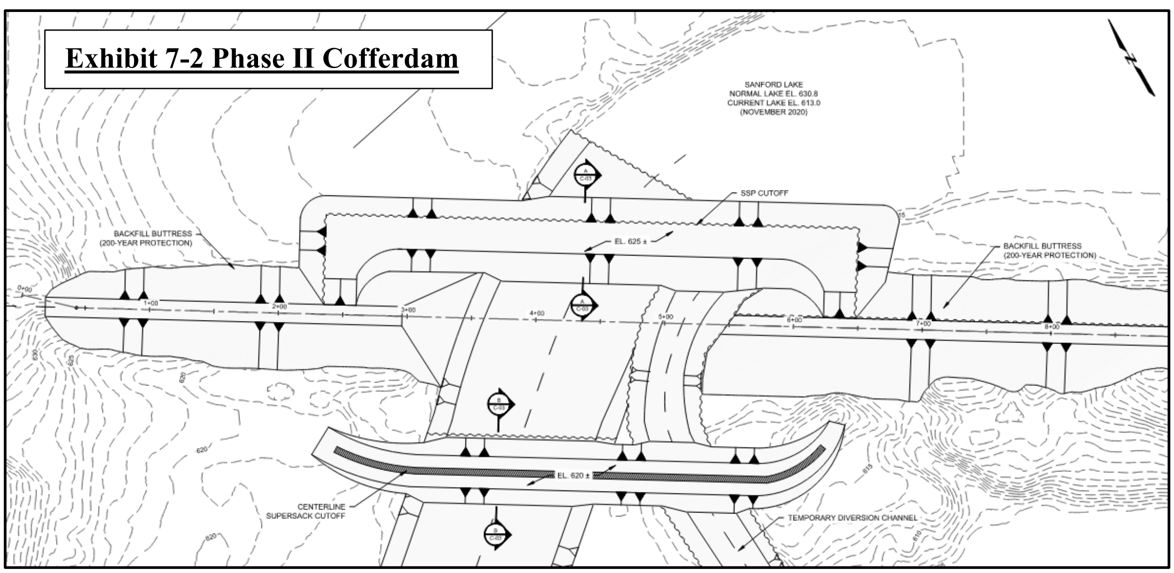


Exhibit 7-2 Phase II Cofferdam

7.3 Reservoir Operations During Construction

The reservoir is currently drawn down to approximately El. 613.0 ± as base river flow bypasses the spillway crest (El. 622.3) with the Tainter gates fully open (10 to 11-feet) and dogged off. The reservoir will remain drawn down during construction and the headwater will fluctuate based on seasonal Tittabawassee River flow.

7.4 Dewatering and Diversion Needs

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

- Phase I – Pass base river flow through the former right embankment breach channel while constructing the low-level outlet and new crest gates.
- Phase II – Pass base river flow through the low-level outlet and new crest gates in the full down position while constructing the auxiliary labyrinth spillway.

7.5 Anticipated Construction Sequence

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

1. Fully draw down impoundment, stabilized existing project structures, remove debris, and inspect spillway and powerhouse.

2. Contractor mobilization for left and right abutment reconstruction and develop laydown and contractor work areas.

3. Stabilize the right embankment breach channel and fully divert water from spillway and powerhouse areas. Buttressed I-Wall SSP will be in-place to stabilize the breach area and will be used for new seepage and cofferdam controls for the permanent dam replacement efforts.

4. Construct the Phase I upstream and downstream cofferdams at the gated spillway and powerhouse. Dewater the area between the cofferdams.

5. Demolish the existing gated spillway and two of the three powerhouse units; existing piers left in place.

6. Construct the new gated spillway and low-level outlet.

7. Test and commission the low-level outlet and eight new crest gates.

8. Remove the Phase I cofferdams and divert river flows through the new gated spillway and back into the original river channel. Construct the Phase II upstream and downstream cofferdams at auxiliary labyrinth spillway location.

9. Construct the new auxiliary labyrinth spillway over new steel sheet piling with upstream and downstream cofferdams and reconstruct right and left embankment.

10. Remove the Phase II cofferdams.

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

12. Site restoration and contractor demobilization.

13. Refill Sanford Lake and monitor performance.

8. Engineer's Opinion of Probable Construction Cost

8.1 30% Design Cost Analysis

An engineer's opinions of probable construction costs (OPCC) was developed for the Sanford 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 within a range of ± 25%, typically used for the 30% design phase. 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 Sanford Dam to pass the ½ PMF + design storm is approximately **$51 million**. A summary of the ½ PMF + design storm OPPC for the Sanford project is summarized in **Table 11** and cost estimate worksheets are provided as **Appendix E**.

Table 11: Summary of Opinion of Probable Construction Costs

Item	Description	Estimated Cost
0.00	General Conditions	$ 2,532,000
1.00	Site Preparation and Cofferdams	$ 7,830,000
2.00	Site Demolition (Spillway and Powerhouse)	$ 3,873,000
3.00	Left Embankment Repair and Stabilization	$ 378,000
4.00	Right Embankment Repair and Stabilization	$ 2,887,000
5.00	New Crest Gate Spillway and Outlet Works	$ 13,305,000
6.00	Powerhouse Rehabilitation	$ 2,250,000
7.00	Auxiliary Spillway Structure	$ 3,415,000
8.00	Discharge Channel	$ 1,940,000
9.00	Site Restoration	$ 150,000
	Subtotal	$ 38,560,000
	Contingency (25%)	$ 9,640,000
	Construction Subtotal	$ 48,200,000
	Site Investigations, Engineering, Permitting and Construction Management	$ 3,000,000
	Total Estimated Cost	**$ 51,200,000**

8.2 Closing

Our opinions of probable design and construction costs should be considered rough budgetary estimates based on conceptual level designs, costs for similar projects and engineering judgment. Detailed designs and quantities have not yet been prepared. Actual bids and total project costs may vary based on contractor's perceived risk, site access, season, market conditions, etc. No warranties concerning the accuracy of costs presented herein are expressed or implied.

9. References

(ACI). American Concrete Institute. “Building Code Requirements for Structural Concrete (ACI 318-11).”

(ASCE, 1993). American Society of Civil Engineers. “Strength Design of Reinforced-Concrete Hydraulic Structures.”

(ASCE, 1995). American Society of Civil Engineers (ASCE) (1995) Hydraulic Design of Spillways.

(Ayres, 2020). “Probable Maximum Flood Determination, Tittabawassee River Hydroelectric Projects.” Ayres Associates, May 2020.

(Chow, Ven Te, 1959). “Open-Channel Hydraulics.” New York: McGraw-Hill Company, Inc.

(CSIR, 2016). “2016 Consultants Safety Inspection Report (CSIR), Purkeypile Consulting, LLC. December 2016.

(Falvey, 2003). “The Hydraulic Design of Labyrinth Weirs,” Henry T. Falvey, July 2003.

(FEMA, 2011). “Federal Emergency Management Agency (2011) Filters for Embankment Dams - Best Practices for Design and Construction.” October 2011.

(FEMA, 2013). “Selecting and Accommodating Inflow Design Floods for Dams, FEMA P94.” Federal Emergency Management Agency, 2013.

(FERC). Federal Energy Regulatory Commission. “Engineering Guidelines for Evaluation of Hydropower Projects,” Chapters, 3, 4 and 10 (most recent versions).

(GEI, 2020a). “Post Failure Reconstruction Costs Analysis.” GEI Consultants of Michigan, P.C., April 2020.

(GEI, 2020b). “Discharge Rating Curves (Secord, Smallwood, Edenville and Sanford Projects).” GEI Consultants of Michigan, P.C., April 2020.

(GEI, 2021a). “Flood Study of the Tittabawassee River from Secord to Sanford Dam.” GEI Consultants of Michigan, P.C., March 2021.

(GEI, 2021b). “Desktop Review – Sanford Dam.” GEI Consultants of Michigan, P.C., March 2021.

(NOAA 2019). "NOAA Atlas 14, Volume 8, Version 2 – Precipitation Frequency Data Server." May 2019.

(STID, Rev. 2017). "Supporting Technical Information Document" (STID), Mill Road Engineering. Revised 2017.

(USACE, 1990). U.S. Army Corps of Engineers, Engineering Manual EM 1110-2-1603, "Hydraulic Design of Spillways," January 16, 1990.

(USACE, 2005). U.S. Army Corps of Engineers, Engineering Manual EM 1110-2-2100, "Stability Analysis of Concrete Structures," December 1, 2005.

(USACE, 2016). United States Army Corp of Engineers, Engineering Manual EM 1110-2-2104, "Strength Design for Reinforced Concrete Hydraulic Structures," November 30, 2016.

(USACE, 2016a). United States Army Corp of Engineers, "HEC-RAS River Analysis System, Hydraulic User's Manual," Version 5.0, February 2016.

(USACE 2016b). "HEC-RAS River Analysis System, Hydraulic Reference Manual", Version 5.0, February 2016.

(USACE (2019). "Hydrologic Engineering Center - River Analysis System (HEC-RAS)", Version 5.0.7. March 2019.

(USACE, 2021). United States Army Corp of Engineers, "Hydrologic Modeling System (HEC-HMS)," Version 4.6.1. March 2021.

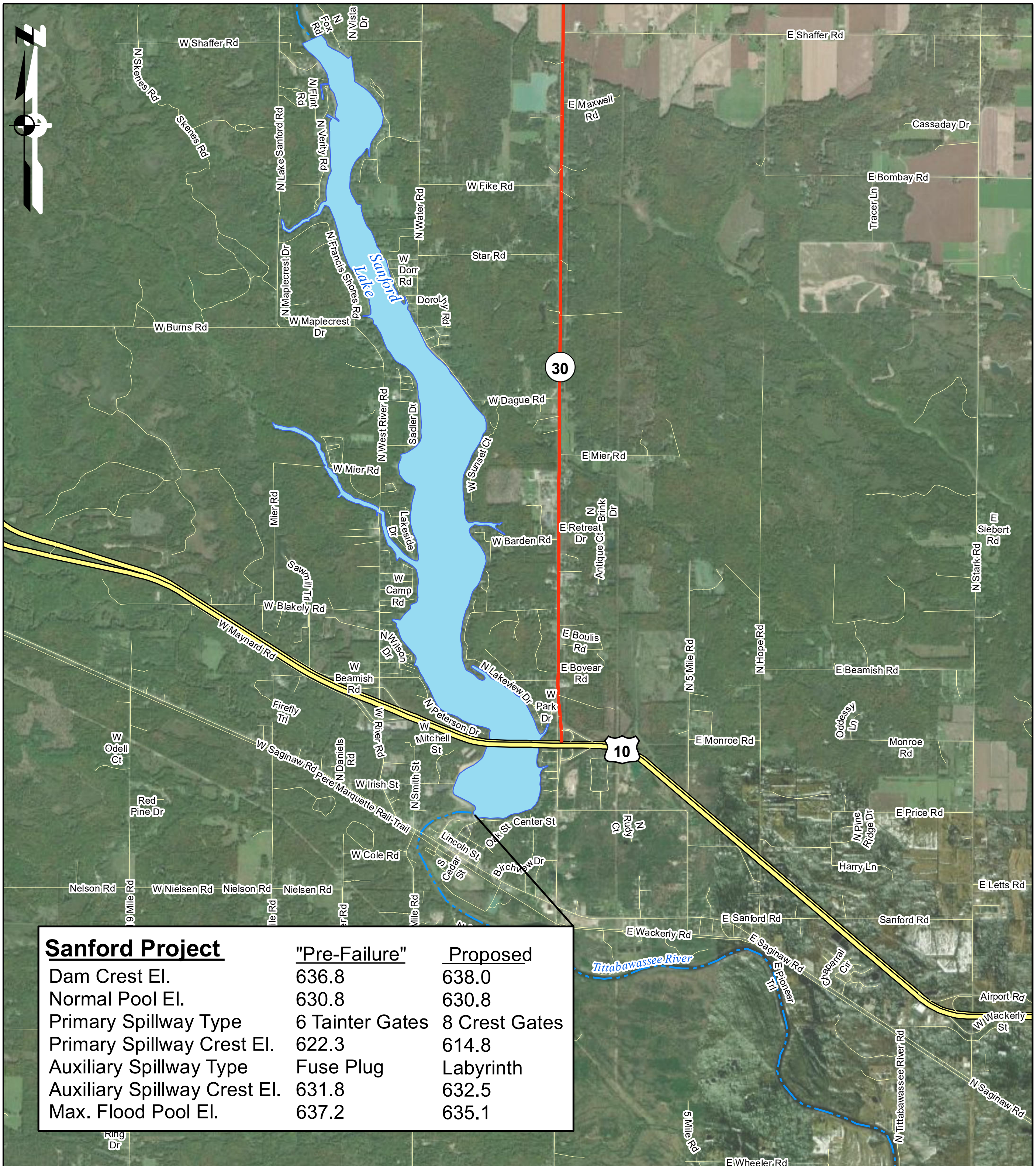
(USBR, 1978). United States Bureau of Reclamation "Hydraulic Design of Stilling Basins and Energy Dissipators," A. J. Peterka, A Water Resources Technical Publication, Engineering Monograph No. 25, January 1978.

(USBR, 1987). United States Bureau of Reclamation "Design of Small Dams," Third Edition 1987.

(USGS, 1968). United States Geological Survey, "Measurement of Peak Discharge at Dams by Indirect Method," 1968.

(USGS, 2014). United States Geological Survey, Earthquake Hazards Program, Unified Hazard Tool, https://earthquake.usgs.gov/hazards/interactive.

Figures



Sanford Project	"Pre-Failure"	Proposed
Dam Crest El.	636.8	638.0
Normal Pool El.	630.8	630.8
Primary Spillway Type	6 Tainter Gates	8 Crest Gates
Primary Spillway Crest El.	622.3	614.8
Auxiliary Spillway Type	Fuse Plug	Labyrinth
Auxiliary Spillway Crest El.	631.8	632.5
Max. Flood Pool El.	637.2	635.1

0 1 2
Scale, Miles

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

Conceptual Design Basis Report
Sanford Dam

Four Lakes Task Force
Gladwin and Midland County, Michigan

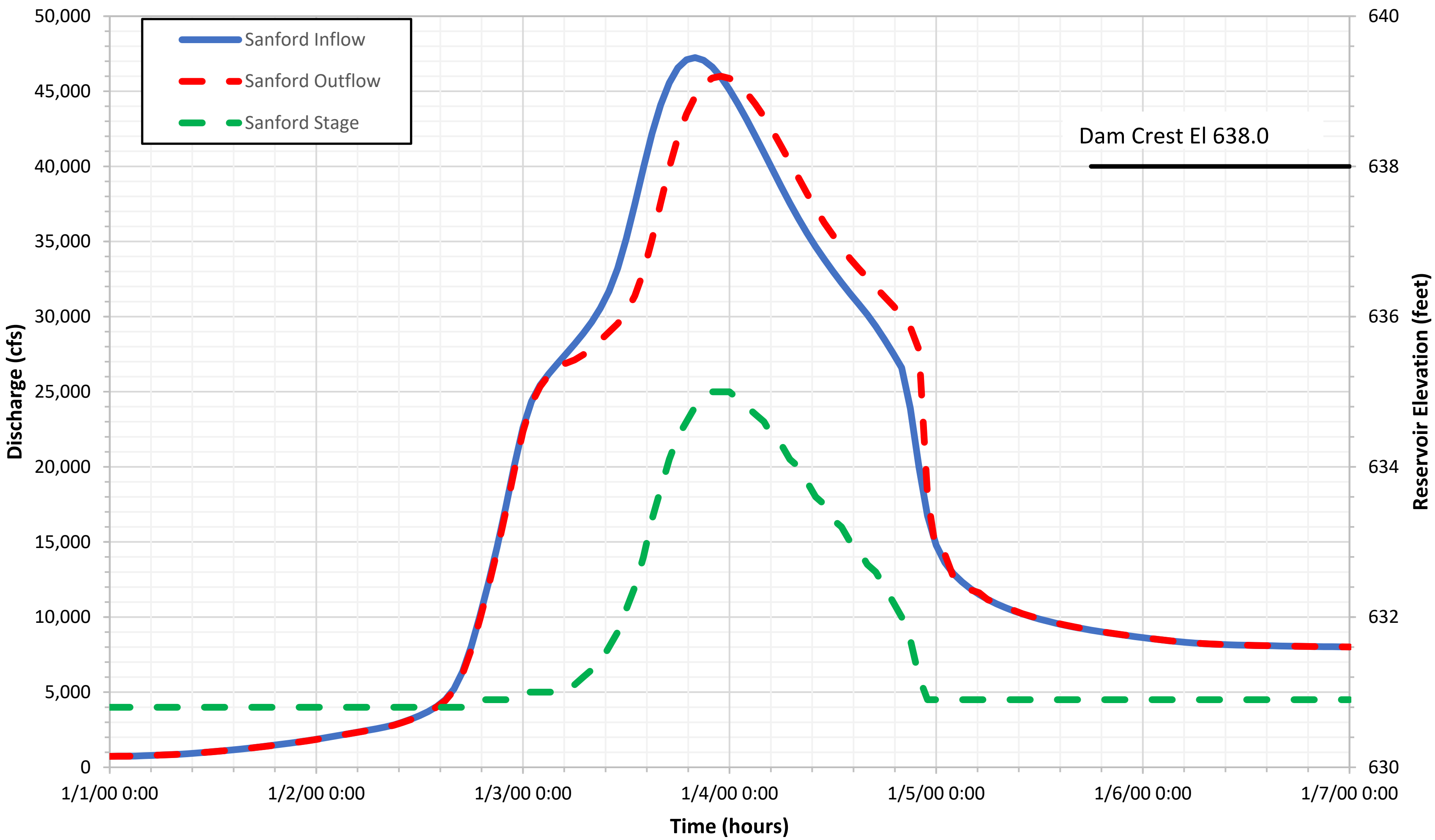
GEI Consultants

Project 2002879

SANFORD DAM
SITE LOCATION MAP

March 2021

Figure 1

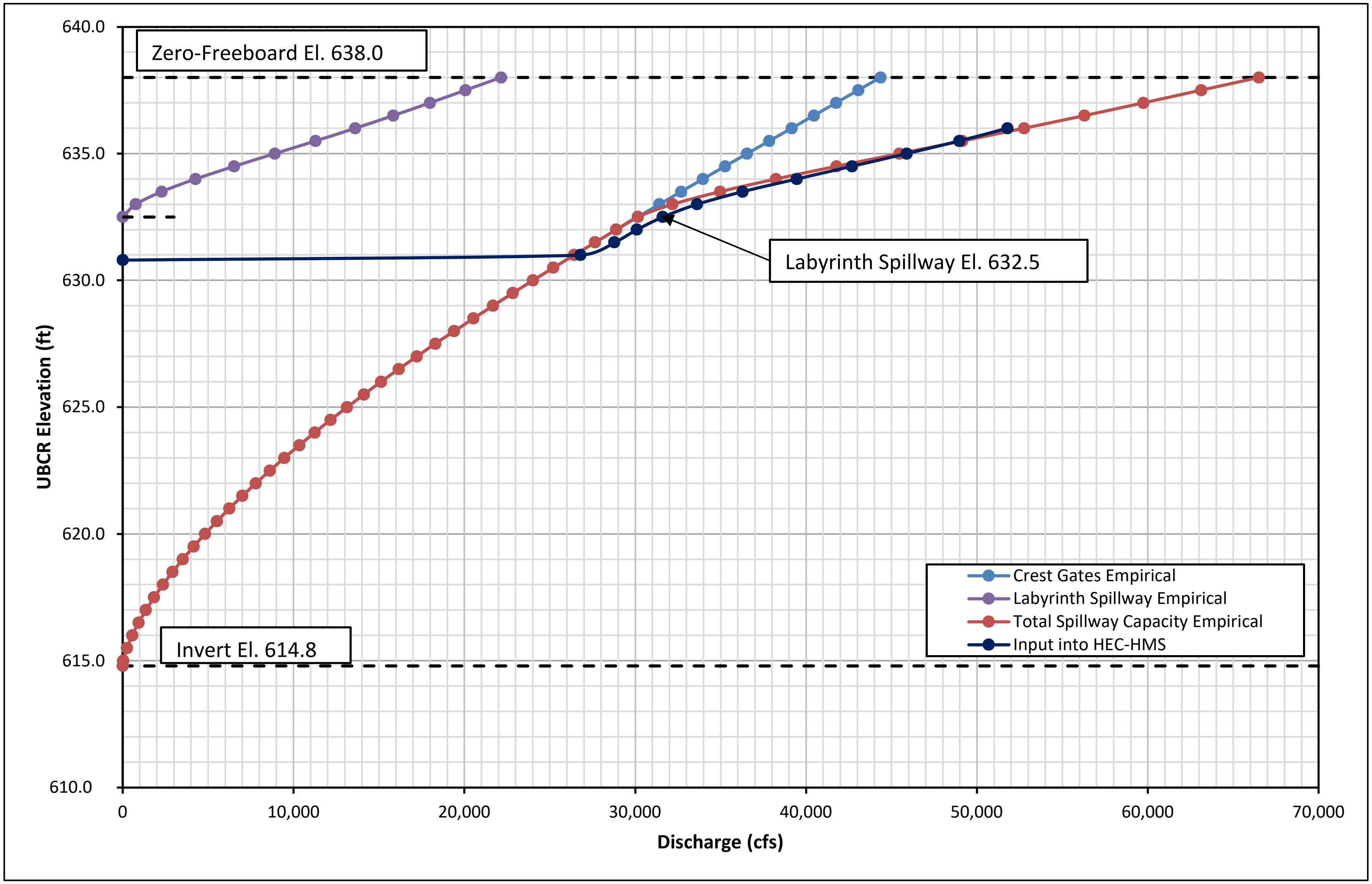


Sanford Dam
Client: Four Lakes Task Force
Location: Gladwin County, Michigan

GEI Consultants

Proposed Conditions 1/2 PMF + Flood Routing Results

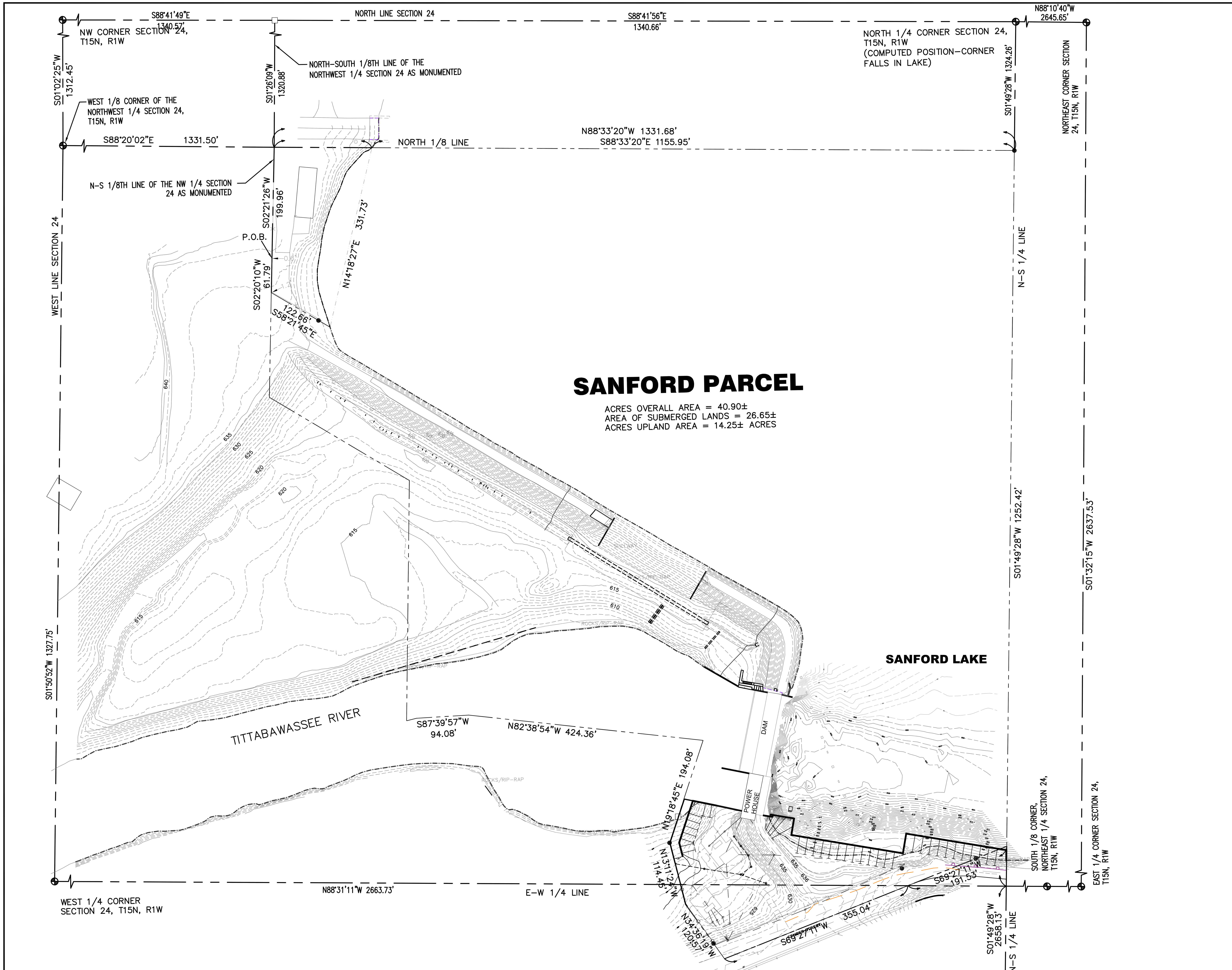
Project 2002879 **March 2021** **Figure 2**



Sanford Dam **Client: Four Lakes Task Force** **Location: Gladwin County, Michigan**	GEI Consultants	**Sanford Dam Spillway Rating Curves**
	Project 2002879	**March 2021** **Figure 3**

Appendix A

Exhibit F Drawings



-- CONTAINS CRITICAL ENERGY INFRASTRUCTURE INFORMATION; DO NOT RELEASE --

BOYCE HYDRO POWER, LLC
Lee W. Mueller, Architect, Co-Member Manager

PO BOX 15
6000 S-M30
EDENVILLE, MI 48620
(989) 689-3161

LICENSED PROFESSIONAL

REVISIONS

NO.	DATE	BY
DESCRIPTION		
0	9/23/2013	MGM
DRAWING ORIGINATION		
1	05/24/2019	MGM
SHOW SITE AFTER UPGRADE		

THIS DRAWING IS SCALED TO PRINT ON 24" x 36" PAPER

DRAWING TITLE

NEW TURBINE UNIT #1
GENERAL PLAN

FILE	Sanford U1 turbine upgrade Ex F
SCALE	AS NOTED
DRAWN	MGM
CHECKED	LWM
APPROVED	
REV. DATE	05/24/2019

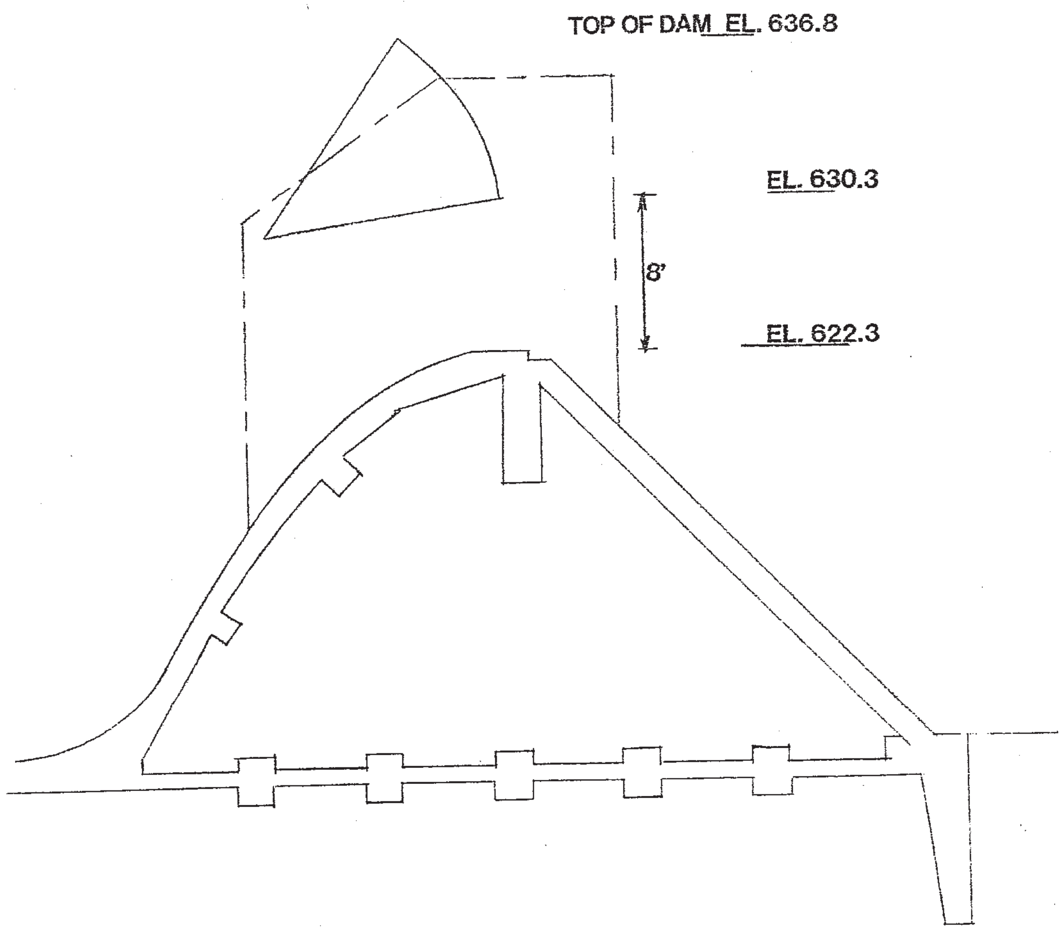
DRAWING NO.

P-2785-17

FERC PROJECT NO. 2785
SANFORD DAM EXHIBIT F-1
GENERAL PLAN

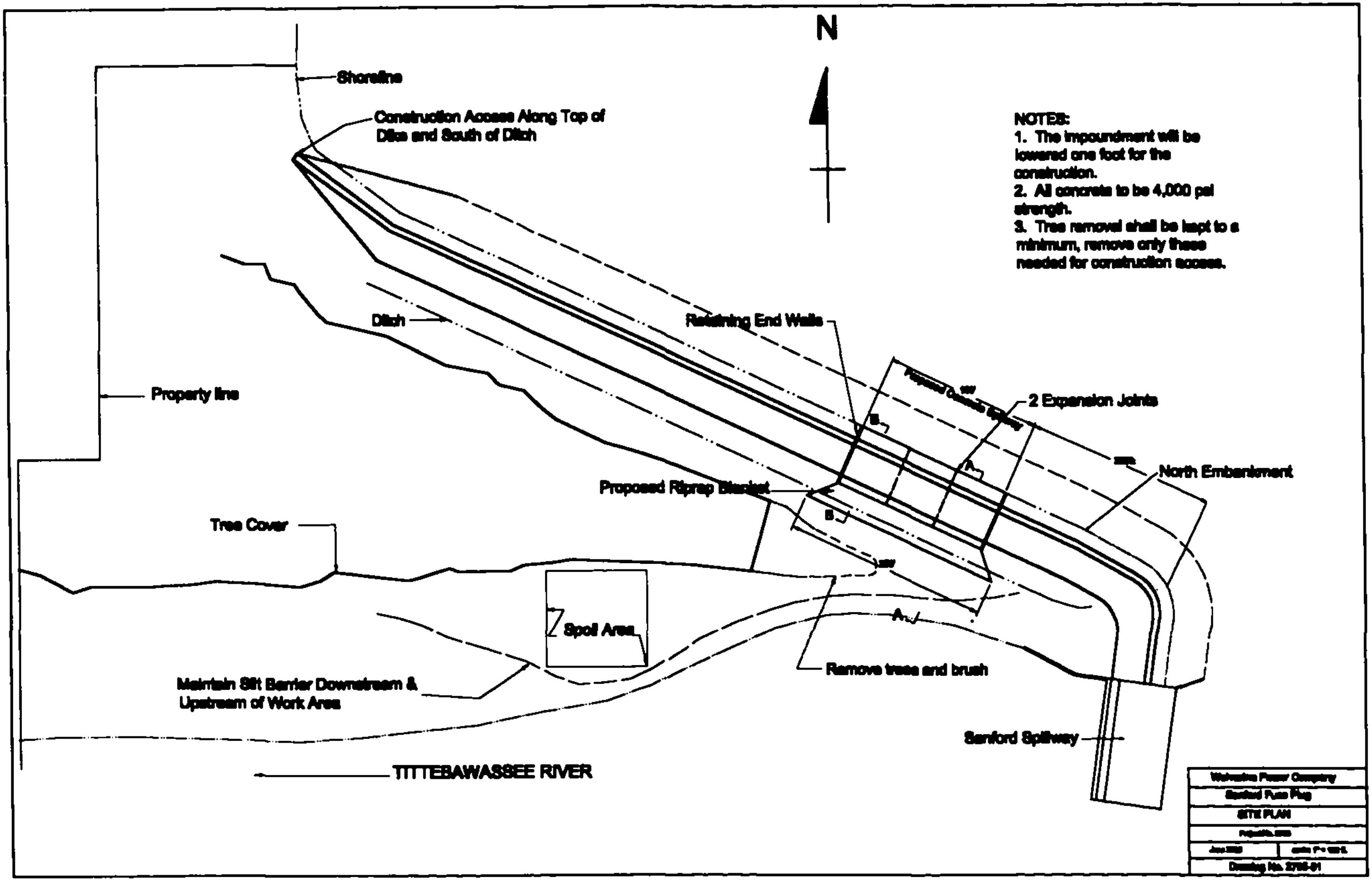
0 80 160 240
SCALE: 1"= 80'

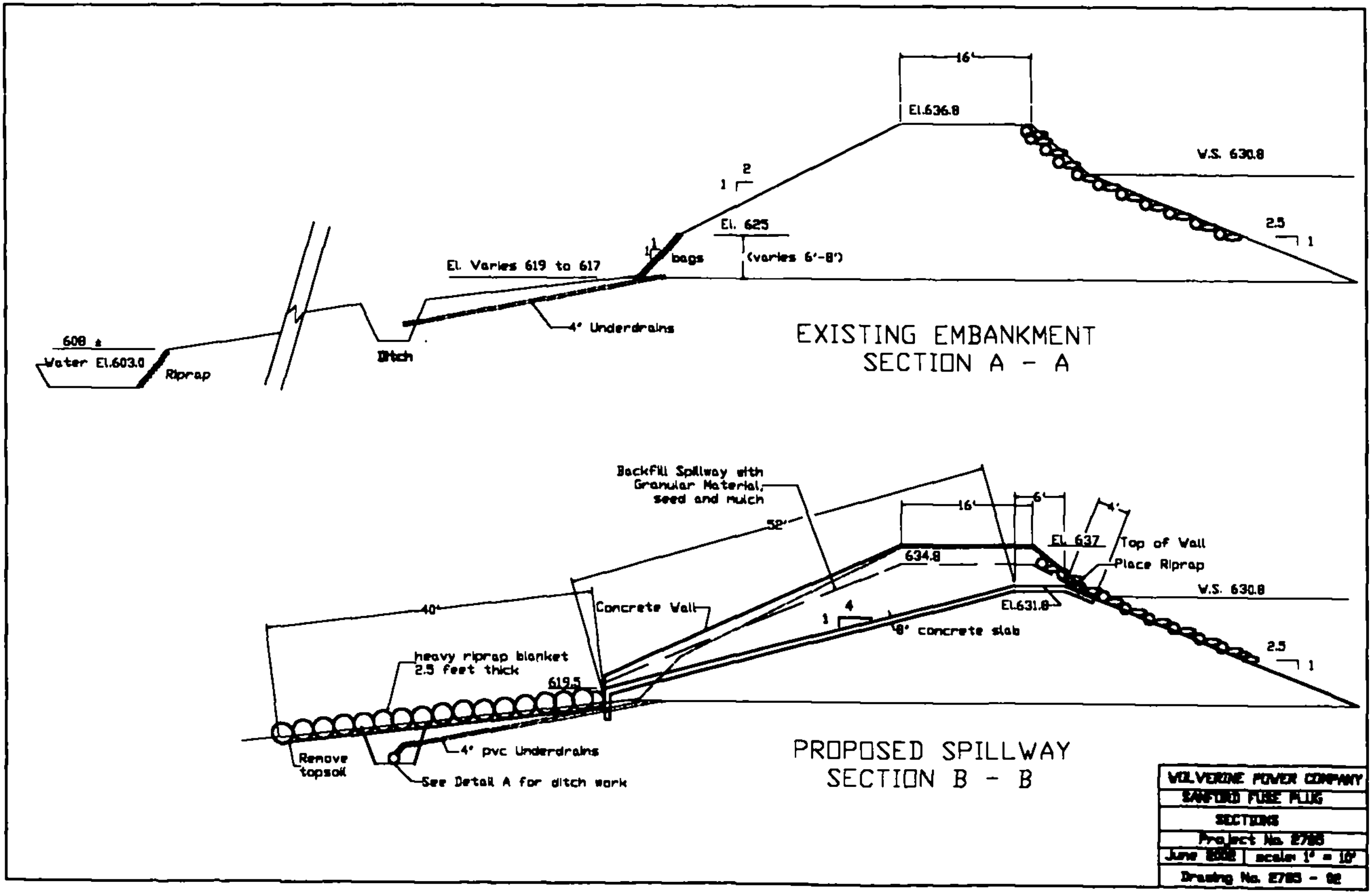
5/24/2019, D:\Boyce Trusts 2012\Boyce Hydro\FERC\Sanford\Exhibit F\Sanford U1 turbine upgrade Ex F



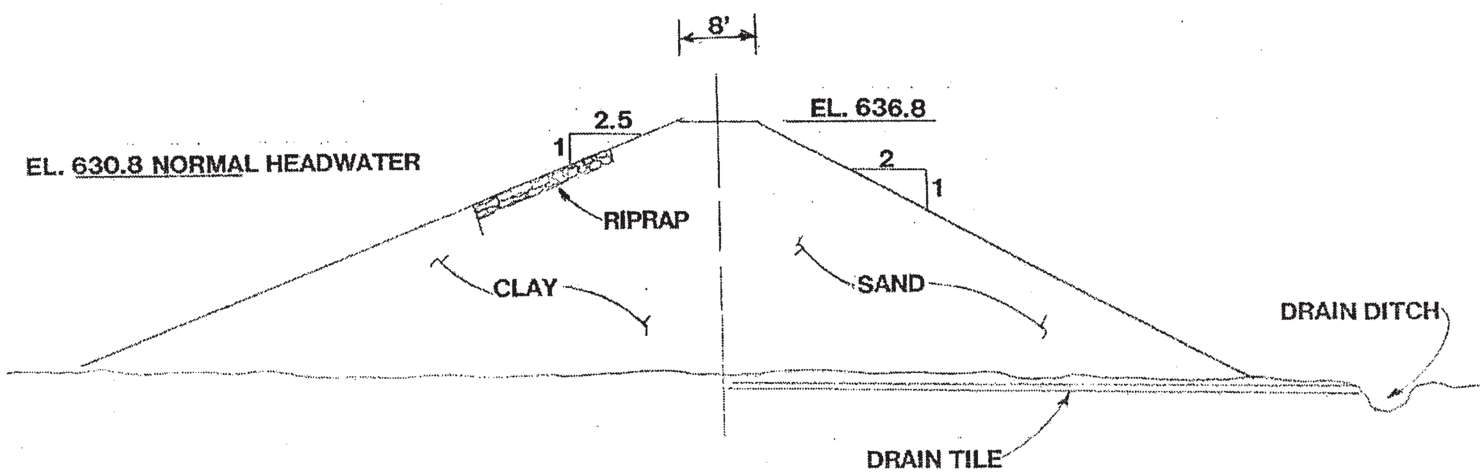
TYPICAL SPILLWAY CROSS SECTION

FIGURE 4


N
Shoreline
Construction Access Along Top of Dike and South of Ditch
NOTES:
1. The impoundment will be lowered one foot for the construction.
2. All concrete to be 4,000 psi strength.
3. Tree removal shall be kept to a minimum, remove only those needed for construction access.
Ditch
Retaining End Walls
Property line
2 Expansion Joints
North Embankment
Proposed Riprap Blanket
Tree Cover
Spoil Area
Remove trees and brush
Maintain Silt Barrier Downstream & Upstream of Work Area
Sanford Spillway
TITTEBAWASSEE RIVER
SITE PLAN

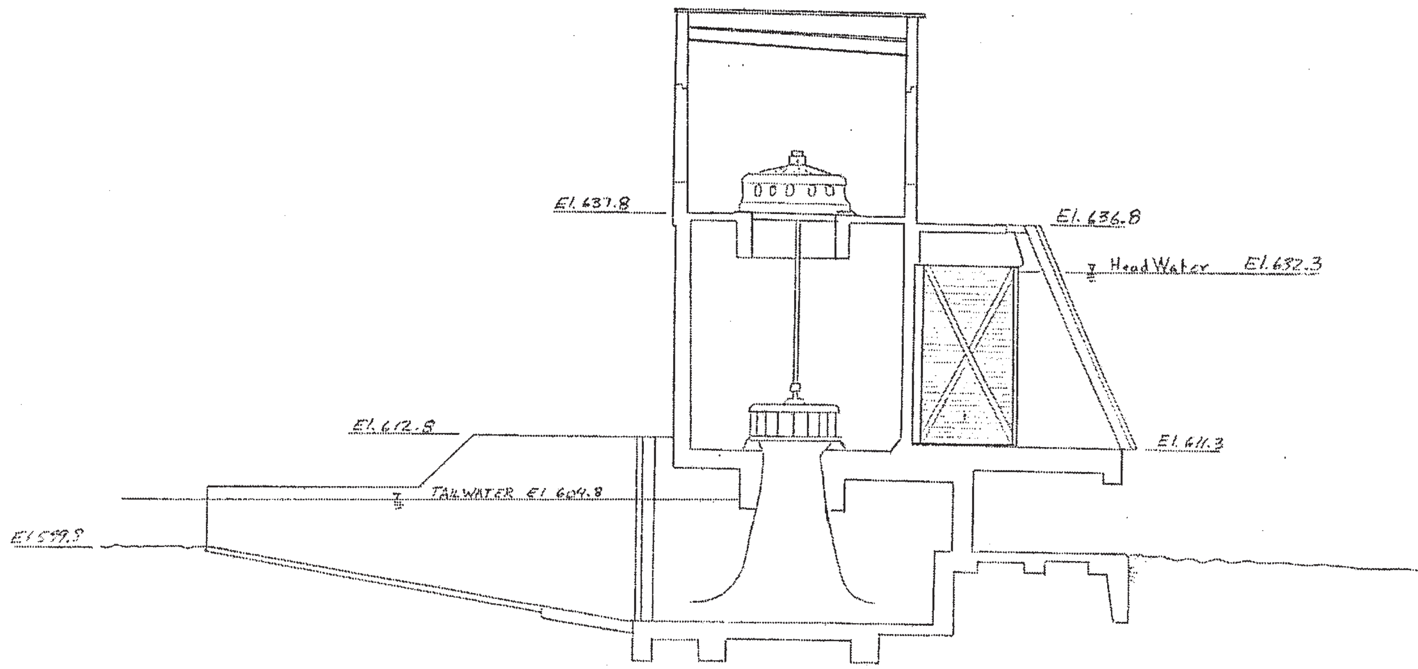


16'
El.636.8
V.S. 630.8
1 2
El. 625
2.5 1
bags
(varies 6'-8')
El. Varies 619 to 617
4" Underdrains
608 ±
Water El.603.0
Riprap
Ditch
EXISTING EMBANKMENT
SECTION A - A
Backfill Spillway with
Granular Material,
seed and mulch
16'
6'
4'
52'
El. 637
Top of Wall
634.8
Place Riprap
V.S. 630.8
El.631.8
40'
Concrete Wall
1 4
8" concrete slab
2.5 1
heavy riprap blanket
2.5 feet thick
619.5
Remove
topsoil
4" pvc Underdrains
See Detail A for ditch work
PROPOSED SPILLWAY
SECTION B - B
WOLVERINE POWER COMPANY
SANFORD FUSE PLUG
SECTIONS
Project No. 2785
June 2002
scale: 1" = 10'
Drawing No. 2785 - 02



EMBANKMENT CROSS SECTION

FIGURE 3



TYPICAL SECTION THRU POWERHOUSE

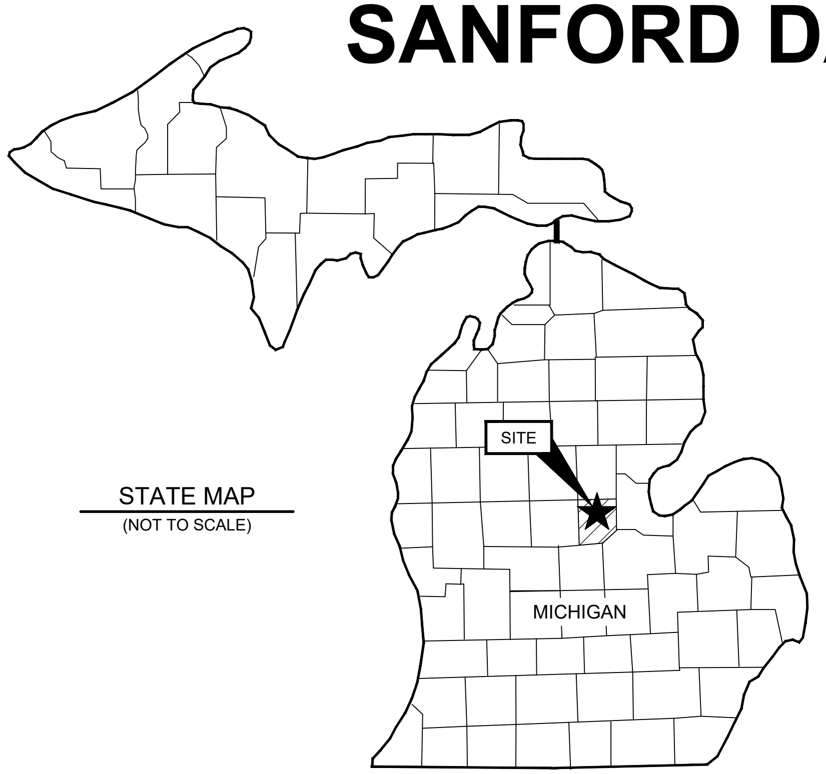
FIGURE 5

Appendix B

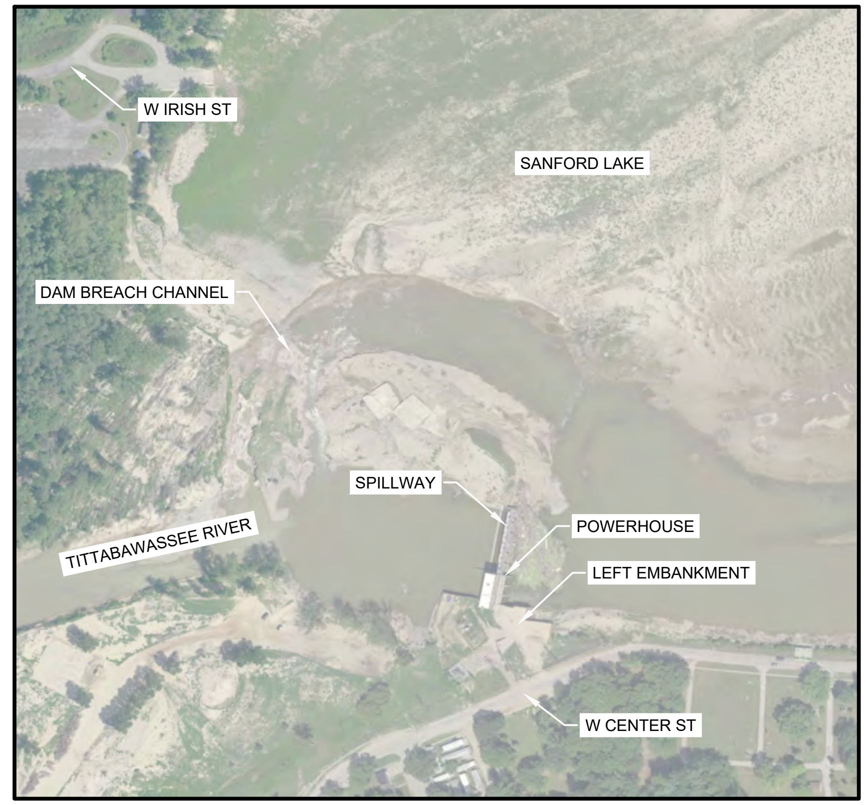
Preliminary Sanford Dam Stabilization Drawings

SANFORD DAM - CONCEPTUAL STABILIZATION DESIGN

MIDLAND COUNTY, MICHIGAN
FOUR LAKES TASK FORCE
FERC PROJECT NO. 2785



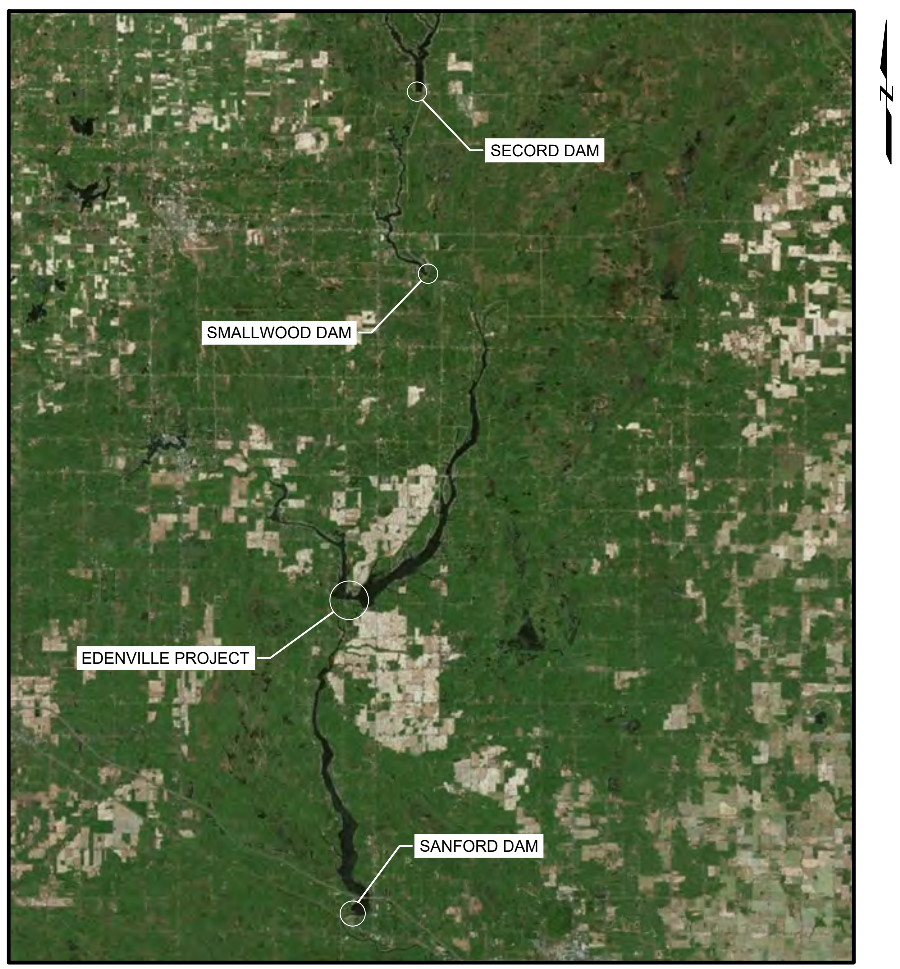
STATE MAP
(NOT TO SCALE)



SITE AERIAL
(NOT TO SCALE)

SHEET INDEX

SHEET NO.	DRAWING NO.	TITLE
1	G-01	COVER SHEET AND SITE LOCATION
2	C-01	EXISTING CONDITIONS / SITE PLAN
3	C-02	RIGHT EMBANKMENT STABILIZATION SITE PLAN
4	C-03	RIGHT EMBANKMENT STABILIZATION PROFILES AND SECTIONS
5	C-04	RIGHT EMBANKMENT STABILIZATION SITE PLAN



SOURCE:
AERIAL IMAGE TAKEN FROM GOOGLE EARTH

SITE LOCATION
(NOT TO SCALE)

PREPARED FOR:

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

PREPARED BY:

GEI CONSULTANTS OF MICHIGAN, P.C.
10501 WEST RESEARCH DRIVE G100
MILWAUKEE, WI 53226
(414) 930-7534

GEI Consultants

SPICER GROUP INC.
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TEL. (989) 754-4717
FAX. (989) 754-4440

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GEI PROJECT NO. 2002879

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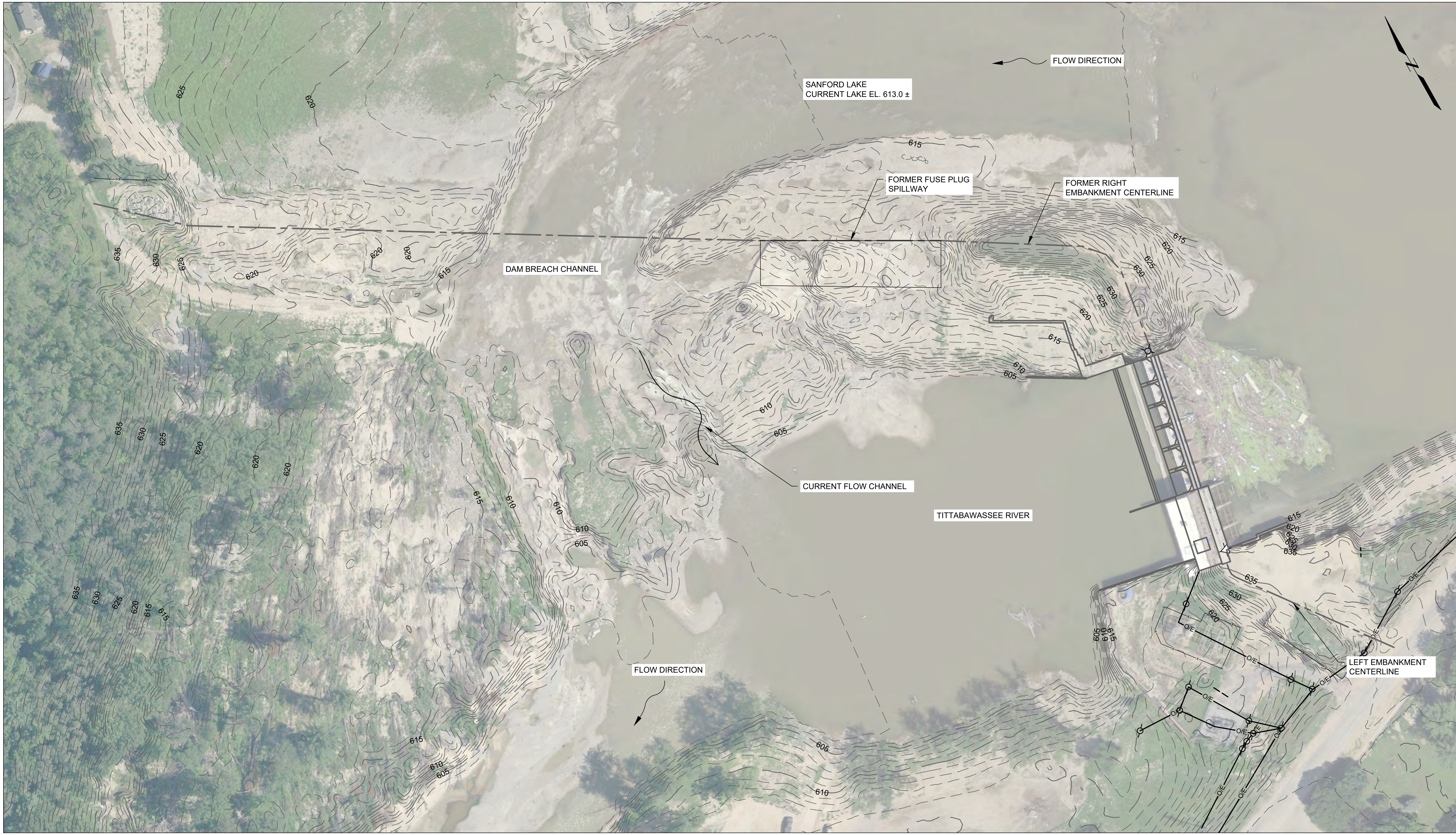
NO.	DATE	ISSUE/REVISION	APP
0	11/6/2020	NRCS EWP SUBMITTAL	XXX

DWG. NO.
G-01

SHEET NO.
1

\\MSN1L-AMICH C:\Temp Local C\FLTF\Sanford\DWG\G-01_Cover Sheet and Site Location.dwg - 10/29/2020



EXISTING CONDITIONS SITE PLAN

0 50 100
SCALE: 1" = 50'

CUI/CEII, DO NOT RELEASE

Attention:

0 1"

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

NO.	DATE	ISSUE/REVISION	APP
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Designed:	R. ANDERSON
Checked:	P. DREW
Drawn:	A. MICHAUD
Approved By:	W. WALTON

Sanford Dam
Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

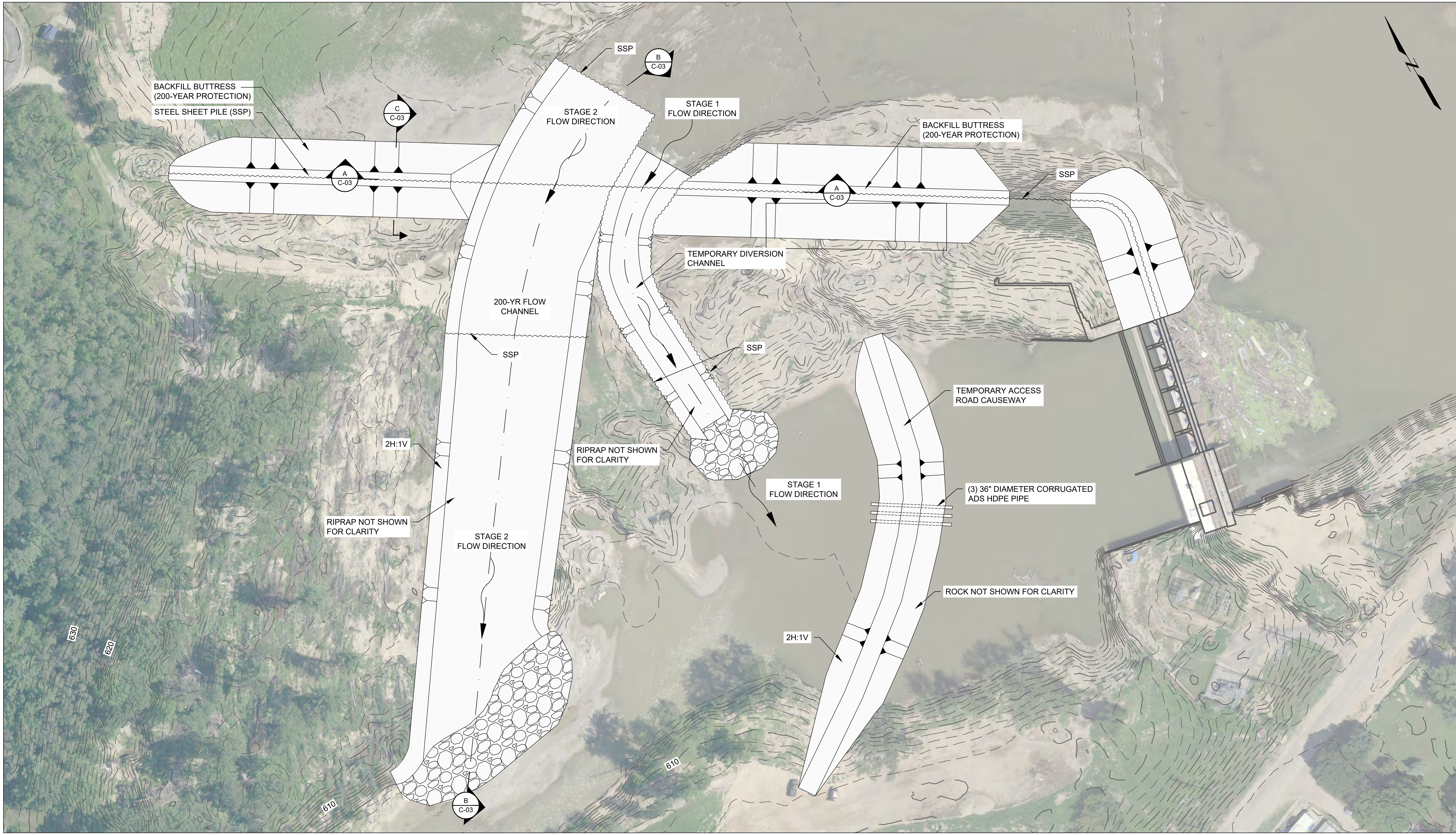
Sanford Dam
Midland County, Michigan

EXISTING CONDITIONS / SITE PLAN

DWG. NO. C-01

SHEET NO. 2

\\MSN1L-AMICH C:\Temp Local C\FLTF\Sanford\DWG\C-01_Existing Conditions.dwg - 10/30/2020



INTERIM MEASURES SITE PLAN

0 50 100
SCALE: 1" = 50'

CUI/CEII, DO NOT RELEASE

CONSTRUCTION SEQUENCE:

1. *CONSTRUCT TEMPORARY ACCESS ROAD CAUSEWAY.*
2. *DRIVE SHEETING AND PLACE ROCK WITHIN TEMPORARY DIVERSION CHANNEL.*
3. *DRIVE SHEETING AND BUTTRESS ON RIGHT EMBANKMENT (TO THE LEFT OF THE DIVERSION CHANNEL).*
4. *DRIVE SHEETING AND BUTTRESS ON THE RIGHT EMBANKMENT (TO THE RIGHT OF THE DIVERSION CHANNEL).*
5. *CONSTRUCT 200-YEAR FLOW CHANNEL.*
6. *CUT DOWN STEEL SHEET PILE IN FRONT OF THE 200-YEAR FLOW CHANNEL AND DIVERT BASE-FLOW FROM THE TEMPORARY DIVERSION CHANNEL (STAGE 1 FLOW DIRECTION) TO 200-YEAR FLOW CHANNEL (STAGE 2 FLOW DIRECTION).*

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

NO.	DATE	ISSUE/REVISION	APP
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Sanford Dam
Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

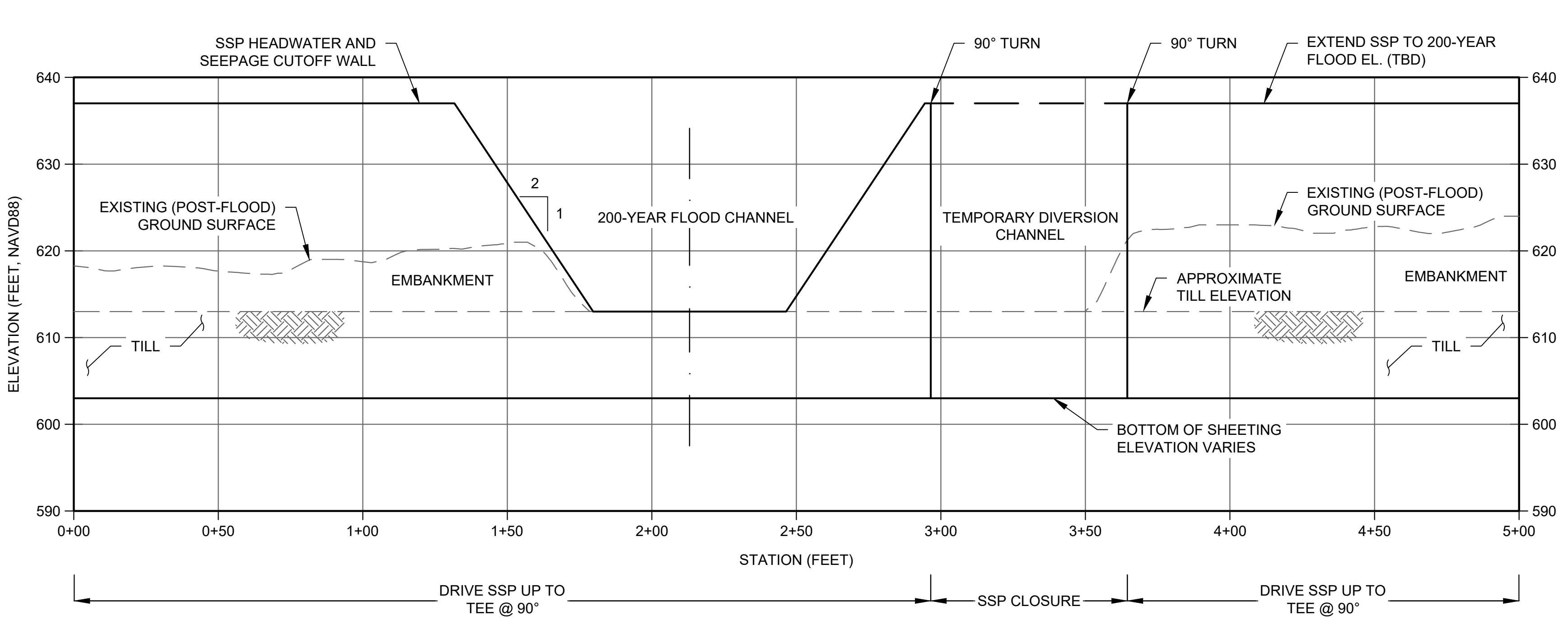
Sanford Dam
Midland County, Michigan

RIGHT EMBANKMENT
STABILIZATION
SITE PLAN

DWG. NO.
C-02

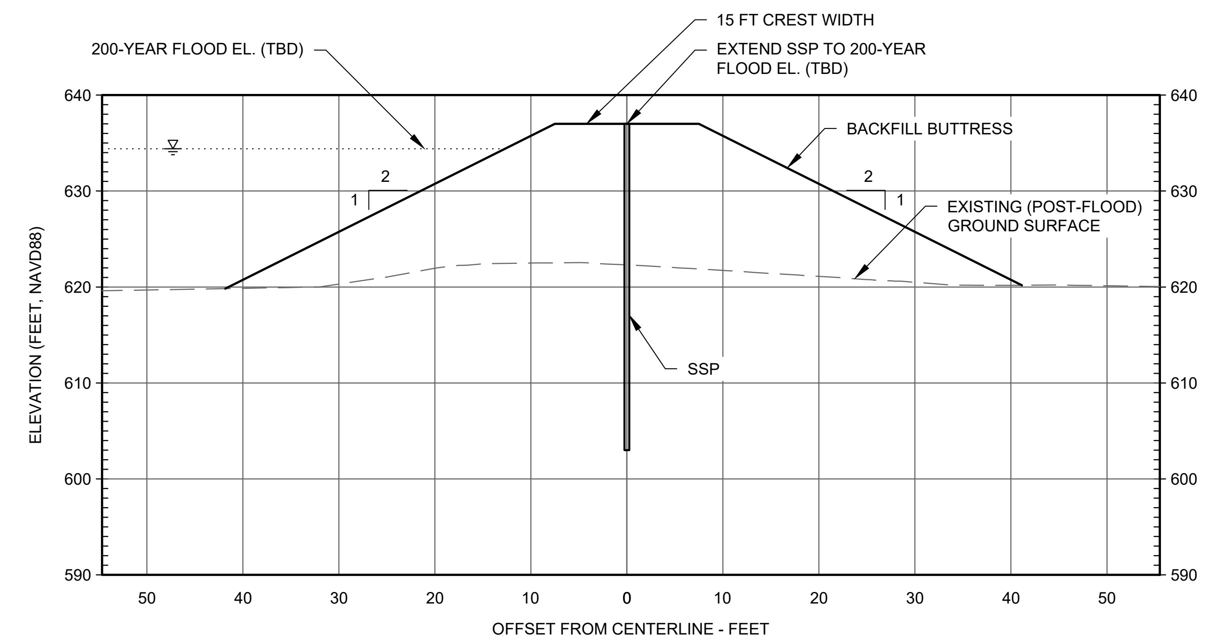
SHEET NO.
3

\\MSN1L-AMICH C:\Temp Local C\FLTF\Sanford\DWG\C-02_Right Embankment Interim Measures_PLAN.dwg - 10/29/2020



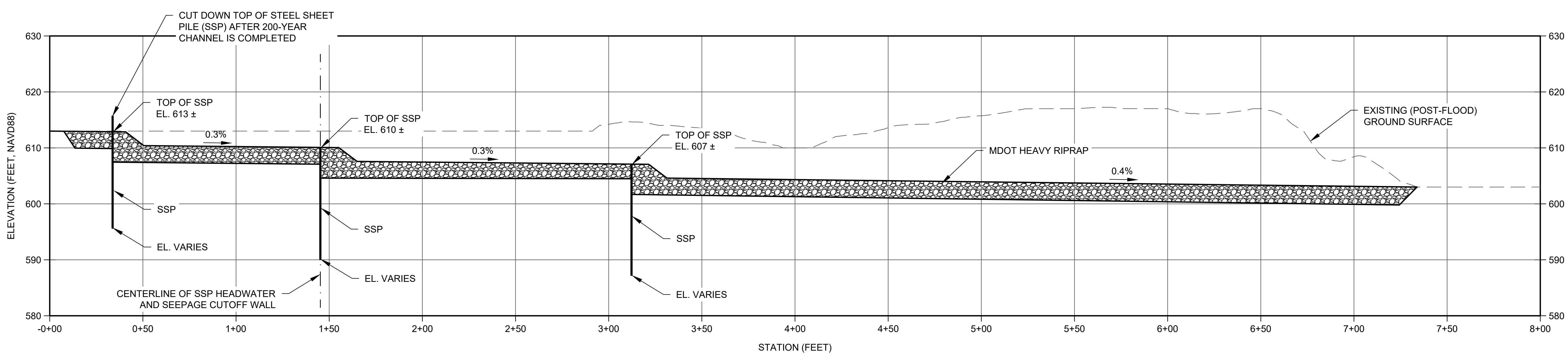
A
C-02
ELEVATION VIEW

HORIZONTAL SCALE, FEET
0 30' 60'
0 10' 20'
VERTICAL SCALE, FEET
NOTE: 3x VERTICAL EXAGGERATION



C
C-02
SECTION VIEW

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



B
C-02
PROFILE VIEW

HORIZONTAL SCALE, FEET
0 30' 60'
0 10' 20'
VERTICAL SCALE, FEET
NOTE: 3x VERTICAL EXAGGERATION

CUI/CEII, DO NOT RELEASE

NOTES:

1. STEEL SHEET PILING SHALL BE HEAVY, HOT-ROLLED SHEETS (PZC-27, NZ-38, OR EQUAL)
2. STEEL SHEET PILING CAN BE SET ALONG ITS ALIGNMENT USING A VIBRATORY HAMMER, BUT SHALL BE DRIVEN TO FINAL DEPTH INTO GLACIAL TELL USING A HEAVY IMPACT HAMMER.

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

NO.	DATE	ISSUE/REVISION	APP
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Designed:	R. ANDERSON
Checked:	P. DREW
Drawn:	A. MICHAUD
Approved By:	W. WALTON

Sanford Dam
Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

Sanford Dam
Midland County, Michigan

RIGHT EMBANKMENT STABILIZATION PROFILES AND SECTIONS

DWG. NO.
C-03

SHEET NO.
4

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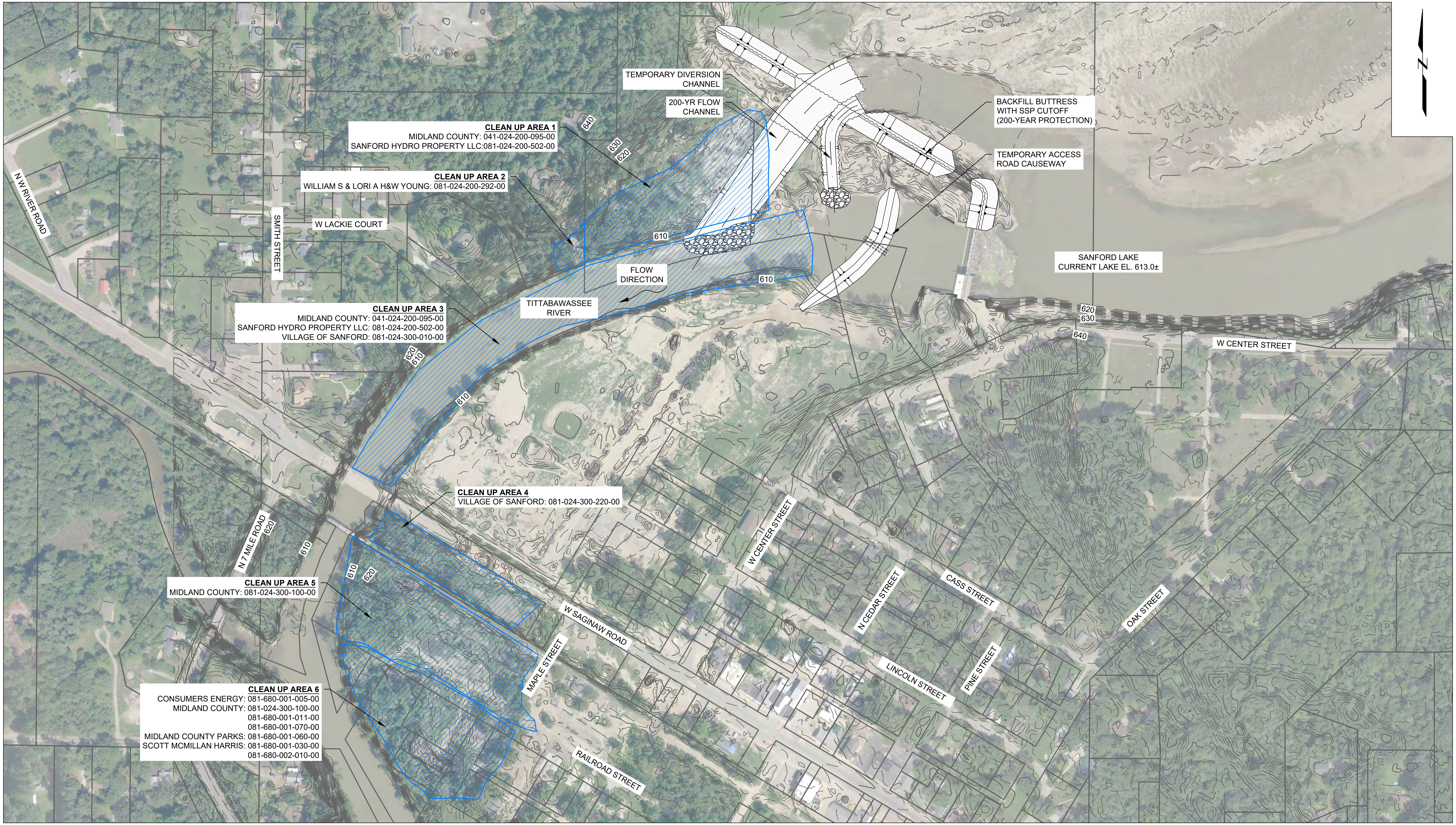

INTERIM MEASURES SITE PLAN

0 150' 300'
SCALE, FEET

CUI/CEII, DO NOT RELEASE

LEGEND

DEBRIS REMOVAL AREA

NOTES:

1. CONTRACTOR SHALL REMOVE MOBILE DEBRIS IN AREAS IDENTIFIED IN THE PLAN. TREES WITH INTACT ROOT SYSTEM AND NOT MOBILE SHALL BE LEFT IN PLACE. TREES CAN BE REMOVED AS NEEDED TO ACCESS MOBILE DEBRIS. THESE COSTS ARE INCLUDED IN THE LUMP SUM BID FOR DEBRIS REMOVAL.

Attention:

0 1"

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

NO.	DATE	ISSUE/REVISION	APP
0	11/6/2020	NRCS EWP SUBMITTAL	WHW

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Designed:	R. ANDERSON
Checked:	P. DREW
Drawn:	A. MICHAUD
Approved By:	W. WALTON

Sanford Dam
Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

Sanford Dam
Midland County, Michigan

RIGHT EMBANKMENT STABILIZATION SITE PLAN

DWG. NO. C-04

SHEET NO. 5

\\MSN1L-AMICH C:\Temp Local C\FLTF\Sanford\DWG\C-02_Right Embankment Interim Measures_PLAN.dwg - 10/29/2020

Appendix C

Spillway Rating Curve Calculations

GEI Consultants

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

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

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

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

Input Variables:

Weir Crest El.	614.8	ft	L, Width Along Dam Axis	16.00	ft
Avg. Gate 1 Weir Crest Width, b	18.6	ft	Number of Piers, N (1,3)	1.0	-
Upstream Slope	2H:1V	Hor:Ver	Pier Contraction Coeff., Kp	0.0	-
Upstream Slope factor, Kr	Varies	-	Abutment Shape	45 Degree	-
Downstream Slope	2H:1V	Hor:Ver	Contraction Coeff., Ka (1,3)	0.1	-
Downstream Slope Factor	Varies	-			
Number of Gates	8				

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
614.8	0.0	0.0	2.88	1.00	2.88	18.6	0	0	Spillway Invert
615.0	0.2	0.0	2.88	1.00	2.88	18.6	5	38	
615.5	0.7	0.0	2.87	1.00	2.87	18.5	31	248	
616.0	1.2	0.1	2.86	1.00	2.86	18.4	69	553	
616.5	1.7	0.1	2.86	1.00	2.86	18.3	116	926	
617.0	2.2	0.1	2.85	1.00	2.85	18.2	169	1,355	
617.5	2.7	0.2	2.85	1.00	2.85	18.1	229	1,832	
618.0	3.2	0.2	2.86	1.00	2.86	18.0	294	2,353	
618.5	3.7	0.2	2.86	1.00	2.86	17.9	364	2,913	
619.0	4.2	0.3	2.87	1.00	2.87	17.8	439	3,511	
619.5	4.7	0.3	2.87	1.00	2.87	17.7	518	4,143	
620.0	5.2	0.3	2.88	1.00	2.88	17.6	601	4,809	
620.5	5.7	0.4	2.89	1.00	2.89	17.5	689	5,508	
621.0	6.2	0.4	2.91	1.00	2.91	17.4	780	6,238	
621.5	6.7	0.4	2.92	1.00	2.92	17.3	875	6,999	
622.0	7.2	0.5	2.93	1.00	2.93	17.2	974	7,790	
622.5	7.7	0.5	2.95	1.00	2.95	17.1	1,076	8,610	
623.0	8.2	0.5	2.96	1.00	2.96	17.0	1,182	9,459	
623.5	8.7	0.5	2.98	1.00	2.98	16.9	1,292	10,336	
624.0	9.2	0.6	3.00	1.00	3.00	16.8	1,405	11,240	
624.5	9.7	0.6	3.02	1.00	3.02	16.7	1,522	12,172	
625.0	10.2	0.6	3.04	1.00	3.04	16.6	1,641	13,130	
625.5	10.7	0.7	3.06	1.00	3.06	16.5	1,764	14,114	
626.0	11.2	0.7	3.08	1.00	3.08	16.4	1,890	15,123	
626.5	11.7	0.7	3.10	1.00	3.10	16.3	2,020	16,157	
627.0	12.2	0.8	3.12	1.00	3.12	16.2	2,152	17,214	
627.5	12.7	0.8	3.14	1.00	3.14	16.1	2,287	18,294	
628.0	13.2	0.8	3.16	1.00	3.16	16.0	2,425	19,397	
628.5	13.7	0.9	3.18	1.00	3.18	15.9	2,565	20,520	
629.0	14.2	0.9	3.21	1.00	3.21	15.8	2,708	21,664	
629.5	14.7	0.9	3.23	1.00	3.23	15.7	2,853	22,826	
630.0	15.2	1.0	3.25	1.00	3.25	15.6	3,001	24,007	
630.5	15.7	1.0	3.27	1.00	3.27	15.5	3,151	25,205	
631.0	16.2	1.0	3.29	1.00	3.29	15.4	3,302	26,419	
631.5	16.7	1.0	3.31	1.00	3.31	15.3	3,456	27,648	
632.0	17.2	1.1	3.33	1.00	3.33	15.2	3,611	28,890	
632.5	17.7	1.1	3.35	1.00	3.35	15.1	3,768	30,144	
633.0	18.2	1.1	3.37	1.00	3.37	15.0	3,926	31,409	
633.5	18.7	1.2	3.39	1.00	3.39	14.9	4,085	32,683	
634.0	19.2	1.2	3.41	1.00	3.41	14.8	4,246	33,966	
634.5	19.7	1.2	3.43	1.00	3.43	14.7	4,407	35,256	
635.0	20.2	1.3	3.45	1.00	3.45	14.6	4,569	36,551	
635.5	20.7	1.3	3.47	1.00	3.47	14.5	4,731	37,850	
636.0	21.2	1.3	3.49	1.00	3.49	14.4	4,894	39,151	
636.5	21.7	1.4	3.50	1.00	3.50	14.3	5,057	40,454	
637.0	22.2	1.4	3.52	1.00	3.52	14.2	5,220	41,757	
637.5	22.7	1.4	3.53	1.00	3.53	14.1	5,382	43,058	
638.0	23.2	1.5	3.55	1.00	3.55	14.0	5,544	44,356	Zero-Freeboard

LABYRINTH WEIR DESIGN
No Approach Velocity

PROJECT:	Sanford Labyrinth	**TIME:**	17:04:02
PROJECT NO.	2002879	**DATE:**	17-Feb-21
FLOOD CRITERIA:	1/2 PMF +	**BY:**	PDD

USER INPUT

Max. Res	**Zr**	636.0	**ft**	**Thickness**			
Crest el.	**Zc**	632.5	**ft**	**Wall**	**Tw**	1.25	**ft**
Floor el.	**Zf**	624.5	**ft**	**Slab**	**Ts**	1.25	**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

L_{de}/B = 0.34 **Ld/B RATIO IS OK**
H_o/P = 0.44 **Ho/P RATIO IS OK**
α = 15.22 **Angle IS OK**

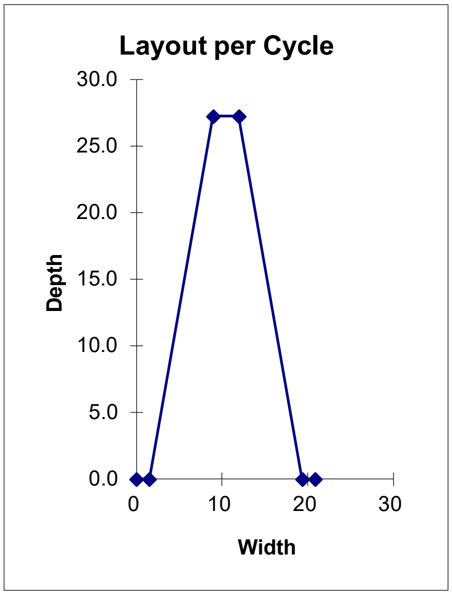
Note: L_{de}/B must be <= 0.35
Ho/P must be <= 0.9
α must be >= 6 deg

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



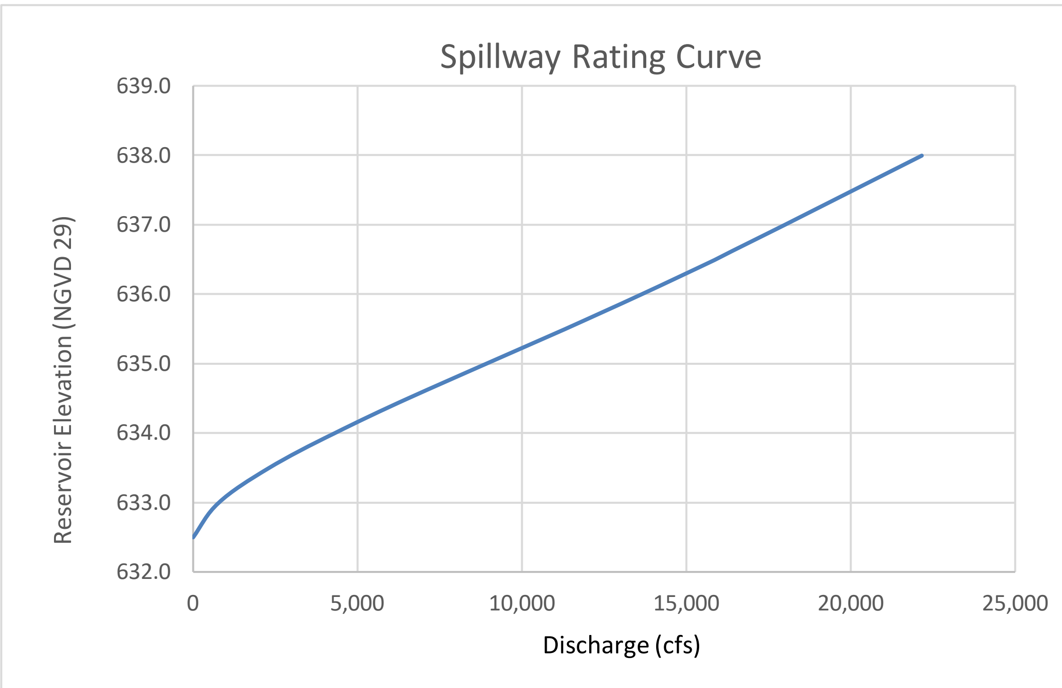
DISCHARGE
Qmax 13,614 **cfs**

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
5.50	0.69	0.42	0.49	0.43	22147	638.00
5.00	0.63	0.44	0.51	0.45	20068	637.50
4.50	0.56	0.46	0.53	0.47	17982	637.00
4.00	0.50	0.49	0.55	0.49	15842	636.50
3.50	0.44	0.51	0.58	0.52	13614	636.00
3.00	0.38	0.54	0.60	0.54	11292	635.50
2.50	0.31	0.56	0.61	0.56	8905	635.00
2.00	0.25	0.57	0.62	0.57	6525	634.50
1.50	0.19	0.58	0.62	0.58	4265	634.00
1.00	0.13	0.57	0.60	0.57	2282	633.50
0.50	0.06	0.54	0.56	0.54	767	633.00
0	0	0.49	0.49	0.49	0	632.5



<u>**Discharge Coefficient Table Tullis et al. (1995)**</u>

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	

GEI Consultants

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

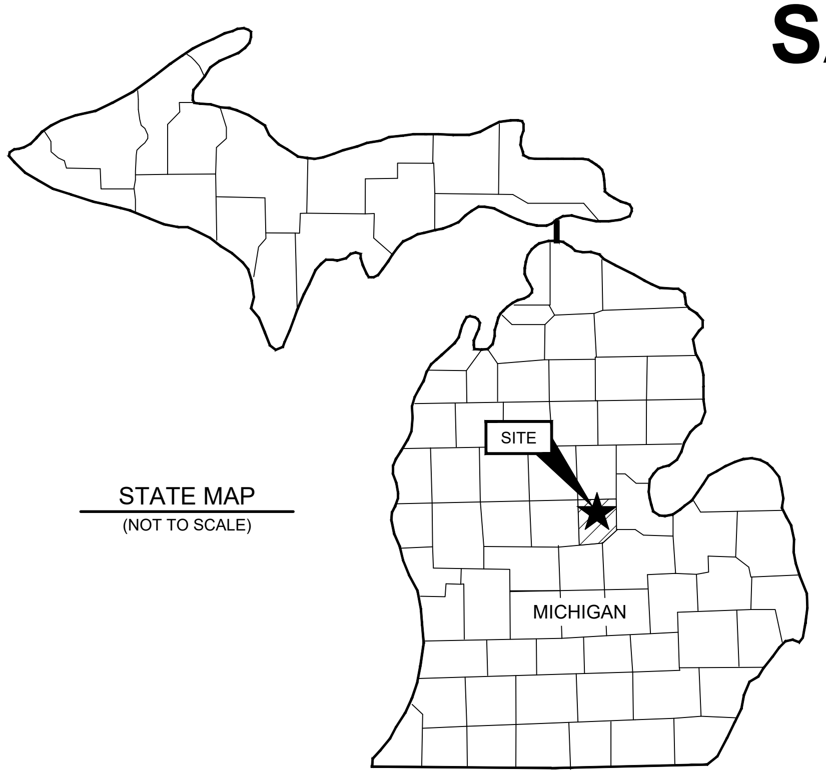
Reservoir El. (ft)	Gated Spillway (cfs)	Labyrinth Spillway (cfs)	Total Spilway (cfs)	Comments
614.8	0	0	0	Spillway Invert
615.0	38	0	38	
615.5	248	0	248	
616.0	553	0	553	
616.5	926	0	926	
617.0	1,355	0	1,355	
617.5	1,832	0	1,832	
618.0	2,353	0	2,353	
618.5	2,913	0	2,913	
619.0	3,511	0	3,511	
619.5	4,143	0	4,143	
620.0	4,809	0	4,809	
620.5	5,508	0	5,508	
621.0	6,238	0	6,238	
621.5	6,999	0	6,999	
622.0	7,790	0	7,790	
622.5	8,610	0	8,610	
623.0	9,459	0	9,459	
623.5	10,336	0	10,336	
624.0	11,240	0	11,240	
624.5	12,172	0	12,172	
625.0	13,130	0	13,130	
625.5	14,114	0	14,114	
626.0	15,123	0	15,123	
626.5	16,157	0	16,157	
627.0	17,214	0	17,214	
627.5	18,294	0	18,294	
628.0	19,397	0	19,397	
628.5	20,520	0	20,520	
629.0	21,664	0	21,664	
629.5	22,826	0	22,826	
630.0	24,007	0	24,007	
630.5	25,205	0	25,205	
631.0	26,419	0	26,419	
631.5	27,648	0	27,648	
632.0	28,890	0	28,890	
632.5	30,144	0	30,144	Auxiliary Spillway
633.0	31,409	767	32,176	
633.5	32,683	2,282	34,965	
634.0	33,966	4,265	38,231	
634.5	35,256	6,525	41,780	
635.0	36,551	8,905	45,456	
635.5	37,850	11,292	49,142	
636.0	39,151	13,614	52,766	
636.5	40,454	15,842	56,296	
637.0	41,757	17,982	59,739	
637.5	43,058	20,068	63,125	
638.0	44,356	22,147	66,502	Zero-Freeboard

Appendix D

Sanford Dam Conceptual Design Drawings

SANFORD DAM CONCEPT DESIGN

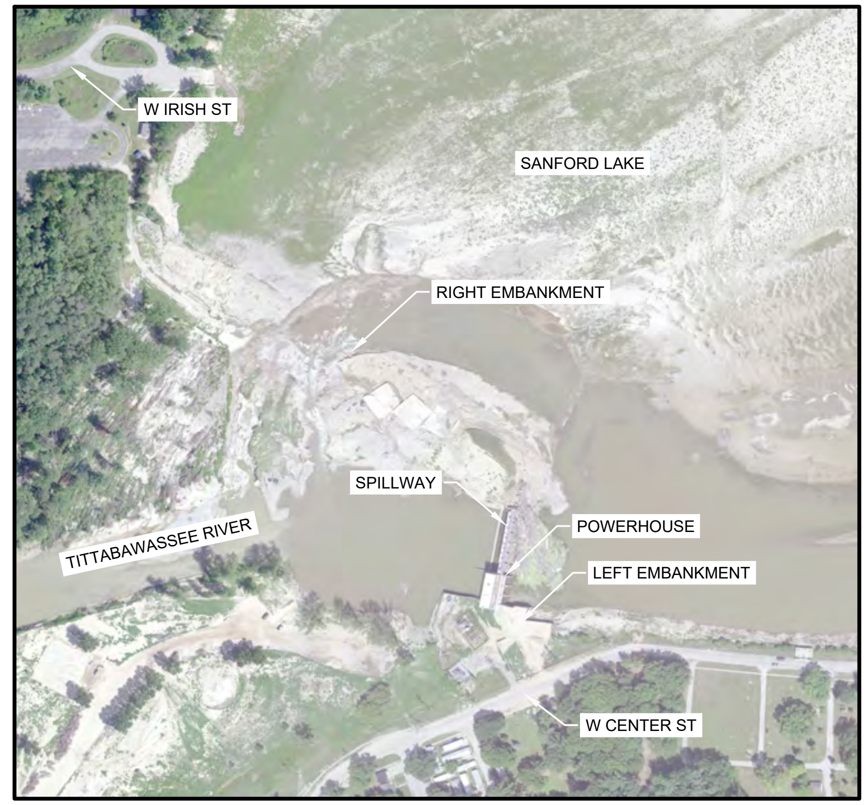
MIDLAND COUNTY, MICHIGAN
FOUR LAKES TASK FORCE
FERC PROJECT NO. 2785



STATE MAP
(NOT TO SCALE)

SOURCE:
AERIAL IMAGE TAKEN FROM GOOGLE EARTH

SITE LOCATION
(NOT TO SCALE)



SITE AERIAL
(NOT TO SCALE)

SHEET INDEX

SHEET NO.	DRAWING NO.	TITLE
1	G-01	COVER SHEET AND SITE LOCATION
2	G-02	GENERAL NOTES AND LEGEND
3	C-01	SITE PLAN - EXISTING CONDITIONS PLAN POST-EMBANKMENT BREACH
4	C-02	SITE PLAN - EXISTING CONDITIONS POST-BREACH CHANNEL TEMPORARY STABILIZATION
5	C-03	OUTLET WORKS - TEMPORARY COFFERDAMS PLAN & SECTIONS
6	C-04	OUTLET WORKS - DEMOLITION PLAN
7	C-05	OUTLET WORKS - DEMOLITION SECTION
8	C-06	POWERHOUSE - DEMOLITION SECTION
9	C-07	OUTLET WORKS - MODIFICATIONS PLAN
10	C-08	PRIMARY SPILLWAY - MODIFICATIONS SECTION
11	C-09	PRIMARY SPILLWAY - CREST GATE DETAILS
12	C-10	POWERHOUSE - MODIFICATIONS SECTION
13	C-11	POWERHOUSE - LOW LEVEL OUTLET - MODIFICATIONS SECTION
14	C-12	SITE PLAN - PROPOSED MODIFICATIONS
15	C-13	EMBANKMENTS - MODIFICATIONS SECTIONS
16	C-14	PHASE 2 LABYRINTH SPILLWAY TEMPORARY COFFERDAM PLAN
17	C-15	LABYRINTH SPILLWAY - PROPOSED PLAN VIEW
18	C-16	LABYRINTH SPILLWAY - PROPOSED SPILLWAY & CHANNEL CROSS SECTIONS

PREPARED FOR:

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

PREPARED BY:

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GEI PROJECT NO. 2002879

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

DRAFT

DWG. NO. G-01

SHEET NO. 1

1. GENERAL

SPACIAL DATUM INFORMATION

- VERTICAL: NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD29).
- HORIZONTAL: NORTH AMERICAN DATUM OF 1983 (NAD83), MICHIGAN STATE PLANE, CENTRAL ZONE.
- A CONVERSION OF +5.8' IS REQUIRED WHEN CONVERTING VERTICAL DAM DATUM TO NGVD29 (E.G., HEADWATER ELEVATION AT DAM DATUM IS 625.0' AND AT NGVD29 DATUM IS 630.8').
- A CONVERSION OF -0.568' 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 630.8' (+0.3' / -0.4')
- WINTER RESERVOIR OPERATIONS: MINIMUM 627.8' (+0.7')
- SDF RESERVOIR ELEVATION 635.4'

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

A / C-03 — INDICATES SECTION DESIGNATION; INDICATES DRAWING NUMBER ON WHICH SECTION IS DRAWN — A / C-03

DETAIL

1 / C-02 — INDICATES DETAIL NUMBER; INDICATES DRAWING NUMBER ON WHICH DETAIL IS DRAWN

LINETYPE LEGEND

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

SYMBOLS LEGEND

- WATER ELEVATION
- FLOW DIRECTION
- 1H:1V — CUT SLOPE
- 1H:1V — FILL SLOPE
- POWER POLE
- SB-1 — SOIL BORING
- MW #1 — MONITORING WELL
- BM #1 — SURVEY REFERENCE MONUMENT (CONTORL POINT / BENCHMARK)
- SURVEY MOVEMENT MONUMENT

HATCH LEGEND

EXISTING CONCRETE	CONCRETE PLATFORM (IN PLAN VIEW)	CONCRETE DEMOLITION	BERM FILL AREA	STRUCTURAL FILL
PROPOSED REINFORCED CONCRETE	STEEL	GRATING	TIMBER	TOPSOIL AND SEED
WOOD STRUCTURE	EXISTING FOUNDATION	RIPRAP	AGGREGATE	CELLULAR GROUT FILL
FILTER STONE	DRAINAGE STONE	CREST GATES	REINFORCED CONCRETE CAP	

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	--

DRAFT

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

Four Lakes Task Force
FERC Project No. 2785

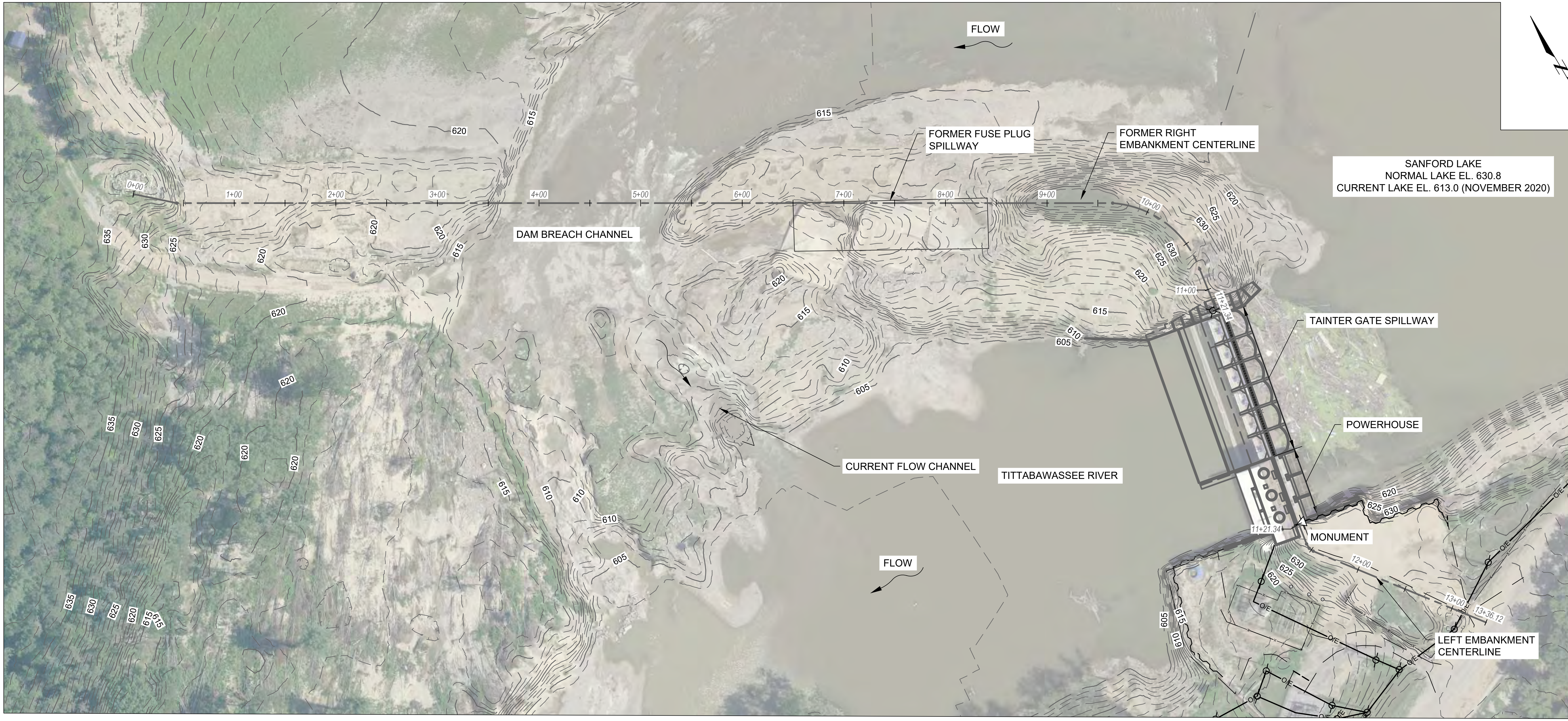
GEI Project 2002879

Sanford Dam Conceptual Design
Midland County, Michigan

GENERAL NOTES AND LEGEND

DWG. NO. G-02

SHEET NO. 2



LINETYPE LEGEND

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

SYMBOLS LEGEND

- DRAIN TILES
- FLOW DIRECTION
- BM #1 — SURVEY REFERENCE MONUMENT

EXISTING CONDITIONS SITE PLAN

0 50 100
SCALE, FEET

SURVEY CONTROL MONUMENT LOCATIONS

ID	ELEVATION	NORTHING	EASTING
MONUMENT	637.86	793,278.682	13,119,772.561

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

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

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0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	--

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Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

Sanford Dam Conceptual Design
Midland County, Michigan

SITE PLAN - EXISTING CONDITIONS
POST-EMBANKMENT BREACH

DWG. NO.
C-01

SHEET NO.
3

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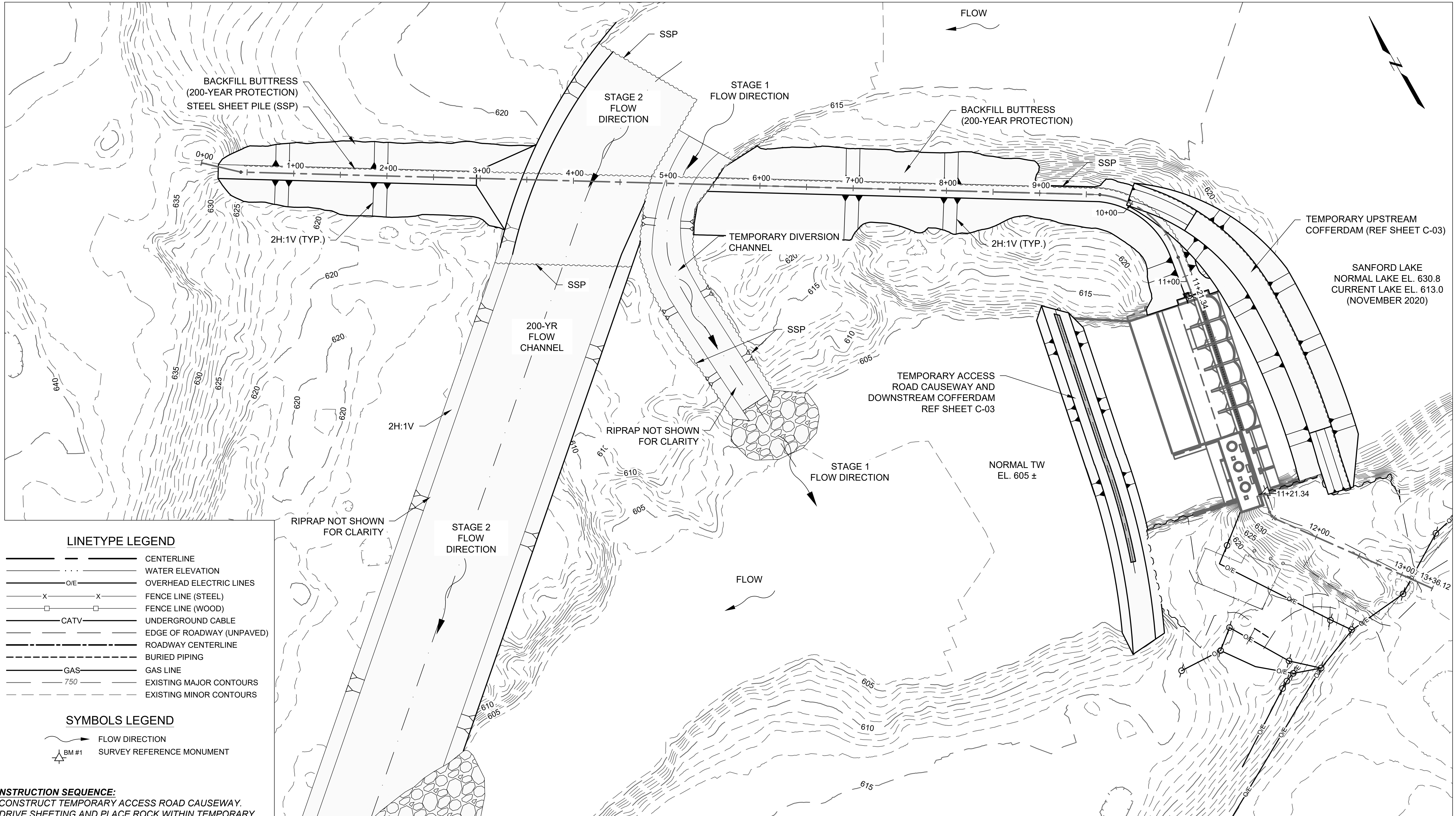

LINETYPE LEGEND

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

SYMBOLS LEGEND

- FLOW DIRECTION
- BM #1 SURVEY REFERENCE MONUMENT

CONSTRUCTION SEQUENCE:

1. *CONSTRUCT TEMPORARY ACCESS ROAD CAUSEWAY.*
2. *DRIVE SHEETING AND PLACE ROCK WITHIN TEMPORARY DIVERSION CHANNEL.*
3. *DRIVE SHEETING AND BUTTRESS ON RIGHT EMBANKMENT (TO THE LEFT OF THE DIVERSION CHANNEL).*
4. *DRIVE SHEETING AND BUTTRESS ON THE RIGHT EMBANKMENT (TO THE RIGHT OF THE DIVERSION CHANNEL).*
5. *CONSTRUCT 200-YEAR FLOW CHANNEL.*
6. *CUT DOWN STEEL SHEET PILE IN FRONT OF THE 200-YEAR FLOW CHANNEL AND DIVERT BASE-FLOW FROM THE TEMPORARY DIVERSION CHANNEL (STAGE 1 FLOW DIRECTION) TO 200-YEAR FLOW CHANNEL (STAGE 2 FLOW DIRECTION).*

EXISTING CONDITIONS - SITE PLAN

0 50 100
SCALE, FEET

Attention:
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Sanford Dam Conceptual Design
Midland County, Michigan

SITE PLAN - EXISTING CONDITIONS
POST-BREACH CHANNEL
TEMPORARY STABILIZATION

DWG. NO.
C-02

SHEET NO.
4

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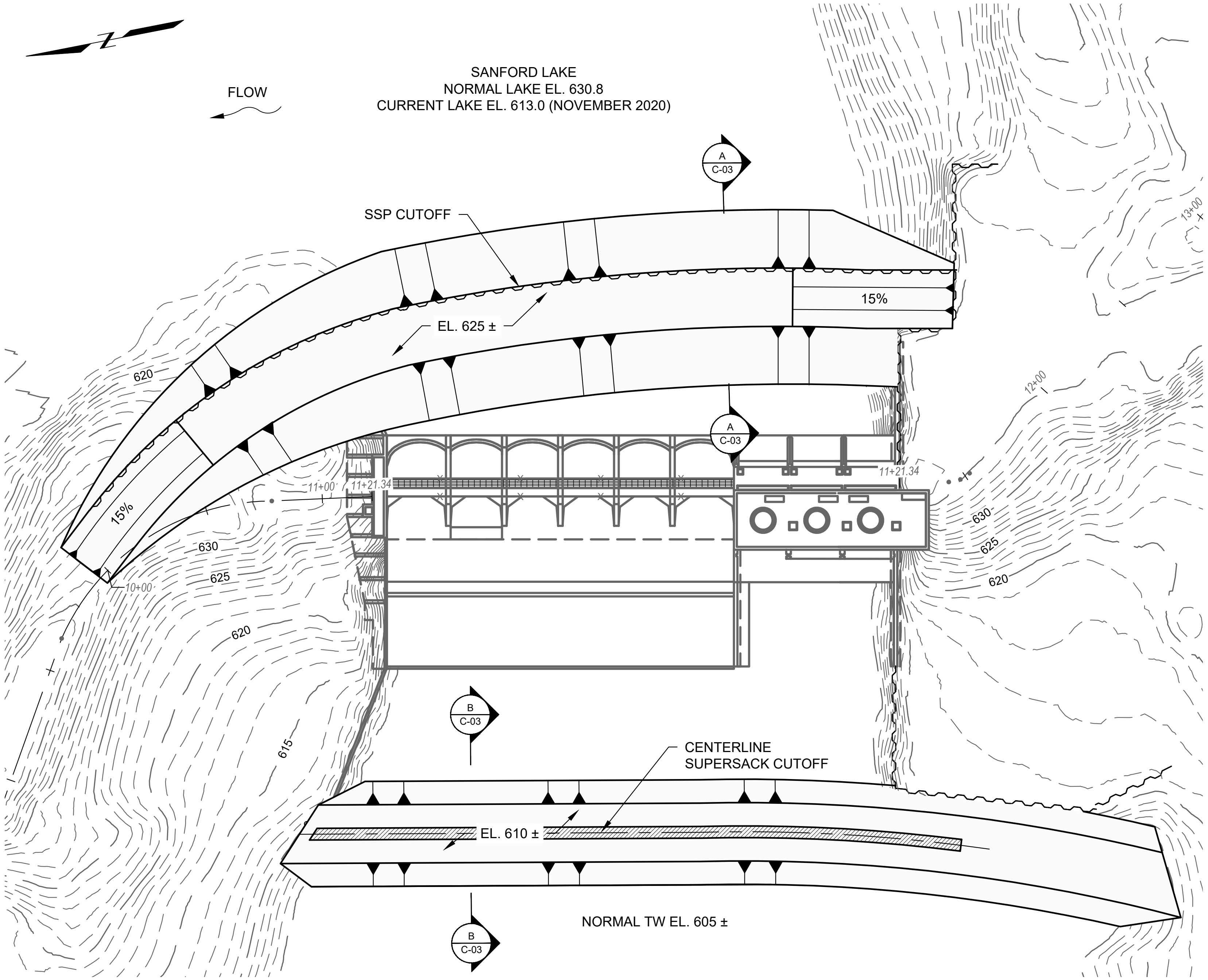
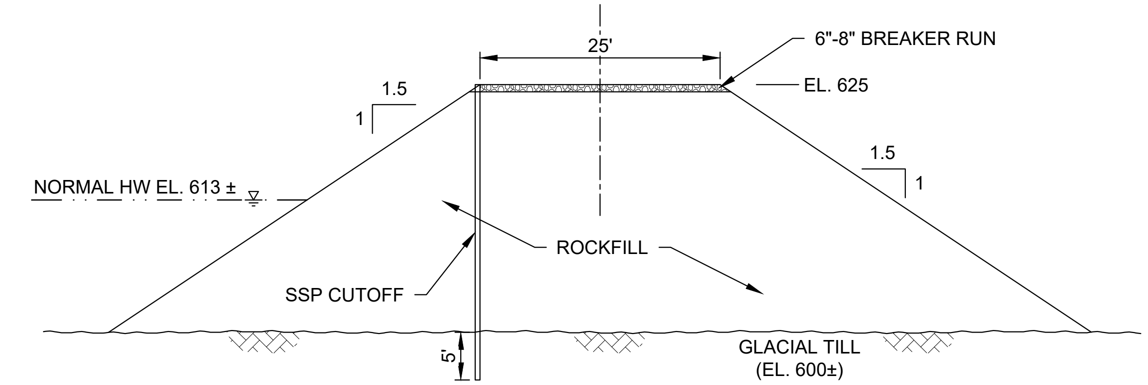


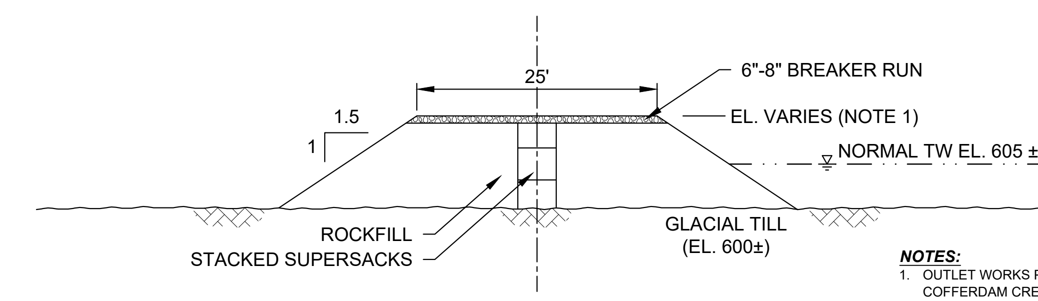
SITE PLAN - PROPOSED MODIFICATIONS

0 30 60
SCALE, FEET



A C-03 C-14 SECTION
UPSTREAM COFFERDAM

0 10 20
SCALE, FEET



B C-03 C-14 SECTION
DOWNSTREAM COFFERDAM

0 10 20
SCALE, FEET

NOTES:
1. OUTLET WORKS PHASE 1 DOWNSTREAM COFFERDAM CREST ELEVATION 610 ±.
2. LABYRINTH SPILLWAY PHASE 2 DOWNSTREAM COFFERDAM CREST ELEVATION 620 ±.

LINETYPE LEGEND

- CENTERLINE
- 750 EXISTING MAJOR CONTOURS
- EXISTING MINOR CONTOURS
- WATER ELEVATION

SYMBOLS LEGEND

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

PROPOSED CONSTRUCTION SEQUENCE:
1. FULLY DRAW DOWN IMPOUNDMENT, STABILIZE EXISTING PROJECT STRUCTURES, REMOVE DEBRIS AND INSPECT SPILLWAY AND POWERHOUSE. (TO BE COMPLETED BY BOYCE)
2. CONTRACTOR MOBILIZATION, LEFT AND RIGHT ABUTMENT RECONSTRUCTION AND DEVELOP LAYDOWN AND CONTRACTOR WORK AREAS.
3. STABILIZE RIGHT EMBANKMENT BREACH CHANNEL AND FULLY DIVERT WATER FROM SPILLWAY AND POWERHOUSE AREA.
4. CONSTRUCT PHASE I UPSTREAM AND DOWNSTREAM COFFERDAMS AT GATED SPILLWAY AND POWERHOUSE.
5. DEMOLISH EXISTING GATED SPILLWAY AND POWERHOUSE.
6. CONSTRUCT NEW GATED SPILLWAY.
7. REMOVE PHASE I COFFERDAMS AND CONSTRUCT PHASE II UPSTREAM AND DOWNSTREAM COFFERDAMS AT NEW AUXILIARY LABYRINTH SPILLWAY LOCATED AT BREACH CHANNEL AREA. DIVERT RIVER FLOWS THROUGH NEW GATED SPILLWAY.
8. CONSTRUCT NEW AUXILIARY LABYRINTH SPILLWAY AND RECONSTRUCT FLANKING EMBANKMENTS.
9. REMOVE PHASE II COFFERDAMS.
10. REFILL SANFORD LAKE AND MONITOR PERFORMANCE.
11. FINAL SITE RESTORATION AND CONTRACTOR DEMOBILIZATIONS.

Attention:
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Sanford Dam Conceptual Design
Midland County, Michigan

OUTLET WORKS - TEMPORARY COFFERDAMS PLAN & SECTIONS

DWG. NO.
C-03

SHEET NO.
5

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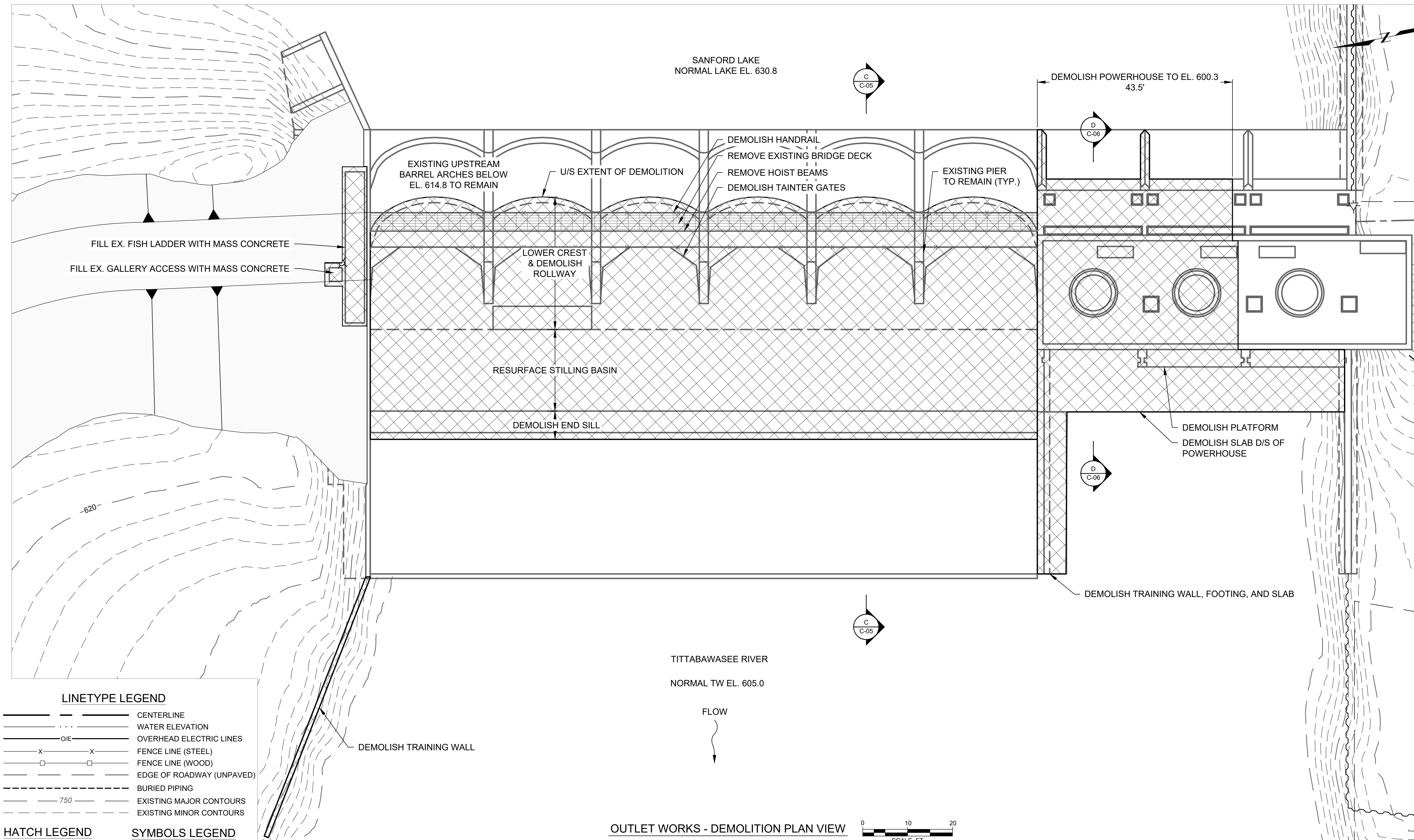

OUTLET WORKS - DEMOLITION PLAN VIEW

0 10 20
SCALE, FT

LINETYPE LEGEND

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

HATCH LEGEND

GRATING
DEMOLITION

SYMBOLS LEGEND

BENCHMARK
FLOW DIRECTION

Attention:
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Midland County, Michigan

OUTLET WORKS - DEMOLITION PLAN

DWG. NO.
C-04

SHEET NO.
6

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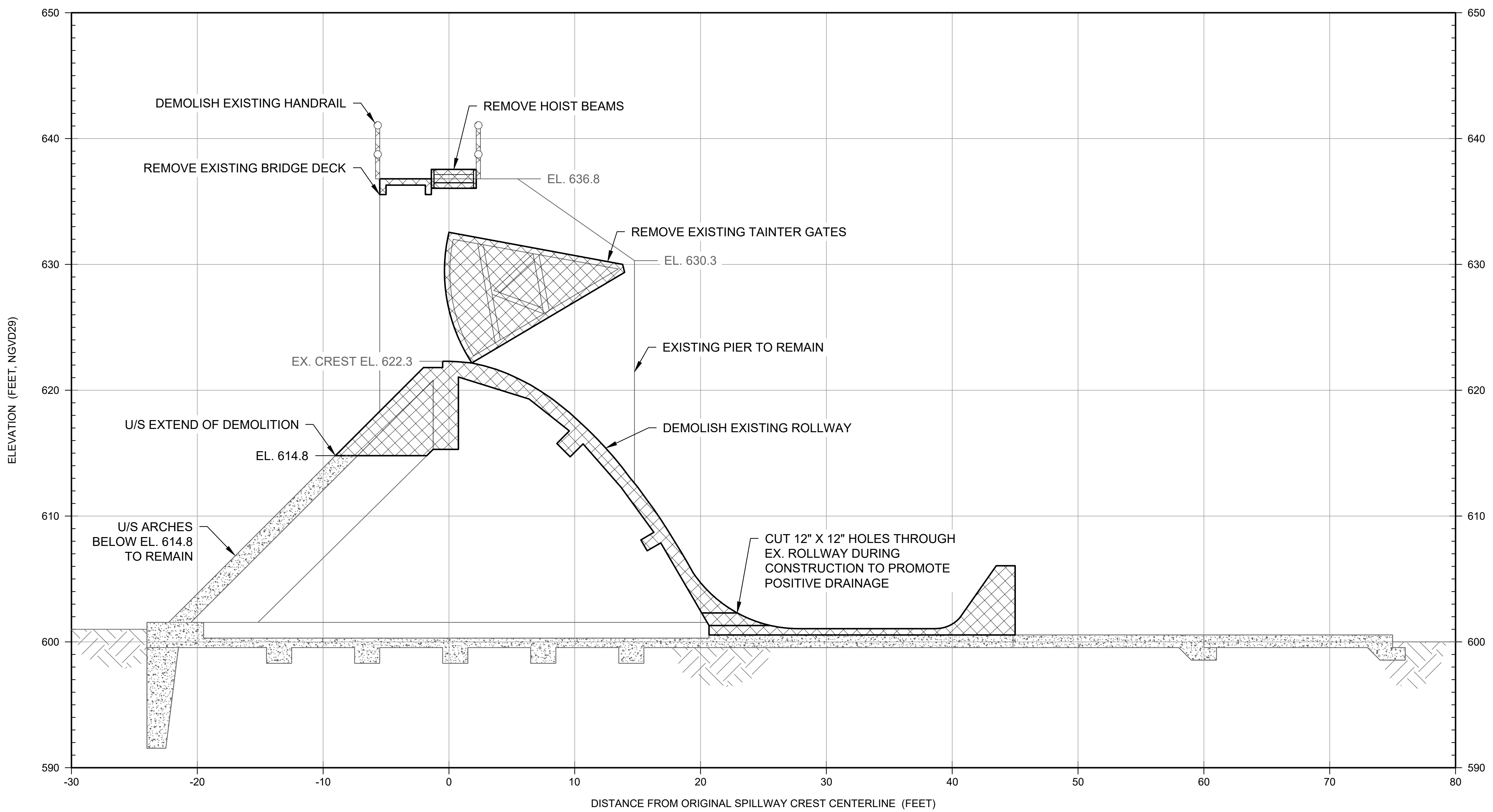

C
C-04

SECTION
SPILLWAY DEMOLITION

0 5 10
SCALE, FT

HATCH LEGEND

CONCRETE DEMOLITION | EXISTING CONCRETE | EXISTING FOUNDATION

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

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Midland County, Michigan

OUTLET WORKS - DEMOLITION SECTION

DWG. NO.
C-05

SHEET NO.
7

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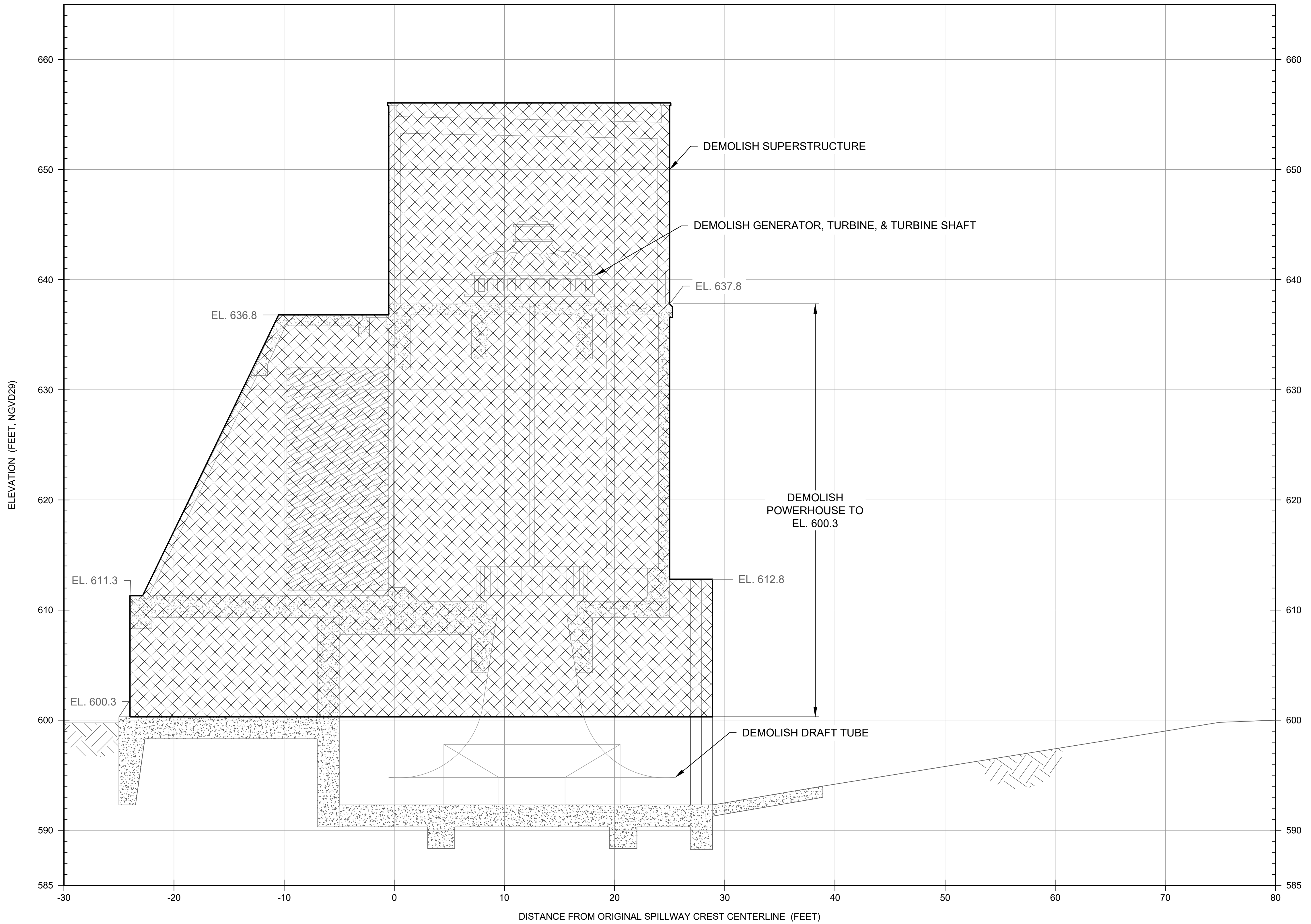

D
C-04

SECTION
POWERHOUSE DEMOLITION

0 5 10
SCALE, FT

HATCH LEGEND

CONCRETE DEMOLITION | EXISTING CONCRETE | EXISTING FOUNDATION

Attention:
0 1"
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Midland County, Michigan

POWERHOUSE - DEMOLITION SECTION

DWG. NO.
C-06

SHEET NO.
8

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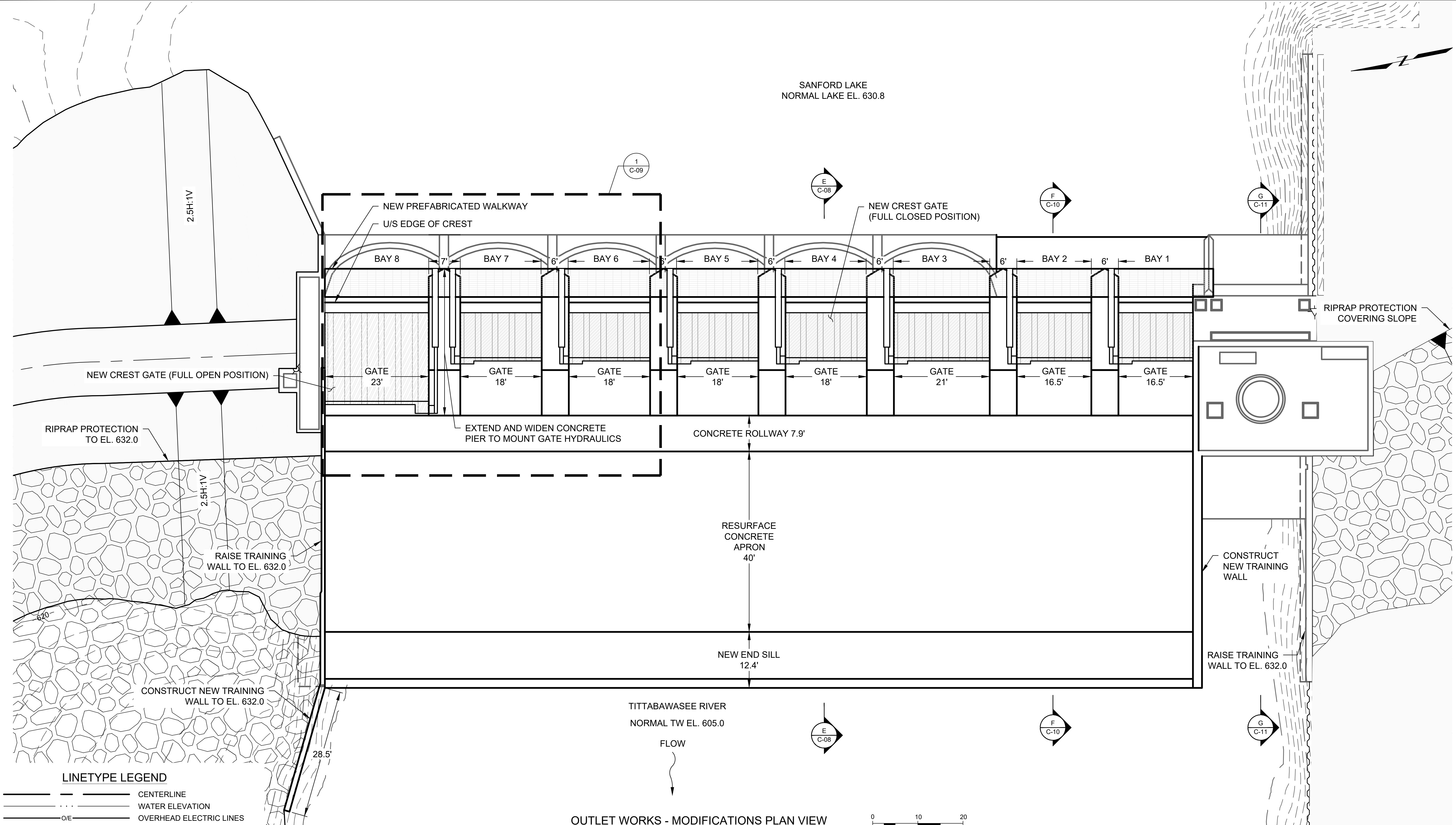

OUTLET WORKS - MODIFICATIONS PLAN VIEW

0 10 20
SCALE, FT

LINETYPE LEGEND

CENTERLINE
WATER ELEVATION
O/E OVERHEAD ELECTRIC LINES
EDGE OF ROADWAY (UNPAVED)
750 EXISTING MAJOR CONTOURS
EXISTING MINOR CONTOURS

HATCH LEGEND

RIPRAP
CREST GATES
GRATING

SYMBOLS LEGEND

BENCHMARK
FLOW DIRECTION

Attention:

0 1"

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Midland County, Michigan

OUTLET WORKS - MODIFICATIONS PLAN

DWG. NO.
C-07

SHEET NO.
9

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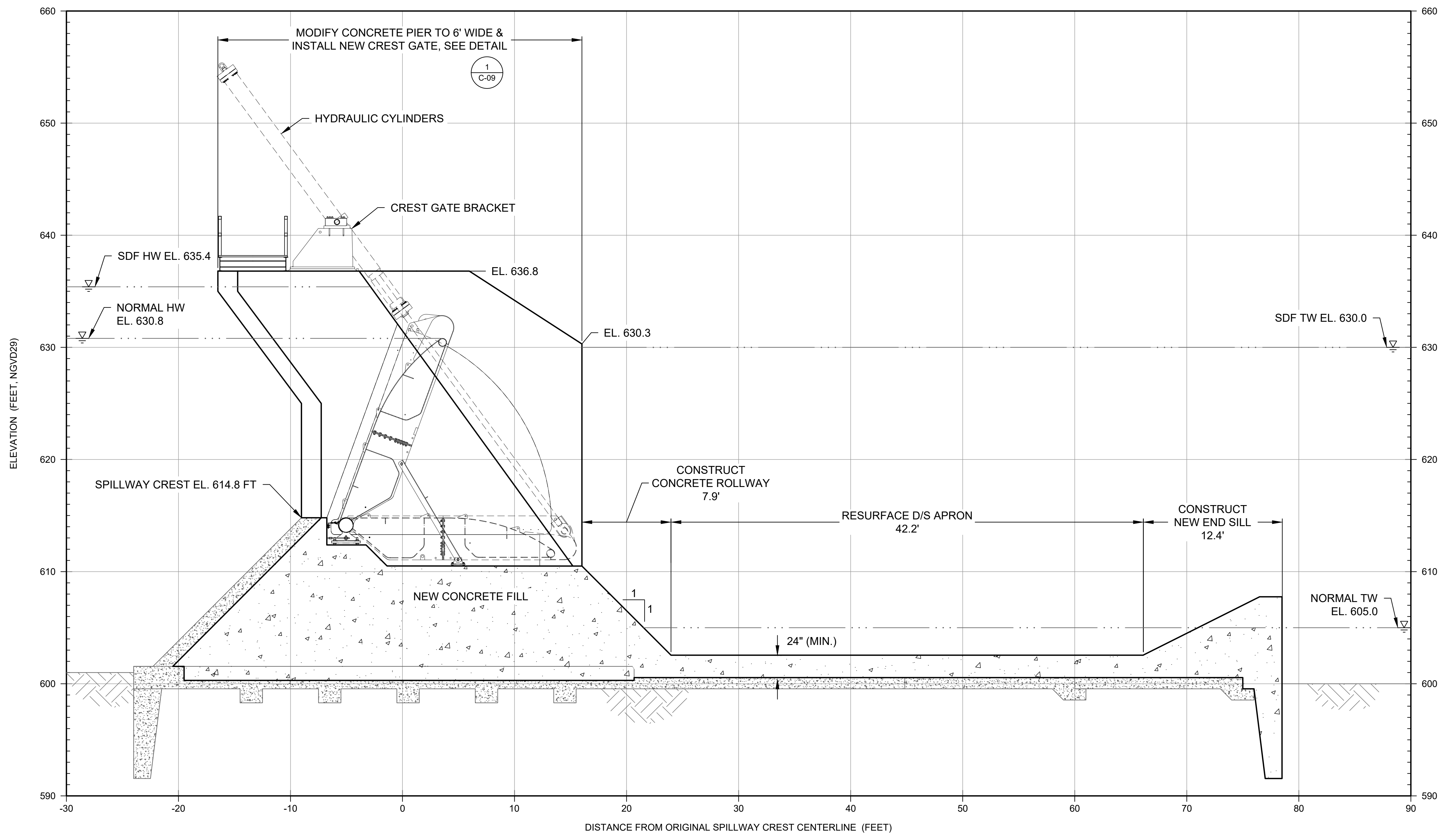

E
C-07
SECTION
BAY 4 SPILLWAY

0 5 10
SCALE, FT

HATCH LEGEND

PROPOSED REINFORCED CONCRETE
EXISTING CONCRETE
EXISTING FOUNDATION

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PRIMARY SPILLWAY - MODIFICATIONS SECTION

DWG. NO. C-08

SHEET NO. 10

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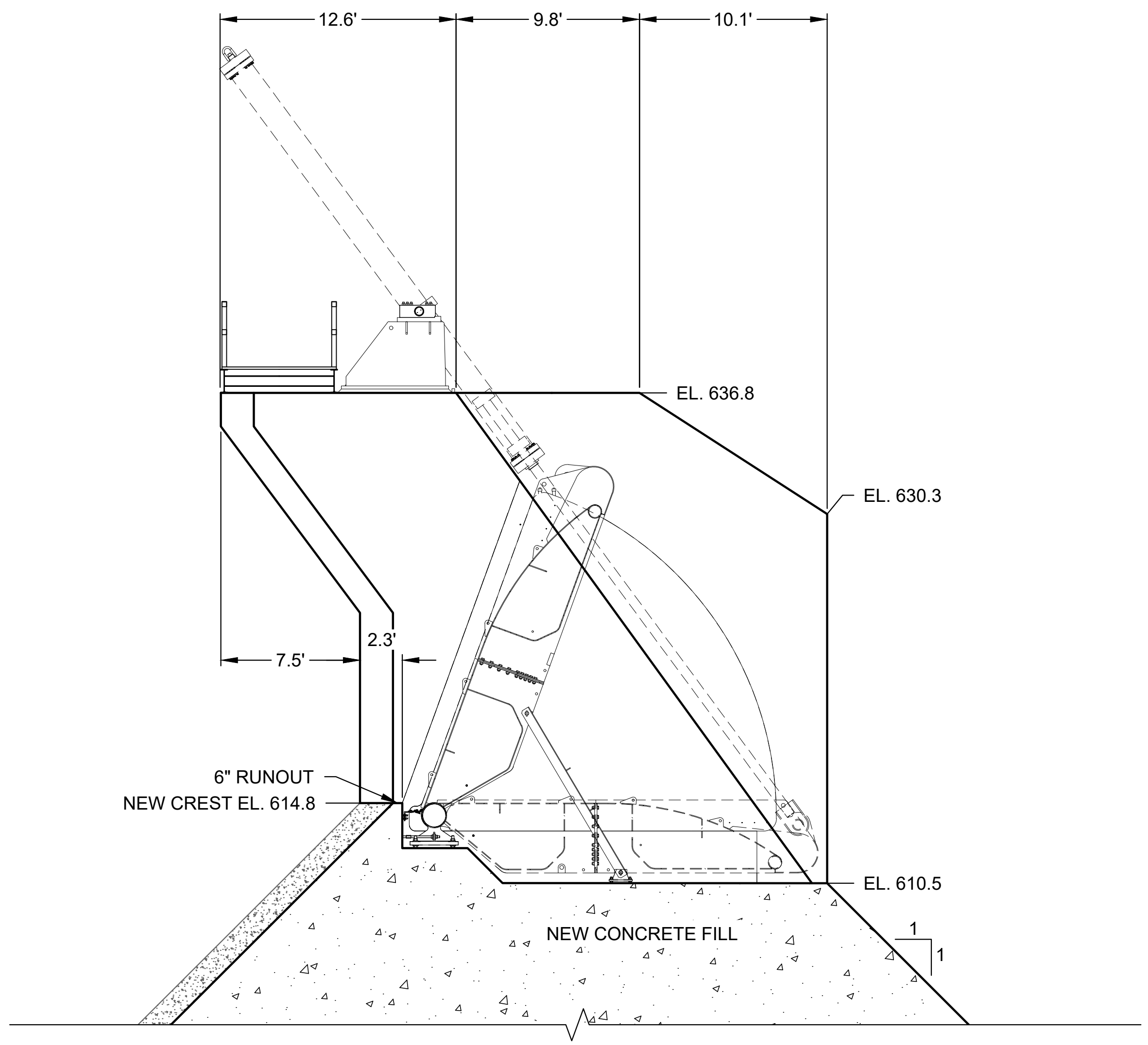
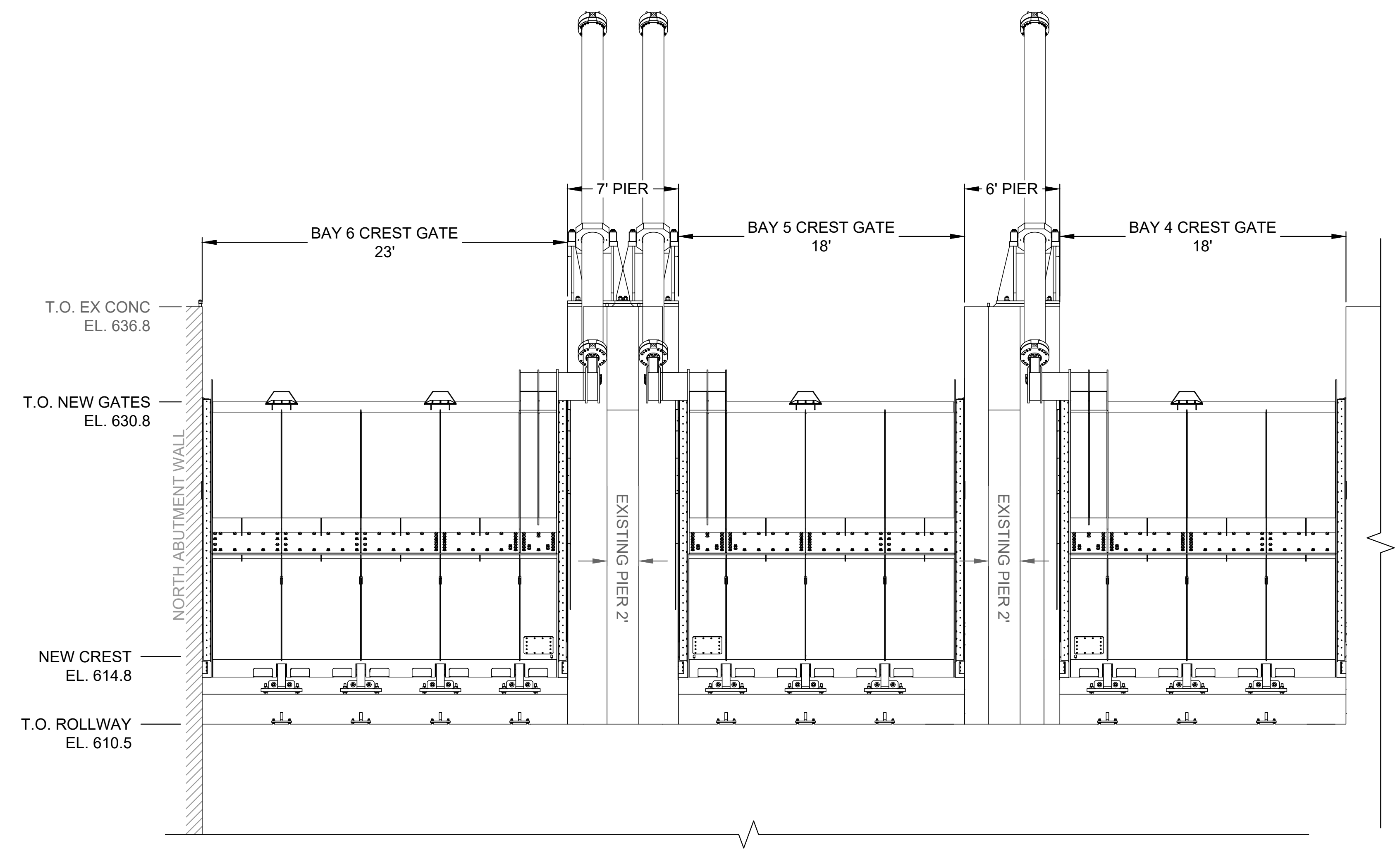


SECTION



DOWNSTREAM ELEVATION
(LOOKING UPSTREAM)

1 DETAIL
C-08 C-10 PIER-MOUNTED CREST GATE

0 5 10
SCALE, FT

HATCH LEGEND

PROPOSED REINFORCED CONCRETE

EXISTING CONCRETE

Attention:
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PRIMARY SPILLWAY - CREST GATE DETAILS

DWG. NO.
C-09

SHEET NO.
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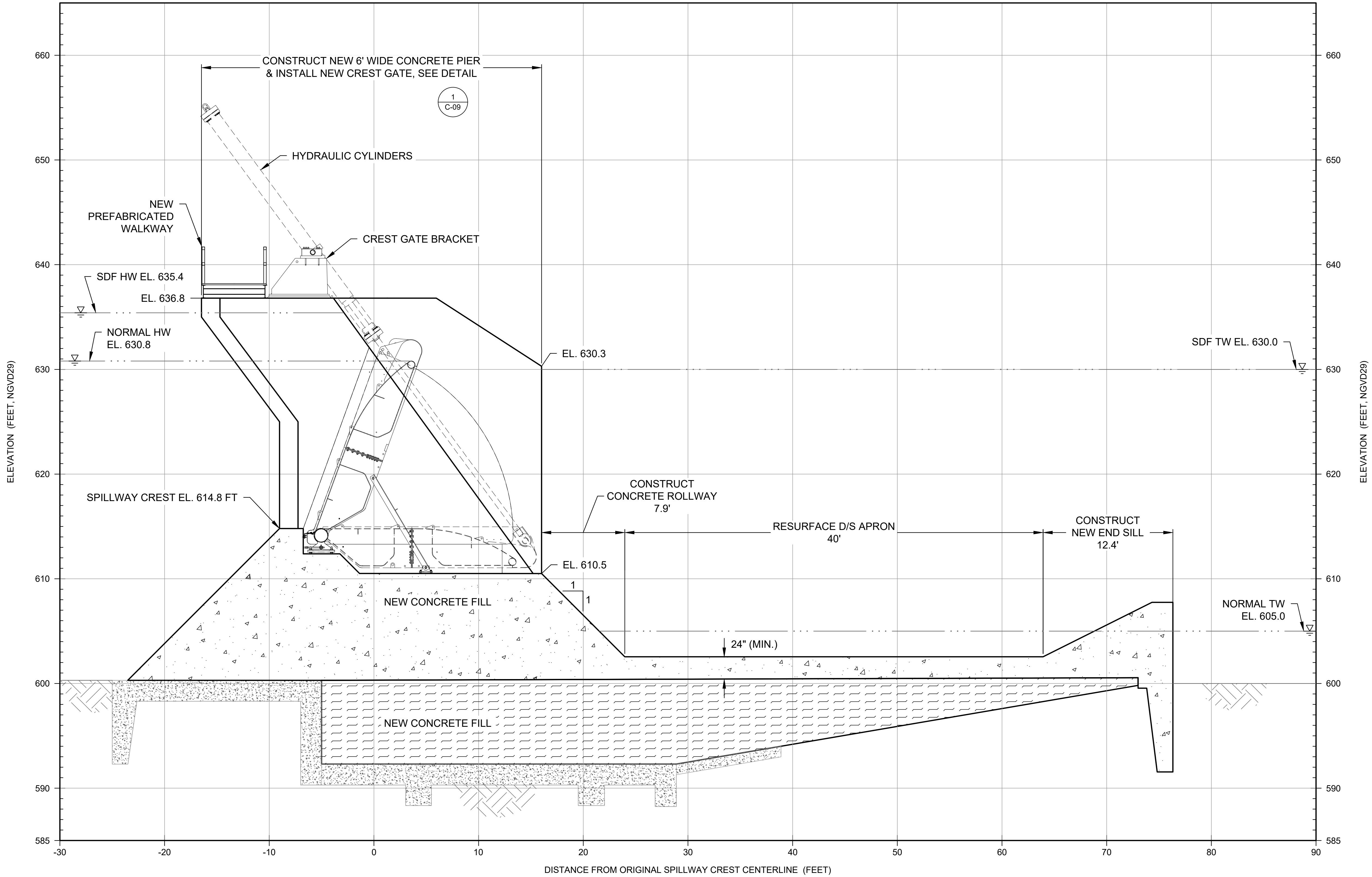

F
C-07
SECTION
POWERHOUSE BAY 2

0 5 10
SCALE, FT

HATCH LEGEND

EXISTING CONCRETE | EXISTING FOUNDATION | PROPOSED REINFORCED CONCRETE | CONCRETE FILL

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Midland County, Michigan

POWERHOUSE - MODIFICATIONS
SECTION

DWG. NO.
C-10

SHEET NO.
12

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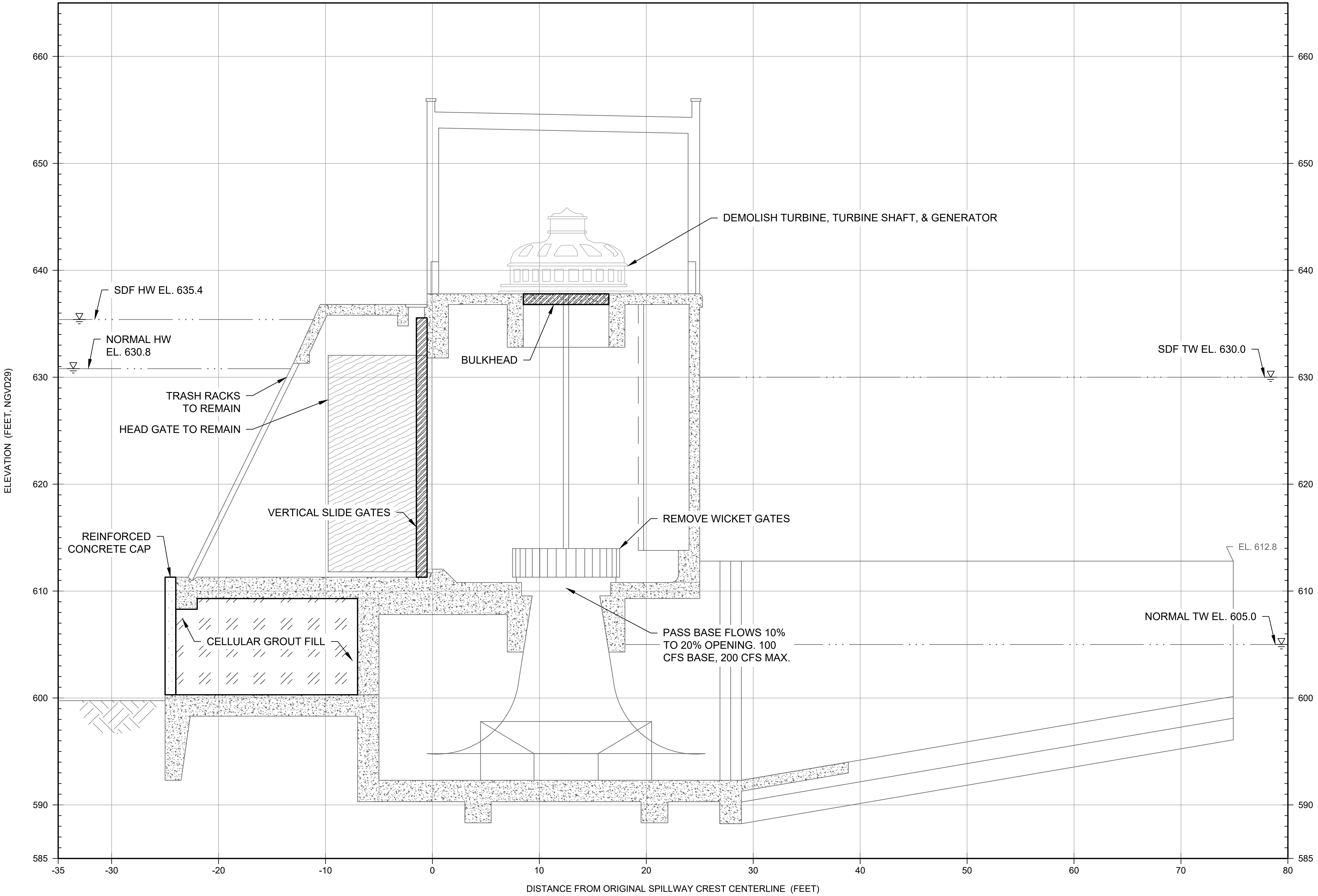

G
C-07
SECTION
POWERHOUSE

SCALE, FT

HATCH LEGEND

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

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

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GEI Project 2002879

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Midland County, Michigan

POWERHOUSE - LOW LEVEL OUTLET - MODIFICATIONS SECTION

DWG. NO. C-11
SHEET NO. 13

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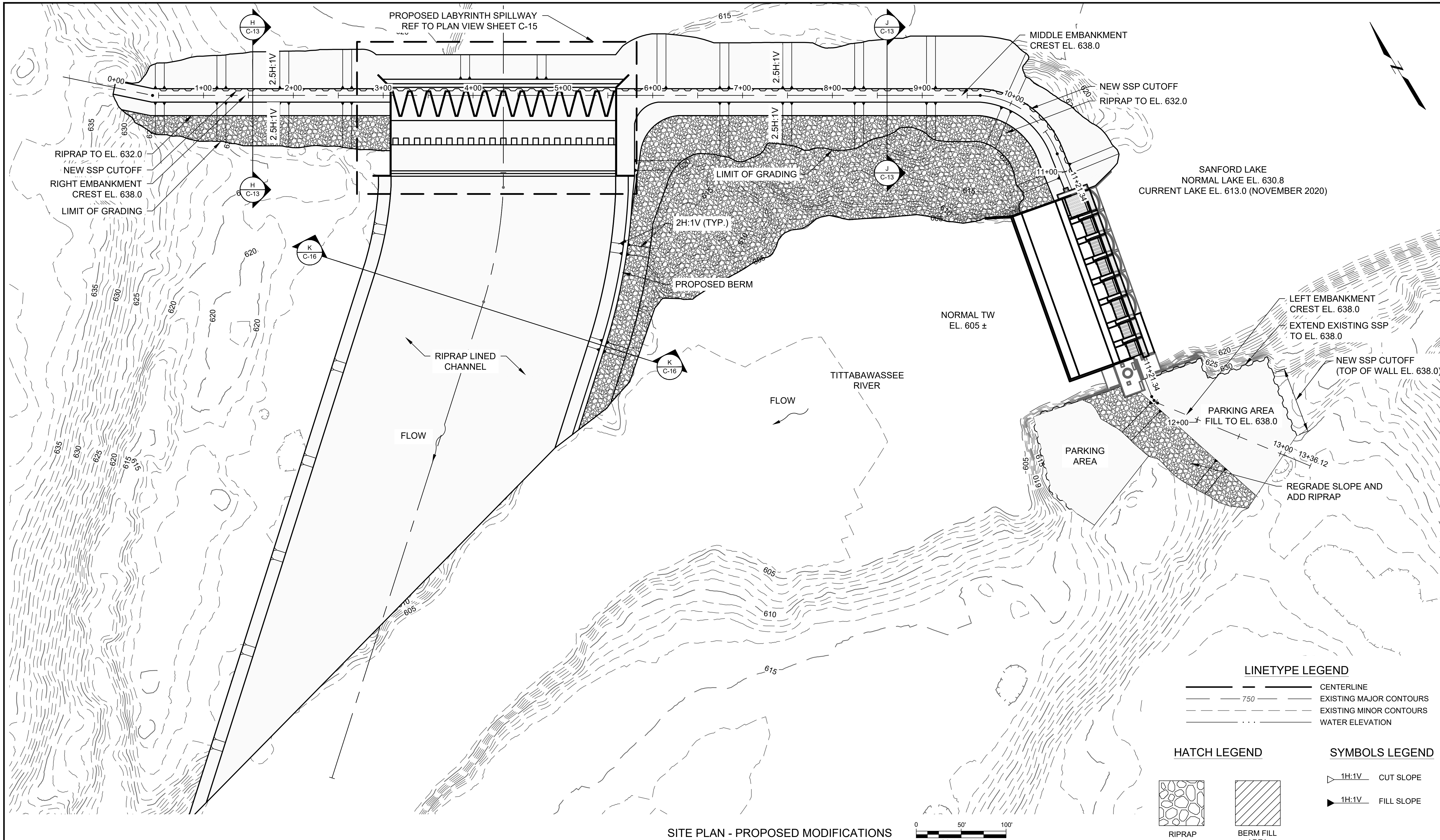

SITE PLAN - PROPOSED MODIFICATIONS

NO.	DATE	ISSUE/REVISION	APP
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SITE PLAN -
PROPOSED MODIFICATIONS

DWG. NO. C-12

SHEET NO. 14

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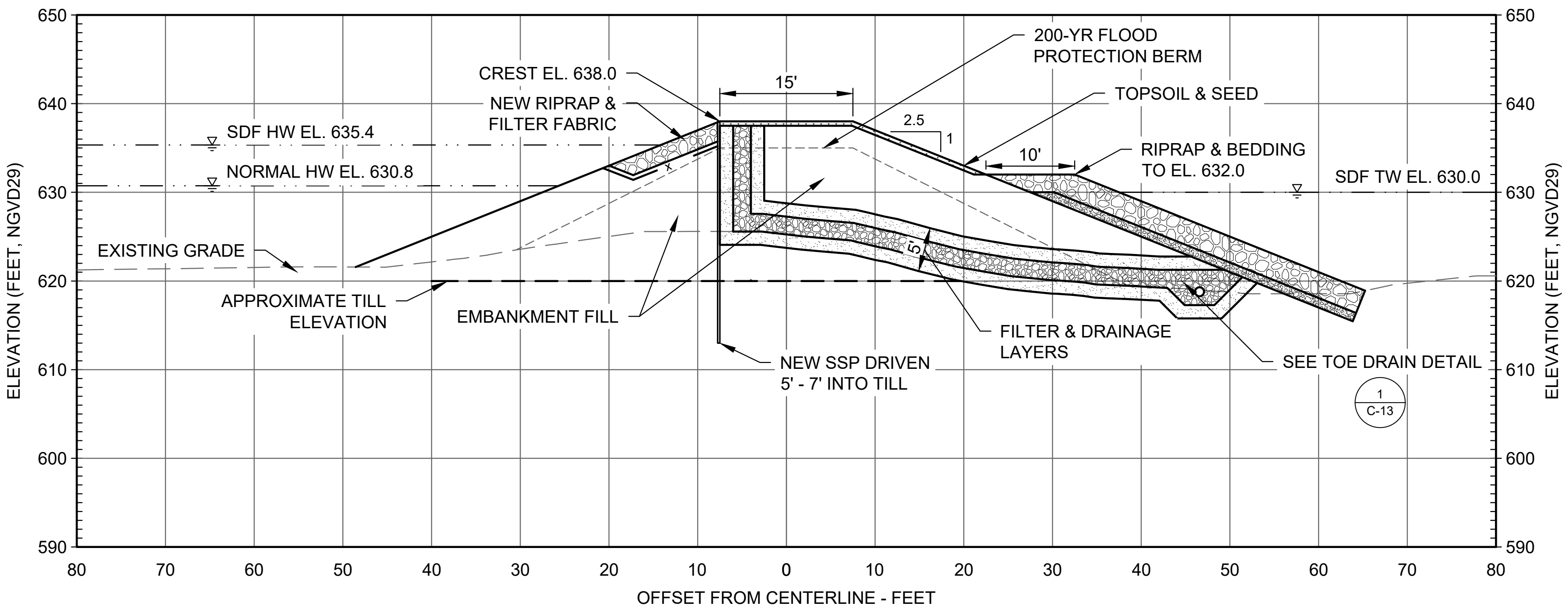
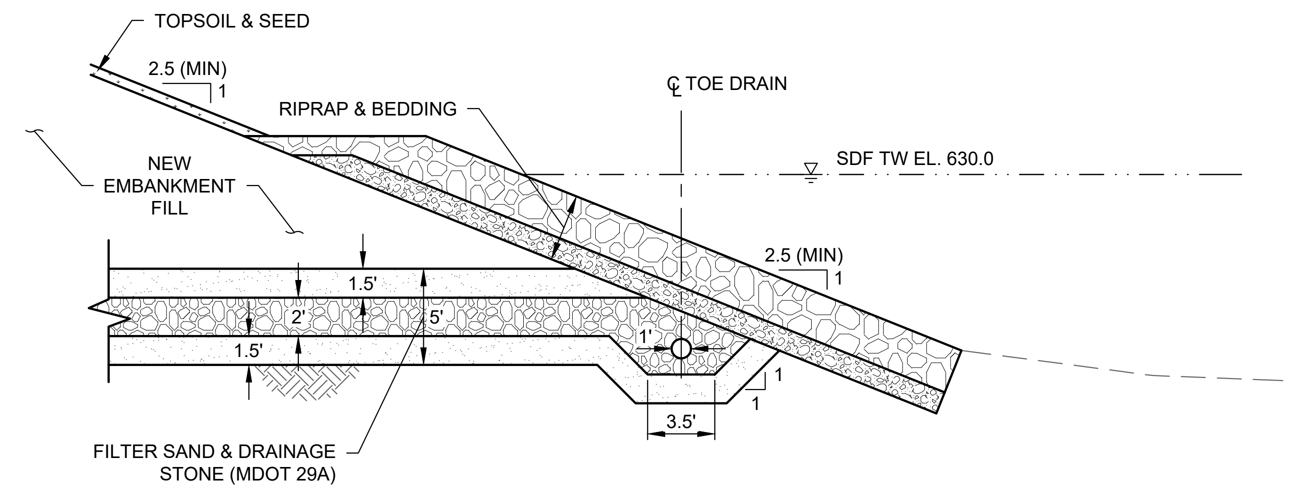


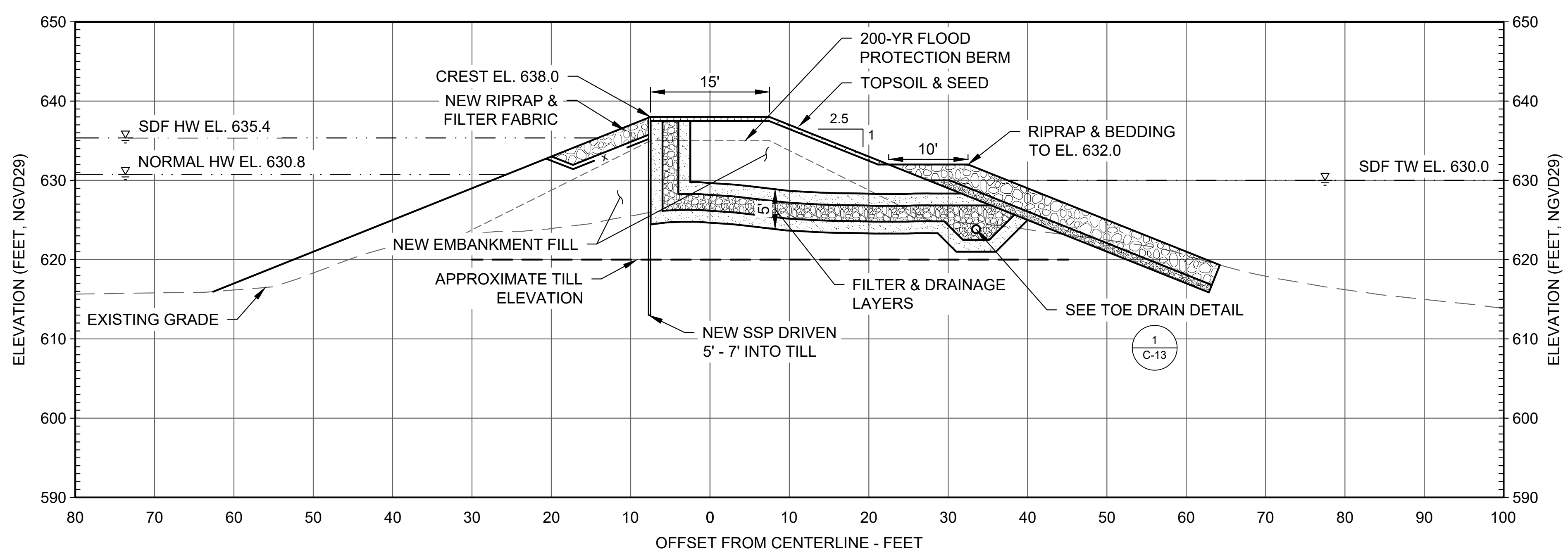
H
C-12
SECTION
RIGHT EMBANKMENT

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



1
C-13
DETAIL
TOE DRAIN

SCALE, FEET 0 5 10



J
C-12
SECTION
MIDDLE EMBANKMENT

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

NO.	DATE	ISSUE/REVISION	APP
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Attention: 0 1" If this scale bar does not measure 1" then drawing is not original scale.

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

Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

Sanford Dam Conceptual Design
Midland County, Michigan

EMBANKMENTS - MODIFICATIONS
SECTIONS

DWG. NO. C-13

SHEET NO. 15

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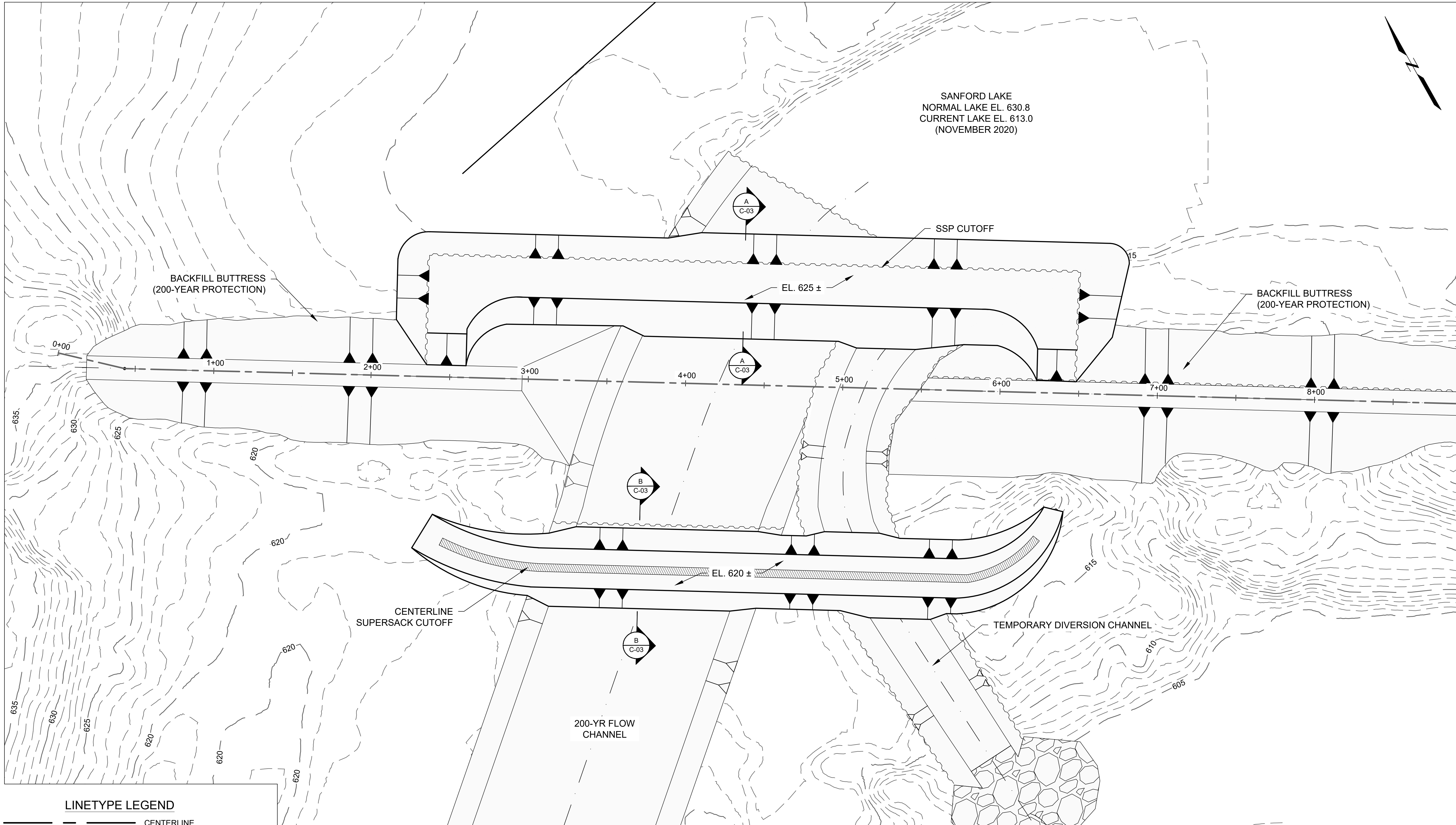

LINETYPE LEGEND

CENTERLINE
750 EXISTING MAJOR CONTOURS
EXISTING MINOR CONTOURS

SITE PLAN

0 30 60
SCALE, FEET

SYMBOLS LEGEND

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

Attention:
0 1"
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Midland County, Michigan

PHASE 2 LABYRINTH SPILLWAY
TEMPORARY COFFERDAM PLAN

DWG. NO.
C-14

SHEET NO.
16

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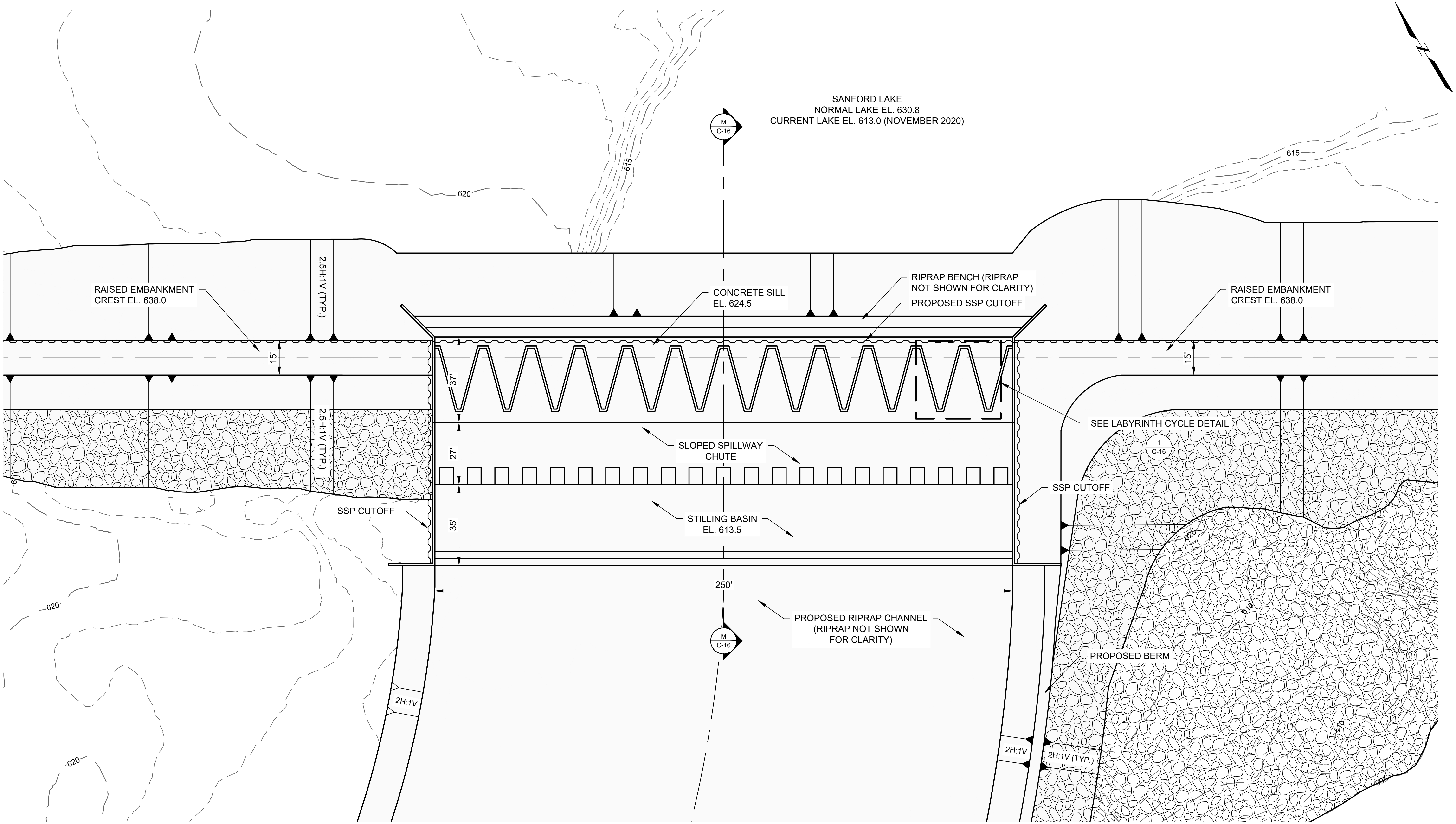

PLAN VIEW

PROPOSED LABYRINTH SPILLWAY

0 20 40

SCALE: 1" = 20'

Attention:

0 1"

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

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0	xx/xx/xxxx	CONCEPTUAL DESIGN SUBMITTAL	--

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FERC Project No. 2785

GEI Project 2002879

Sanford Dam Conceptual Design
Midland County, Michigan

LABYRINTH SPILLWAY -
PROPOSED PLAN VIEW

DWG. NO.
C-15

SHEET NO.
17

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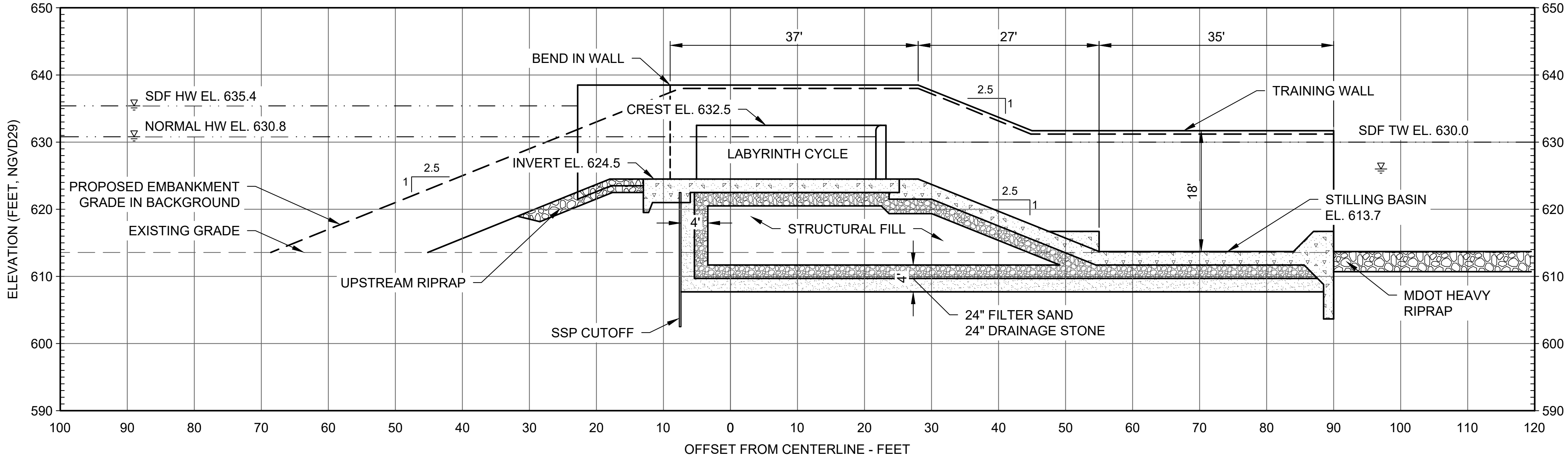
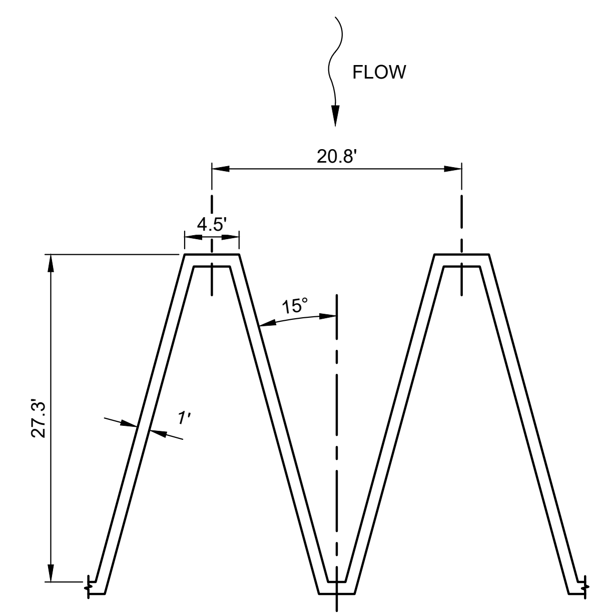
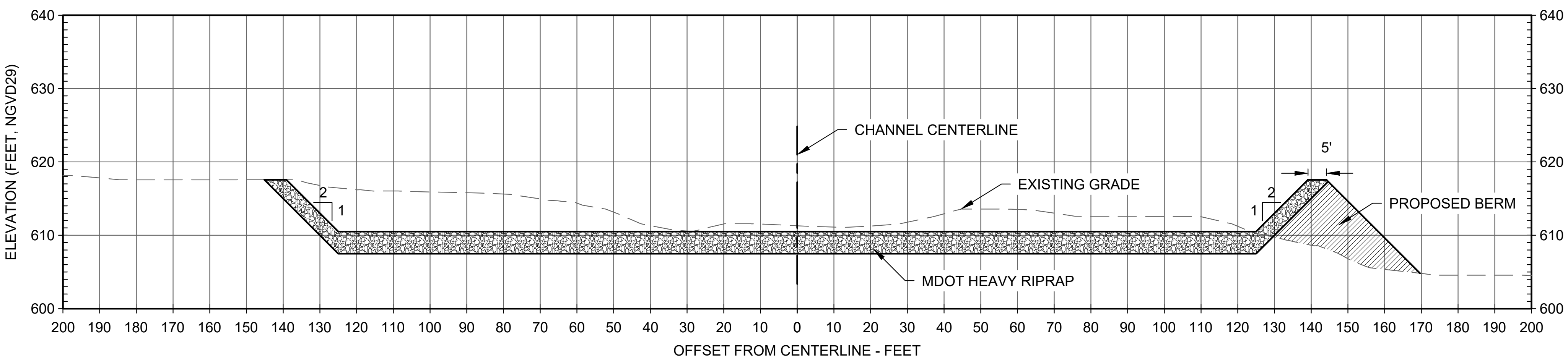


M
C-15
SECTION
PROPOSED SPILLWAY

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





K
C-12
SECTION
PROPOSED SPILLWAY CHANNEL

HORIZONTAL SCALE, FEET
0 20 40
VERTICAL SCALE, FEET
0 10 20
NOTE: 2x VERTICAL EXAGGERATION

1
C-15
DETAIL
LABYRINTH WEIR CYCLE

0 8 16
SCALE, FEET

Attention:
0 1"
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NO.	DATE	ISSUE/REVISION	APP
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Four Lakes Task Force
FERC Project No. 2785

GEI Project 2002879

Sanford Dam Conceptual Design
Midland County, Michigan

LABYRINTH SPILLWAY - PROPOSED SPILLWAY & CHANNEL CROSS SECTIONS

DWG. NO.
C-16

SHEET NO.
18

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Appendix E

Opinions of Probable Construction Costs (OPCC) Worksheets

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

Project No.: 2002879
Date: 2/23/2021
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	$ 1,801,000	$ 1,801,000	5% of Other Costs
0.02	Bonds and Insurance	1	LS	$ 721,000	$ 721,000	2% of Other Costs
0.03	Construction Permits	1	LS	$ 10,000	$ 10,000	
				Subtotal	**$ 2,532,000**	
1.00	**Site Preparation**					
1.01	Erosion and Sediment Control	1	LS	$ 20,000	$ 20,000	
1.02	Temporary Access Roads, Facilities and Laydown Areas	1	LS	$ 200,000	$ 200,000	
1.03	Phase 1 Cofferdams - Outlet Works - Rockfill	28,554	CY	$ 70	$ 1,998,768	
1.04	Phase 1 Cofferdams - Outlet Works - Steel Sheet Pile Cutoffs	12,300	SF	$ 65	$ 799,500	
1.05	Phase 1 Cofferdams - Outlet Works - Supersack Cutoff	2,800	SF	$ 10	$ 28,000	
1.06	Phase 2 Cofferdams - Labyrinth Spillway - Rockfill	48,941	CY	$ 70	$ 3,425,873	
1.07	Phase 2 Cofferdams - Labyrinth Spillway - Steel Sheetpile Cutoffs	16,500	SF	$ 65	$ 1,072,500	
1.08	Phase 2 Cofferdams - Labyrinth Spillway - Supersack Cutoff	8,500	SF	$ 10	$ 85,000	
1.09	Construction Dewatering	1	LS	$ 200,000	$ 200,000	
				Subtotal	**$ 7,829,641**	
2.00	**Site Demolition (Spillway & Powerhouse)**					
2.01	Powerhouse Superstructure Demolition	1	LS	$ 1,000,000	$ 1,000,000	
2.02	Gated Spillway Demolition and Disposal	1	LS	$ 300,000	$ 300,000	
2.03	Powerhouse Concrete Demolition	711	CY	$ 100	$ 71,136	
2.04	Mass Concrete Fill within Sluiceway	243	CY	$ 700	$ 170,294	
2.05	Reinforced Concrete Cap	18	CY	$ 700	$ 12,406	
2.06	Gated Spillway Concrete Demolition	691	CY	$ 100	$ 69,139	
2.07	Mechanical and Electrical Equipment Demolition and Disposal	1	LS	$ 2,250,000	$ 2,250,000	
				Subtotal	**$ 3,872,975**	
3.00	**Left Embankment Repair**					
3.01	Sheet Pile Cutoffs	1,875	SF	$ 65	$ 121,875	Assumes SSP length of 25 ft
3.02	Embankment Fill	2,178	CY	$ 30	$ 65,333	
3.03	Riprap Protection	1,245	CY	$ 125	$ 155,648	
3.04	Geotextile	9,225	SF	$ 2	$ 18,450	
3.05	Crest/Parking Area Gravel	467	CY	$ 35	$ 16,333	
				Subtotal	**$ 377,640**	
4.00	**Middle Embankment Repair and Stabilization (L = 570 feet)**					
4.01	Concrete Cutoff Extension	127	CY	$ 700	$ 88,667	Assumes 3 ft concrete cutoff wall added to top of existing SSP cutoff
4.02	Excavation	4,080	CY	$ 20	$ 81,606	
4.03	Embankment Fill	14,387	CY	$ 30	$ 431,599	
4.04	Filter Sand	4,382	CY	$ 40	$ 175,269	
4.05	Drainage Stone	3,122	CY	$ 40	$ 124,878	
4.06	Toe Drain	570	LF	$ 25	$ 14,250	
4.07	Upstream Riprap Protection	487	CY	$ 125	$ 60,890	
4.08	Downstream Riprap Protection	8,309	CY	$ 125	$ 1,038,663	
4.09	Geotextile	78,996	SF	$ 2	$ 157,992	
4.10	Bedding Stone	852	CY	$ 45	$ 38,353	
4.11	Crest Gravel	158	CY	$ 35	$ 5,542	
4.12	Topsoil, Seed and Temporary Erosion Protection	623	CY	$ 45	$ 28,047	
				Subtotal	**$ 2,245,754**	
5.00	**Right Embankment Repair and Stabilization (L = 310 feet)**					
5.01	Concrete Cutoff Extension	69	CY	$ 700	$ 48,222	Assumes 3 ft concrete cutoff wall added to top of existing SSP cutoff
5.02	Excavation	1,390	CY	$ 20	$ 27,797	
5.03	Embankment Fill	5,984	CY	$ 30	$ 179,531	
5.04	Filter Sand	2,134	CY	$ 40	$ 85,364	
5.05	Drainage Stone	1,537	CY	$ 40	$ 61,480	
5.06	Toe Drain	310	LF	$ 25	$ 7,750	
5.07	Upstream Riprap Protection	245	CY	$ 125	$ 30,662	
5.08	Downstream Riprap Protection	1,133	CY	$ 125	$ 141,631	
5.09	Geotextile	13,818	SF	$ 2	$ 27,635	
5.10	Bedding Stone	389	CY	$ 45	$ 17,504	
5.11	Crest Gravel	86	CY	$ 35	$ 3,014	
5.12	Topsoil, Seed and Temporary Erosion Protection	224	CY	$ 45	$ 10,079	
				Subtotal	**$ 640,669**	
6.00	**New 8-Bay Gated Spillway and Outlet Works**					
6.01	Mass Concrete	3,769	CY	$ 700	$ 2,638,144	
6.02	Reinforced Concrete Downstream Apron	569	CY	$ 700	$ 398,222	
6.03	Reinforced Concrete End Sill	586	CY	$ 700	$ 410,304	
6.04	Reinforced Concrete Structure Piers	615	CY	$ 900	$ 553,107	
6.05	Crest Gates (Shallow) Installed with Hoists and Controls	8	LS	$ 750,000	$ 6,000,000	
6.06	Steel Frame Operators Deck	1	LS	$ 3,001,000	$ 3,001,000	
6.07	Reinforced Concrete - Left and Right Training Wall Extensions	338	CY	$ 900	$ 303,983	
				Subtotal	**$ 13,304,760**	
7.01	**Powerhouse Rehabilitation**					
7.02	Misc surface concrete and masonry repairs	1	EA	$ 750,000	$ 750,000	
7.03	Convert water passages to low level outlet	1	EA	$ 1,000,000	$ 1,000,000	
7.04	Head Gate and Hoist	1	EA	$ 500,000	$ 500,000	
				Subtotal	**$ 2,250,000**	
8.01	**New 250' Labyrinth Spillway**					
8.02	Excavation	10,348	CY	$ 20	$ 206,963	
8.03	Reinforced Concrete Labyrinth Weir	222	CY	$ 900	$ 199,872	
8.04	Reinforced Concrete Sill Slab	819	CY	$ 700	$ 573,611	
8.05	Reinforced Concrete Chute Slab	643	CY	$ 700	$ 449,880	
8.06	Reinforced Concrete Stilling Basin Floor Slab	1,083	CY	$ 700	$ 758,074	
8.07	Reinforced Concrete Energy Dissipators	53	CY	$ 700	$ 36,750	
8.08	Reinforced Concrete End Sill	387	CY	$ 700	$ 270,731	
8.09	Reinforced Concrete Spilllway and Stilling Basin Walls	165	CY	$ 900	$ 148,400	
8.10	Steel Sheet Pile Cutoffs	5,865	SF	$ 65	$ 381,225	Assumes 12 ft SSP cutoff extension added to top of existing SSP cutoff
8.11	Upstream Riprap	414	CY	$ 125	$ 51,810	
8.12	Geotextile	6,200	SF	$ 2	$ 12,400	
8.13	Bedding	92	CY	$ 45	$ 4,133	
8.14	Filter Sand	1,991	CY	$ 40	$ 79,630	
8.15	Drainage Stone	2,972	CY	$ 40	$ 118,889	
8.16	Structural Fill	3,324	CY	$ 35	$ 116,343	
8.17	Drain Pipe (Solid and Slotted)	270	LF	$ 25	$ 6,750	
				Subtotal	**$ 3,415,461**	
9.01	**New Discharge Channel for Labyrinth Spillway (L = 520 feet)**					
9.02	Excavation	26,963	CY	$ 20	$ 539,259	Assumes 200-year flow channel already excavated and lined with riprap
9.03	Downstream Heavy Riprap (Riprap Lined Channel)	8,089	CY	$ 125	$ 1,011,111	
9.04	Geotextile	85,800	SF	$ 2	$ 171,600	
9.05	Left Berm	2,333	CY	$ 30	$ 70,000	
9.06	Channel Exit - Heavy Riprap	1,085	CY	$ 125	$ 135,622	
9.07	Channel Exit - Bedding Stone	271	CY	$ 45	$ 12,206	
				Subtotal	**$ 1,939,799**	
10.01	**Site Restoration**					
10.02	Place Overburden, Seed, Fertilize, and Mulch Slopes	1	LS	$ 100,000	$ 100,000	
10.03	Dam Safety Monitoring Instrumentation	1	LS	$ 50,000	$ 50,000	
				Subtotal	**$ 150,000**	
	Subtotal				$ 38,558,698	
	Contingency			25%	$ 9,640,000	
	Construction Subtotal				**$ 48,198,698**	
	Engineering Investigations, Design and Construction Engineering	-	-		**$ 3,000,000**	
	Total Estimated Cost				**$ 51,198,698**	
				say	**$ 51,199,000**	

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.