Edenville Dam Emergency Inspection Report

June 19, 2020

Prepared For:

Boyce Hydro, LLC
6000 South M-30 (P.O. Box 15)
Edenville, MI 48620

Prepared By:

TRC Engineers Michigan Inc.
1382 West Ninth Street, Suite 400
Cleveland, Ohio 44113

Dam Name: Edenville Dam

EGLE Dam Inventory No.: 549

Location: Tittabawassee/Tobacco Rivers

County: Midland and Gladwin Counties

State: Michigan

Owner/Operator: Boyce Hydro, LLC

Hazard Potential Classification: High

Name of Inspectors: Shawn McGee, P.E. & Chris Hay, P.E.

Date of Inspection: June 10, 2020

(Photo courtesy of EGLE)

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June 19, 2020

Mr. Lee W. Mueller
Boyce Hydro, LLC
6000 South M-30 (P.O. Box 15)
Edenville, MI 48620

Re: Dam Emergency Inspection Report
Edenville Dam
Edenville, Midland and Gladwin Counties, MI
TRC Project No.: 398511

Dear Mr. Mueller:

TRC Engineers Michigan Inc. (TRC) is pleased to present this Dam Emergency Inspection Report that summarizes our visual observations of the Edenville Dam performed on June 10, 2020. Due to massive inflow from heavy rains and flooding in the area, the earthen embankment of the Edenville Dam breached on May 19, 2020. The Michigan Department of Environment, Great Lakes, and Energy (EGLE) requested that Boyce Hydro, LLC engage a professional engineer to inspect the remaining sections of the Edenville Dam embankment to determine if immediate action should be taken to mitigate risk to public safety, natural resources, and public transportation (specifically highway M-30).

The work was performed in accordance with TRC's proposal dated June 8, 2020 and the subsequent authorization to proceed.

We trust that this Report contains the information you require. We thank you for the opportunity to assist you on this phase project and look forward to working with you in the future. If you have any questions regarding the contents of this report, please do not hesitate to contact Shawn McGee at (216) 307-3646.

Sincerely,

TRC Engineers Michigan Inc.

Shawn D. McGee, P.E.
Geotechnical Engineering Practice Leader

Chris M. Hay, P.E.
Structural Engineer

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ACRONYM LIST

ASCE	American Society of Civil Engineers
EGLE	Michigan Department of Environment, Great Lakes, and Energy
FERC	Federal Energy Regulatory Commission
MDOT	Michigan Department of Transportation

Executive Summary

This Dam Emergency Inspection Report (Report) summarizes the visual observations made during a dam safety inspection completed at the Edenville Dam by TRC Engineers Michigan Inc. (TRC) on June 10, 2020. The Edenville Dam is owned and operated by Boyce Hydro, LLC (Boyce Hydro). Due to massive inflow from heavy rains and flooding in the area, a portion of the earthen embankment of the Edenville Dam breached on May 19, 2020. The Michigan Department of Environment, Great Lakes, and Energy (EGLE) requested in an Emergency Inspection Order (letter dated May 22, 2020) and in a Temporary Restraining Order (filed in the US District Court on June 15, 2020) that Boyce Hydro, LLC engage a professional engineer to inspect the remaining sections of the Edenville Dam embankment to determine if immediate action should be taken to mitigate risk to public safety, natural resources, and public transportation (specifically highway M-30).

The dam emergency inspection was performed by TRC on June 10, 2020. In general, the remaining portions of the Edenville Dam embankment were in fair to satisfactory condition and do not pose a high risk to public safety, natural resources, and public transportation under the conditions at the time the inspection was performed provided that the recommendations outlined herein are implemented. It is critical that the debris and sediment currently impeding flow through the M-30 bridge and the failed portion of the dam embankment be removed and a new drainage/river channel be developed to properly pass the drainage from the Tobacco and Tittabawassee Rivers downstream beyond the dam area without obstruction, and that a sheet pile wall be installed to prevent further erosion and damage to the Left Embankment – Tobacco. Based on our visual field observations and information provided thus far by Boyce Hydro, we present several recommendations and considerations.

The following are considered ***Critical Action*** items that have potential high risk to dam stability and public safety and should be addressed immediately.

C-1 Remove the debris and establish a new drainage/river channel within the Left Embankment - Tittabawassee section to properly control and pass drainage through this area. An extensive hydraulic model will need to be developed for the drainage basin so that a new river section, flow capacity, and alignment can be determined.

C-2 Remove debris from the Tittabawassee Spillway that could potentially move downstream.

C-3 Shore the left side of the Tittabawassee Spillway against further loss of soil to prevent total collapse of spillway.

C-4 Until the Left Embankment – Tobacco can be repaired to satisfactory condition, as an interim measure it is recommended that a temporary sheet pile wall be installed from the existing fishing pier located approximately 275 feet east of M-30 to protect the embankment from further erosion by moving the floodway away from the dam by reestablishing the original path of the stream. Continue to monitor the rate of erosion of the embankment.

C-5 Until a slope stability analysis can be performed and repairs made to the Tobacco Spillway and adjacent slopes to satisfactory conditions, it is recommended that survey monitoring hubs be installed along the downslope (at the crest, toe, and midslope) portion of Right Embankment – Tittabawassee to monitor the slope for additional movement. If

the slope experiences significant displacement and further analyses indicate global instability, the dam may need to be breached to the right of the spillway area so that the loading on the spillway and embankment is reduced by lowering the reservoir water level and passing the flow to the original Tobacco River alignment.

C-6 The tension cracks that have developed to the right of the Tobacco Spillway should be backfilled with soil or bentonite to “seal the voids” to prevent water from entering the cracks and potentially weakening the embankment.

The following are considered ***Recommended Action*** items that have medium risk to dam stability and public safety and should be addressed as soon as feasible.

R-1 Remove loose soil and regrade the edges of the remaining sections of the Left Embankment – Tittabawassee to maximum 3H:1V slopes. Establish vegetation along the disturbed portions of the embankment.

R-2 Shore and stabilize the access to the Powerhouse and perform an interior inspection.

R-3 Backfill and repair the erosion washout immediately to the right of the retaining (side) walls on the upstream slope of the Tittabawassee Spillway to prevent progressive failure of the slope that could potentially impact the upper portion of the structure.

R-4 Continue to perform inspections of the dam embankment on a weekly basis to determine if conditions as described above worsen.

R-5 As the Tobacco Spillway is already under construction, there is nothing structurally that appears to be an immediate threat to public safety, however the retaining (side) wall should be repaired as soon as possible to better contain the earthen embankment.

R-6 Continue to monitor the gauges previously installed along the tension crack observed to the right of the Tobacco Spillway to determine if the tension cracks are widening.

The Report also provides Non-critical Action/Maintenance items that have low risk to dam stability and public safety, and should be addressed as part of routine maintenance.

This Report and the evaluations, conclusions, recommendations and opinions contained herein are subject to the limitations set forth in Section 5, Limitations.

1.0 Project Background

1.1 Purpose of Emergency Inspection

The Edenville Dam was an earthen embankment dam built in the 1920s at the confluence of the Tittabawassee and Tobacco Rivers for hydroelectric power and flood control. The Edenville Dam is owned by Boyce Hydro, LLC. Due to massive inflow from heavy rains and flooding in the area, the earthen embankment of the Edenville Dam breached on May 19, 2020. Consequently, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) requested in an Emergency Inspection Order (letter dated May 22, 2020) and in a Temporary Restraining Order (filed in the US District Court on June 15, 2020) that Boyce Hydro, LLC engage a professional engineer to inspect the remaining sections of the Edenville Dam embankment to determine if immediate action should be taken to mitigate risk to public safety, natural resources, and public transportation (specifically highway M-30).

This Report summarizes the visual observations made during a dam safety inspection completed at the Edenville Dam by TRC on June 10, 2020 and provides recommended measures for mitigating deficiencies that pose an immediate risk to the safety of the remaining dam structure based on current conditions. More specifically, the inspection performed by TRC and this Report were performed to address EGLE's concerns and fulfill their requirements as follows:

1. *EGLE's concerns presented in the **May 22, 2020 Emergency Inspection Order** of the Tobacco River portion of the dam.* Because this section of embankment continues to impound water, EGLE is concerned with global instability of the downslope area to the immediate right and left of the Tobacco Spillway that experienced erosion damage as a result of the May 19th dam breach and where tension cracks have developed.
2. *EGLE's requirement in **Item 1a of the June 15, 2020 Temporary Restraining Order.*** This Order requires that Boyce Hydro engage an engineer to perform an inspection and immediately determine whether the risk posed by the Tobacco River side of the Edenville dam is substantial enough that immediate action should be taken to mitigate the risk to public safety, natural resources, and public transportation (specifically M-30) and what that action should be. This inspection report is to be submitted to EGLE by June 19, 2020.

It should be noted that this Report does not address 1b of the June 15, 2020 Temporary Restraining Order in which a comprehensive report shall be prepared that "(a) evaluates the safety and stability of the remaining portions of the Edenville Dam; (b) identifies any deficiencies that may pose a risk to the remaining dam structure, natural resources, and/or public transportation; (c) recommends necessary measures to mitigate any identified deficiencies; and (d) establishes a timeframe to complete all measures necessary to mitigate the deficiencies". Additional analyses and information will need to be presented in a more comprehensive report and provided to EGLE under a separate cover by July 24, 2020.

1.2 Dam Description

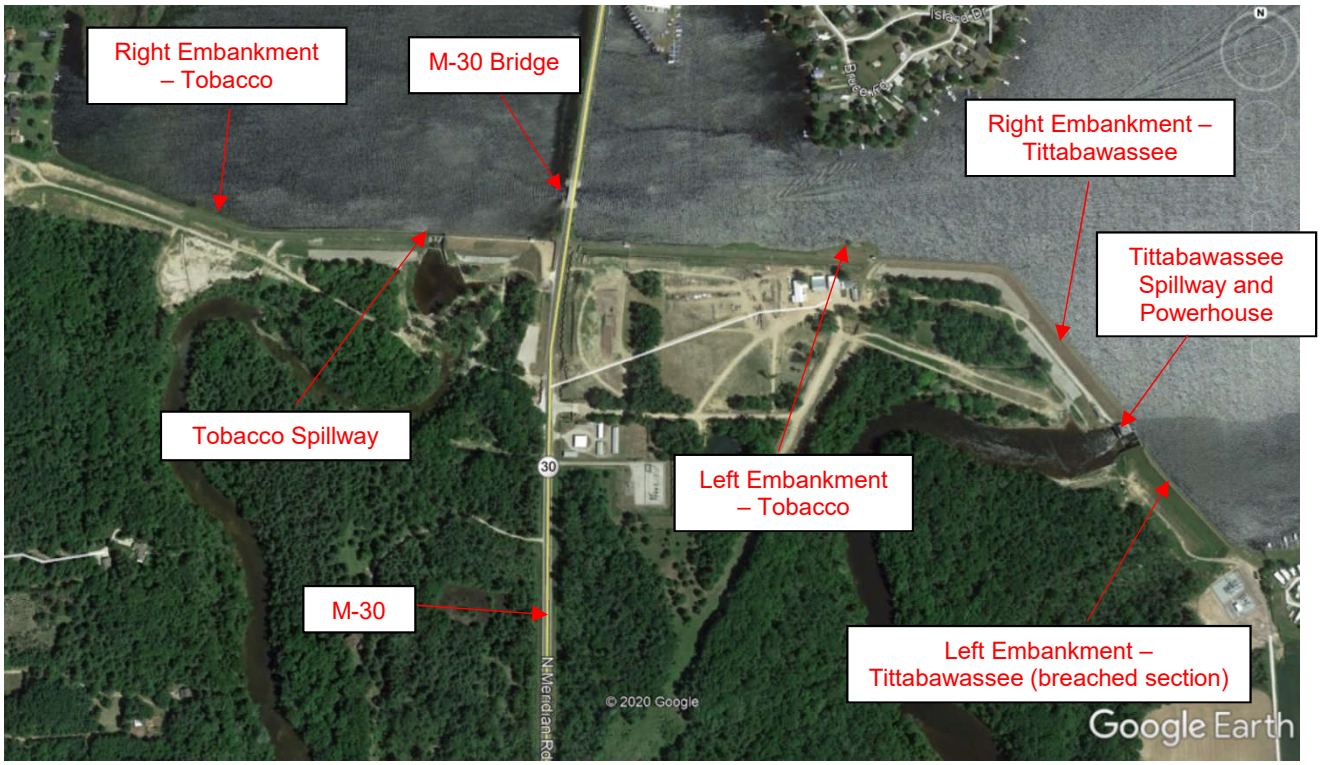
The Edenville Dam was an earthen embankment dam built in 1924 at the confluence of the Tittabawassee and Tobacco Rivers that form Wixom Lake for hydroelectric power and flood control. The dam is located approximately one mile north of the City of Edenville in Tobacco Township, Gladwin County and Edenville Township, Midland County. Its height was 54 feet (16 m), the length was 6,600 feet (2,000 m) at its crest.

The dam is mostly an earthen embankment and two concrete spillways and a hydroelectric power plant. For the purpose of describing the different sections of the dam in this Report, the dam consists from east to west (left to right; when looking downstream):

- ***Left Embankment – Tittabawassee***: a former 850-foot-long earthen embankment on the Tittabawassee River side of Wixom Lake. A majority of this section of embankment is what breached and failed on May 19th.
- ***Tittabawassee Spillway and Powerhouse:*** a 118-foot-long multiple arch spillway with three flood control gates and an integral brick and concrete powerhouse.
- ***Right Embankment – Tittabawassee***: a 3,180-foot-long central earthen embankment.
- ***Left Embankment – Tobacco***: a 520-foot-long earthen embankment
- ***Tobacco Spillway***: a 72-foot-long multiple arch spillway with three gates
- ***Right Embankment – Tobacco***: a 2,040-foot-long earthen embankment. The M-30 road, which failed on May 19, 2020, separates the right and left Tobacco River embankments.

Figure 1 below provides an illustration of the different dam components as listed above.

Figure 1: Site Location Sketch



1.3 Current Regulatory Status

The Edenville Dam is currently regulated under Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), which is administered by EGLE's Water Resources Division. EGLE assumed regulatory authority for the dam in late 2018 after its license to generate hydropower was revoked by the FERC.

2.0 Field Inspection

Inspection by TRC engineers was completed in a systematic approach to ensure that visible features were observed and documented. The inspections started at the top of the dam and proceeded downward. Our field team walked across the dam crest and observed both upstream and downstream slopes while inspecting the crest surface for cracks, rills, settlement/low-lying areas, animal burrows, etc. We also walked across the upstream and downstream slopes in a parallel or zigzag pattern along the embankment to look for the presence of seeps, bulges, erosion areas, bare spots, erosion damage, sloughs, etc. Special attention was given to the downstream slope below the impoundment water level. The concrete surfaces of the spillway(s) and powerhouse were also visually examined for spalling and deterioration due to weathering, unusual or extreme stresses, erosion, cavitation, and other destructive forces. Structural problems are typically indicated by cracking, exposure of reinforcing bars, large areas of broken-out concrete, misalignment at joints, undermining and settlement in the structure.

TRC's site inspection was limited to visual observations and features at the ground surface free of obstruction at the time of the inspection (e.g., the portions of the upstream embankment and spillways underwater at the time of the inspection could not be completed) and was performed to the best of our ability based on the given regulatory schedule. Our authorized scope of work did not include a comprehensive engineering evaluation, including slope stability and seepage analyses or spillway capacity calculations, of the stability or safety of the structures. In addition, intrusive studies (e.g., borings, test pits, concrete cores, etc.), geophysical surveys, underwater inspections, surveying, and/or collection of soil/water samples, were not part of TRC's authorized scope of work. These items not included in our scope of work will be required to further evaluation and design measures to mitigate any identified deficiencies.

Table 1 below contains standard terms that were used in this Report to describe the condition of the project features. These terms are based on the opinion of the inspector at the time of the inspection to describe the physical condition of the component based on visual observations, and are not intended to provide an overall assessment of safety based on engineering analyses and studies.

Table 1: Standard Terms for Conditions of Dam Features

Condition	Description
Satisfactory	Expected to fulfill intended function.
Fair	Expected to fulfill intended function, but maintenance is recommended.
Poor	May not fulfill intended function; maintenance or repairs are necessary.
Unsatisfactory	Is not expected to fulfill intended function; repair, replacement, or modification is necessary.

3.0 Observations from June 10, 2020 Site Inspection

TRC completed the Edenville Dam Emergency Inspection on June 10, 2020. During the inspection, TRC made a visual assessment of the current conditions of the dam by walking the downstream and upstream sides and the crest of the embankment to observe the structural integrity of the earthen embankment (e.g., if tension cracks, sloughing, differential settlement, etc. was present), presence of seeps, animal burrows, condition of vegetation, erosion protection, etc. A visual assessment of the spillways and powerhouse were also performed. Focus was given to the Tobacco River portion of the embankment as it is understood that EGLE has specific concerns with this section.

Weather conditions during the June 10, 2020 site visit was mostly to partly cloudy with temperatures in the 80s ºF with less than ¼" of precipitation reported (by Weather Underground) in the 72 hours prior to the site visit.

Present during the site inspection was Shawn McGee (geotechnical and dam engineer from TRC), Chris Hay (structural engineer from TRC), Greg Uhl (Chief Operator of Boyce Hydro) and Dan DeVaun (dam engineer from EGLE Dam Safety Unit). Dr. Daniel Pradel, Alan Esser, and Adam Lobbestael, representatives from the Embankments, Dams, and Slopes Technical Committee of the Geo-Institute of the American Society of Civil Engineers (ASCE), were also in attendance and walked the entire length of dam with TRC. ASCE funded a team to collect data of the Edenville Dam failure – their observations and findings will be available for its members and used to obtain a better understanding of dam failures. It is our understanding that ASCE is not contracted to collect data for EGLE, private home owners, other engineering consultants, or anyone else outside of ASCE.

The following sections briefly describes the physical condition of the principal features of the inspected portions of the dam and appurtenant structures as they were observed at the time of the field inspection. Photo documentation was also gathered during the site reconnaissance – select pictures are presented below. The following sections also include photo imagery taken from a drone as provided by EGLE to supplement the site photographs taken by TRC to better illustrate the current dam conditions.

TRC notes that the water levels within the impoundment at the time of inspection were significantly lower as compared to normal conditions due to the previous failure of the dam.

3.1 Left Embankment - Tittabawassee

This portion of the embankment was 860 feet long and approximately 55 feet high at the deepest section. A majority of this section of embankment no longer exists as this was the section of dam that was breached on May 19, 2020, see Photo 1. An approximate 50-75 foot long section of embankment currently exists on both the right and left ends of this section. In our opinion, these sections of embankment are unsatisfactory as the structural integrity of these sections of embankment has been compromised and should be replaced when/if the embankment is reconstructed. The eroded edges of the embankment are currently steep and should be sloped to more stable 3H:1V slopes for safety and vegetated to minimize further erosion, see Photo 2.

Flow from the Tittabawassee and Tobacco Rivers are currently cutting in a new channel within the failed section of the embankment within stiff blue clay. The stiff blue clay is noted as hardpan in historic boring logs, and appears to be the foundation material for the embankment, see Photo 3. ***It is highly recommended that the debris (e.g., trees, sediment, and other objects relocated from upstream areas from the flood) be removed and a new drainage channel be installed to properly control and pass drainage through this area. An extensive hydraulic model will need to be developed for the drainage basin so that a new river section, capacity, and alignment can be determined. This modeling should be completed as soon as possible so that future storm events can properly pass through the area and prevent flooding and damage to both upstream and downstream areas.***

Photo 1: Breached section of the Left Embankment – Tittabawassee section looking left.

Photo 2: Left section of embankment that has eroded and requires stabilization.

Photo 3: Breached section of embankment where drainage is currently cutting in a new alignment (drone photo provided by EGLE).

3.2 Tittabawassee Spillway and Powerhouse

The Tittabawassee Spillway is a multi-buttressed arch dam that contains three gates. The spillway is 68.6 feet wide and 38 feet high. A schematic of the spillway and powerhouse structure is provided for Appendix A – this diagram can be used to reference the locations of the structure components described herein. In general, no visual evidence was observed at the time of TRC's inspection that would indicate a concern with regard to immediate global structural instability or major distress to the concrete spillway structure. However, due to the dam failure just east, the ends of the embankment were exposed and another large storm could possibly negatively impact the structure causing additional erosion that would affect the stability of the structure.

A visual inspection was performed on the steel gates from the deck. No signs of fatigue or distress with the gates, trunnions or connectors (bolts, rivets, etc.) were noted. The gates were not operated during the inspection. The safety railing appears to have been recently painted, while the steel supports for the winches used to raise and lower the gates exhibit signs of surface rusting and paint failure. The steel supports should be cleaned and painted to prevent further deterioration. No analysis of the gates was performed at this time.

The spillway and associated concrete structures were inspected visually from the embankments and deck. The spillway and retaining walls exhibited numerous areas of deterioration, including cracks with and without efflorescence, spalls with and without exposed reinforcing steel and delamination. At present, the deterioration does not appear to be structurally threatening. Underlying cracks, voids (both within the concrete and beneath the spillway) will require additional specialized inspection methods. Under water inspections of submerged elements is also recommended. A more detailed list of defects is presented by element below:

Deck: The deck was in poor condition with large areas of spalling and delamination, see Photo 4.

Photo 4: Typical condition of deck looking east. Note recently painted safety railings and deterioration of concrete.

Spillway: The spillway was in poor condition. A visual inspection of the spillway facing and weir was performed from the embankments and deck. The spillway facing shows extensive spalling and delamination, see Photo 5. There is some cracking, concrete deterioration, and exposed rebar at the spillway crest. The depth severity of the deterioration was not able to be determined due to access constraints. The weir shows signs of extensive deterioration along the top with large areas of exposed reinforcing steel. A large sediment deposit was present approximately centered in the spillway adjacent to the downstream side of the weir. The bottom portions of the weir were not visible from the embankments due to standing water, see Photo 6.

Photo 5: Spillway general elevation with extensive spalling, exposed reinforcing steel and likely delamination.

Photo 6: Weir exhibiting large spalls with exposed reinforcing steel and sediment deposits.

Retaining Walls: The retaining walls were generally in fair to poor condition. Near the middle of the left side (east) wall near the toe of the embankment, an isolated area with a large spall and exposed reinforcing steel was noted, see Photo 7. The downstream right side (west) exhibited large areas of cracking, efflorescence. The horizontal extension was separated from the main wall and rotated slightly towards the stream, likely due to an additional surcharge load as a result of the flooding, see Photo 8. Additionally, a portion of the right side (west) wall on the downstream end was broken off. This area also had areas of delamination and cracking with efflorescence, see Photo 9. Both retaining walls exhibited large areas of erosion of backfill at both upstream and downstream ends, see Photos 10 through 13.

Photo 7: Left (east) side retaining wall downstream general elevation including spall with exposed rebar (6'x2'x3").

Photo 8: Right side (west) downstream retaining wall showing cracks, efflorescence and leaking backfill. Note the horizontal extension is separated from the main wall at the toe of the slope and rotated towards the stream.

Photo 9: Portion of right side (west) retaining wall missing with areas of delamination, cracking with efflorescence and erosion.

Photo 10: Erosion behind right side (west) retaining wall at downstream end.

Photo 11: Erosion behind right side (west) retaining wall at upstream end.

Photo 12: Erosion behind left side (east) retaining wall at upstream end.

Photo 13: Erosion behind left side (east) retaining wall at downstream end.

Wingwall (Bulkheads) Upstream: The west wingwall was not able to be inspected due to damage to the embankment from flooding. It is likely that the steel sheet piling is exposed below the concrete cap and will need repaired. There was an approximately 8' drop to the level of the sand as can be seen in Photo 11 (above). The east wingwall is gone due to the recent failure east of the spillway. It can be seen laid over in Photo 12 (above).

Cutoff (Downstream) Walls: The cutoff walls were in poor to unsatisfactory condition. The right side (west) cutoff wall has several large spalls and holes with exposed reinforcing steel. The connection to the retaining wall is non-existent, see Photos 9 (above) and 14. The left side (east) cutoff wall is buried under debris due to the adjacent failure of the dam and erosion from overtopping, see Photo 15.

Photo 14: Right side (west) cutoff wall with large spalls/hole with exposed reinforcing steel.

Photo 15: Left side (east) cutoff buried under debris. Note failure of supporting sheet pile wall in the foreground.

Piers: The piers were in fair condition, with typical cracking and efflorescence present. Spalls without exposed reinforcing steel were present on the intake nosing. Several of the intake trash racks have been displaced by the flooding. See Photos 5 (above), 13 (above) and 16.

Photo 16: Powerhouse intake piers with spalls and displaced or missing trash racks.

Powerhouse: The powerhouse has a concrete substructure and a brick superstructure that is approximately 50.6 feet wide. The powerhouse contains two vertical-shaft generating units. The interior of the powerhouse was not inspected. The exterior concrete foundations show significant cracking adjacent to the spillway. The lower windows at the back of the powerhouse were missing, likely due to the recent flooding, see Photo 17. The access stairway at the west side of the powerhouse was severely undermined due to erosion, see Photo 10 (above). The back porch of the powerhouse had significant areas of spalling along the edge near the safety railing supports, see Photo 18.

Photo 17: Powerhouse foundation with large crack and missing windows.

Photo 18: Powerhouse back porch with significant spalling on edge of slab.

3.3 Right Embankment - Tittabawassee

The right embankment of the Tittabawassee section is 3,180 feet long and approximately 55 feet high at the deepest section. There is a small section of sheet piling that extends from the concrete spillway along the right embankment to reduce seepage along the concrete spillway. As previously discussed, it is likely that the sheet piling is exposed below the concrete cap and will need to be repaired when the dam is reconstructed. FERC has reported in previous inspection reports that the embankment is constructed of loose fill that has a tendency to erode easily and the crest of the embankment has a low spot. Any low spots along the crest were not apparent based on visual inspection alone. A survey should be performed to verify the dam crest is at the appropriate elevation.

The upstream slope of the embankment is in poor condition as it appears that a portion of the toe has been eroded along a majority of the section. Tension cracks have developed at the crest of slope and the riprap appears to have eroded, both probably a result of wave action from the May 19th storm event and the loss of toe buttress, see Photo 19. Although the upstream side of the embankment will need to be repaired and the riprap replaced, based on visual observations only, this is not believed to threaten the overall stability of the embankment for the conditions observed at the time of TRC's site inspection. Under the conditions observed at the time of TRC's inspection, the edge of water was at a safe distance away from the dam.

As part of the hydraulic modeling and reestablishing the river channel as previously discussed, ***the water should continue to be located away from the dam until the dam can be repaired to satisfactory conditions, see Photo 20***.

The toe drain system was not discharging at the time of TRC's inspection, however, some erosion has previously occurred at the drain outlets and should be repaired. Based on visual evidence at the time of TRC's inspection, the downstream slope appears to be in satisfactory condition and has established vegetation, see Photos 21 and 22.

Photo 19: Upstream slope of Right Embankment – Tittabawassee. Note tension cracks that have developed at crest.

Photo 20: Upstream slope of the Right Embankment – Tittabawassee (drone photo provided by EGLE).

Photo 21: Downstream slope of Right Embankment – Tittabawassee.

Photo 22: Downstream slope of Right Embankment – Tittabawassee (drone photo provided by EGLE).

3.4 Left Embankment – Tobacco River

The left embankment of the Tobacco River is 520 feet long and approximately 55 feet high at the deepest section. The downstream slope appears to be in fair condition and has established vegetation, see Photo 23. Some localized sloughing and soft/wet spots were present on the downstream slope, however, this can be considered “normal” for an earthen embankment. Some animal borrows were also present along the downstream slope that will need to be backfilled. Boyce Hydro should continue to monitor the downstream slope on a weekly basis and following storm events for further movement or if the wet spots worsen. The embankment has a toe drain that has some vegetation growth and an accumulation of sandy sediment in the ditch, see Photo

24. The toe drain outlets were not discharging at the time of the inspection. A nominal amount of sloughing of the ditch slopes was occurring and tension cracks were developing within localized sections of the ditch. ***The sediment should be removed and the ditch slopes repaired by removing the failed soil mass and replacing with well compacted clayey soil to the original ditch shape.***

Photo 23: Downstream slope of Left Embankment – Tobacco.

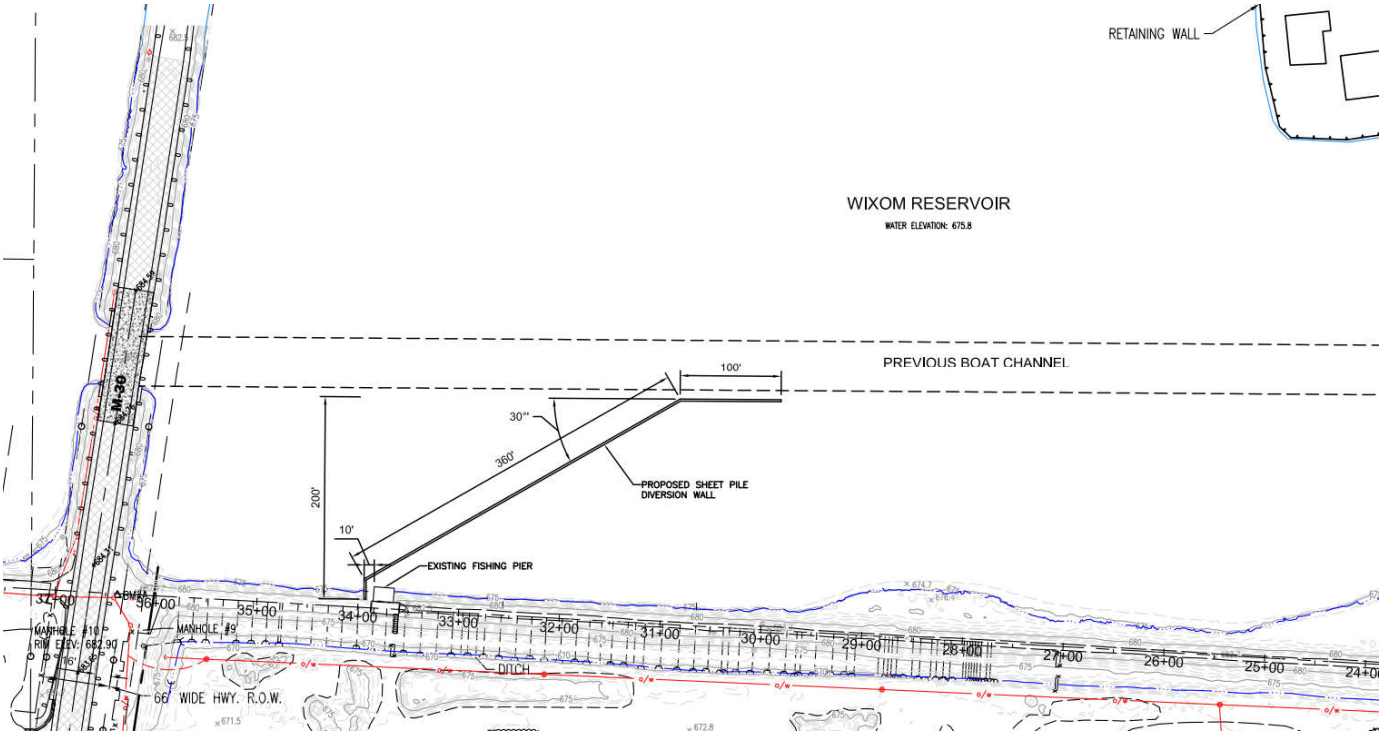
Photo 24: Toe drains of Left Embankment – Tobacco. Note accumulation of sediment in ditch.

The upstream portion of the embankment is in unsatisfactory condition as a majority of the slope has been severely eroded. As a result, tension cracks area also developing at the crest of dam over a majority of the length of section. This section of embankment is at high risk for public safety as the structural integrity of this section of embankment will worsen and can be compromised as the embankment continues to be eroded. ***Therefore, immediate action is recommended to protect the embankment from further erosion.*** Until the dam can be repaired to satisfactory condition, as an interim measure it is recommended that a temporary sheet pile wall be installed from the existing fishing pier located approximately 275 feet east of M-30 to protect the dam from further erosion by moving the edge of the floodway away from the dam by reestablishing the original path of the stream, see Figure 2. There was debris and sediment build-up within the area of the former M-30 bridge. It is understood that MDOT will be removing the debris within the channel so that the river flow is no longer obstructed.

Photo 25: Upstream slope of Left Embankment – Tobacco that has been severely eroded and requires immediate protection.

Photo 26: Upstream slope of Left Embankment – Tobacco that has been severely eroded and requires immediate protection.

Figure 2: Approximate Location of Temporary Sheet Pile Wall for protection of the Left Embankment – Tobacco



3.5 Tobacco Spillway

The Tobacco Spillway is a multi-buttressed arch dam that is 72.2 feet wide and 38 feet high and contains three gates. A schematic of the spillway structure is provided for Appendix B – this diagram can be used to reference the locations of the structure components described herein. In general, no visual evidence was observed at the time that would indicate concern with regard to immediate global structural instability or major distress to the concrete spillway structure.

As access at each end of the deck was locked, an inspection of the gates and associated steel supports was only made from the embankments. Nothing of note was visible from that range. The gates were not operated during the inspection. The safety railing appears to have been recently painted, while the steel supports portions exhibit signs of surface rusting and paint failure. The steel supports should be cleaned and painted to prevent further deterioration. No analysis of the gates was performed at this time.

The spillway and associated concrete structures were inspected visually from the embankments and deck. The spillway and retaining walls exhibited numerous areas of deterioration, including cracks with and without efflorescence, spalls with and without exposed reinforcing steel and delamination. The deterioration does not appear to be structurally threatening currently. A more detailed list of defects is presented by element below:

Deck: The deck was in satisfactory condition with minimal areas of spalling and delamination.

Spillway: The spillway was in fair condition. A visual inspection of the spillway facing and weir was performed from the embankments as the gates to access the deck were locked. The spillway facing showed widespread spalling and delamination, see Photo 27. The depth severity of the deterioration was not able to be determined due to access constraints. The spillway piers appear to have recently been rehabilitated, however areas for cracking with efflorescence were still present, see Photo 28. The weir had a large spall along the base of the downstream side. No exposed reinforcing steel was observed. A large sediment deposit was present across the spillway adjacent to the downstream side of the weir, see Photo 29. The spillway apron is being undermined.

Photo 27: Tobacco spillway with widespread spalling and likely delamination

Photo 28: Tobacco spillway pier with recent patch and still showing cracking with efflorescence.

Photo 29: Tobacco spillway weir with large spall and sediment.

Retaining Walls: The retaining walls were generally in fair to poor condition. Large portions of the walls show minimal defects, however there are numerous isolated areas with large cracks and spalls. The retaining walls have tieback systems constructed but may not provide adequate support for the entire retaining wall systems, especially due to the recent erosion of the downstream slope. The left side (east) downstream retaining wall had an area of cracking with efflorescence near the top and several large spalls along the bottom. It appears that the retaining wall is currently undergoing a rehabilitation as a geometrically cut portion of the wall is missing near the toe of the slope and is reinforced with a stiffened steel plate, see Photos 30 and 31. Several vertical cracks approximately 0.125” wide were also noted near the downstream end, see Photo 32. The downstream right side (west) retaining wall had several large spalls along the bottom with exposed reinforcing steel and a large area of map cracking near the top. It also appeared to be under construction due to the presence of a temporary safety fence, see Photo 33. The upstream portions of the retaining walls were in better condition as compared to downstream. Isolated cracking was found on the right side (west) upstream wall and an area of delamination adjacent to a recent patch was located on the back face of the left (east) upstream wall, see Photos 34 and 35.

Photo 30: Left side (east) retaining wall exhibiting cracking with efflorescence, several large spalls near the bottom and a steel plate reinforcing an area under construction.

Photo 31: Back face of left side (east) retaining wall at steel reinforcing plate. Notice horizontal cut just right of plate.

Photo 32: Vertical crack on back face of left side (east) retaining wall near downstream end.

Photo 33: Right side (west) downstream retaining wall showing map cracking, large spall with exposed reinforcing steel and temporary construction railing.

Photo 34: Upstream right side (west) retaining wall with a crack just right of the vertical line (cable hanging over edge).

Photo 35: Upstream left side (east) retaining wall with delamination near recent patch (2'x4')

Wingwall (Bulkheads) and Concrete Slope Protection Upstream: The wingwalls (bulkheads) were in fair condition. The right side (west) wingwall (bulkhead) had a large area near the bottom where the sheet pile and reinforcing steel were exposed. There were also several vertical cracks in the concrete cap, see Photo 36. The left side wingwall (bulkhead) exhibited similar cracking, however spalling and exposed sheet piling and reinforcing steel were not present. At the east end of the wingwall (bulkhead), concrete slope protection had been installed. A couple of the panels showed signs of undermining and settling, see Photo 37.

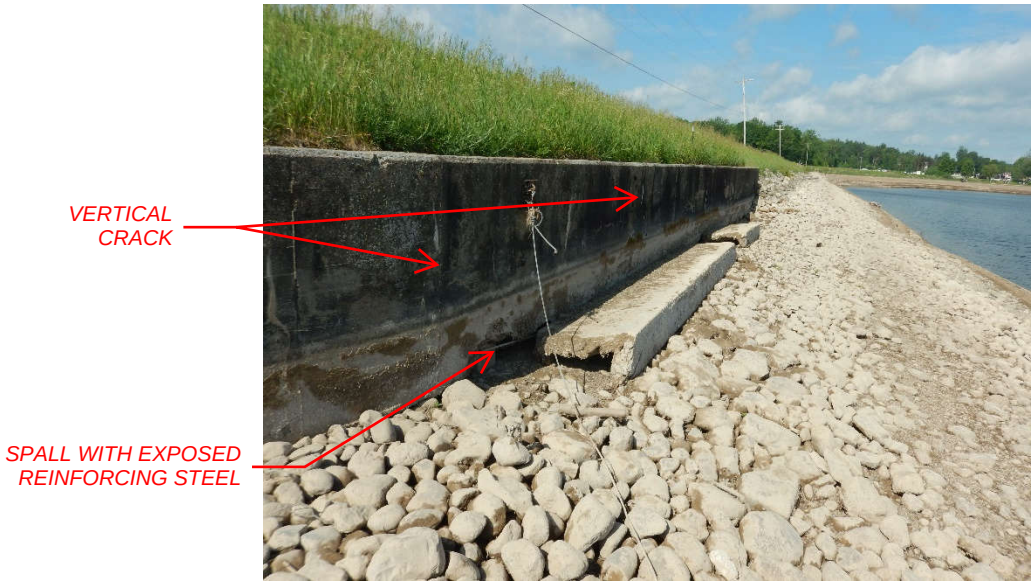


Photo 36: Right side (west) wingwall (bulkhead) with vertical cracks and spalls exposing the sheet piling and reinforcing steel.

Photo 37: Concrete slope protection panel approximately 40' east of the wingwall (bulkhead) with undermining and settlement present.

Cutoff (Downstream) Walls: The left side (east) cutoff wall is cracked and separated from the retaining wall. It also has a large spall near the bottom at the back face with exposed reinforcing steel It is isolated and protected by concrete cribbing, see Photos 38 and 39. The right (west) side cutoff wall showed significant cracking near the top at the connection to the retaining wall, see Photo 40.

Photo 38: Left (east) side cutoff wall isolated with concrete cribbing.

Photo 39: Left (east) side cutoff wall with fully cracked connection to retaining wall and large spall with exposed reinforcing steel.

Photo 40: Right (west) side cutoff wall with large crack near top at connection with retaining wall. Also note the lack of backfill

3.6 Right Embankment - Tittabawassee

The right embankment of the Tittabawassee is 2,030 feet long and approximately 55 feet high at the deepest section. Except for the locations adjacent to the spillway as discussed below, a majority of the upstream and downstream slopes appear to be in fair to satisfactory condition, see Photos 41 to 43. There were no apparent signs of significant slope adjustment/movement, seeps, tension cracks, or rills present on the downslope slope, however, a few animal burrows were present that will need to be backfilled. The embankment has a toe drain system that has some vegetation growth in the ditch. The drain outlets were not discharging at the time of TRC's inspection. There were weeds accumulated along the pipe outlets that should be removed so the filter does not become clogged, see Photo 44. There were no signs of major erosion observed on the upstream slope; however, there are areas in which wave action has reduced the effectiveness of the riprap.

Photo 41: Overall view of Right Embankment – Tittabawassee (drone photo provided by EGLE).

Photo 42: Downstream slope of Right Embankment – Tittabawassee. Established vegetation and minimal slope adjustment/movement and seeps present.

Photo 43:Upstream slope of Right Embankment – Tittabawassee that will require slope protection to be reestablished (vegetation and riprap).

Photo 44:Toe drain outlets not discharging at time of inspection.

Tension cracks and surface sloughing was observed to the immediate right and left of the downstream slope of the Tobacco Spillway, see Photo 45. It is understood that tailwaters developed within the Tobacco River when the dam breached causing erosion damage to the bottom portion of the downstream slope where said cracks and surface sloughing was observed. The toe erosion created a loss of buttress support of the slope and the waves and precipitation during the storm inundated and softened the ground surface, thereby, weakening the slope causing the movement. It is anticipated that the sloughed material is a “sliver fill” overlay that was placed by Boyce Hydro at the request of FERC in 2014 and 2015 for the purpose of flattening the slope so that acceptable factors of safety could be achieved. As an

emergency effort, Boyce Hydro had the erosional areas backfilled with riprap and aggregate. Although it now may be more difficult to determine the location of a seep if one occurs, the riprap will protect the slope from erosion. Boyce Hydro also installed gauges around June 5, 2020 to monitor the tension cracks for additional movement, see Photo 46. Boyce Hydro indicated that since its installation the gauges have indicated the cracks are not increasing in size. These cracks should be backfilled with soil or bentonite to "seal the voids" to prevent water from entering the cracks and potentially weakening the embankment.

Under the conditions observed at the time of TRC's inspection, the slope appears to be stable from a global perspective. Until repairs can be made to the Tobacco Spillway and adjacent slopes, it is recommended that the tension cracks be monitored by Boyce Hydro and that survey hubs be installed along the slope (at the crest, toe, and midslope) to monitor the slope for additional movement – the gauges and survey hubs should be monitored on a weekly basis. If the slope conditions worsen, the dam may need to be breached to the right of the spillway area so that the loading on the spillway and embankment is reduced by lowering the reservoir water level and passing the flow to the original Tobacco River alignment. Boyce Hydro will need to present this approach to EGLE for their review and concurrence if this is to be considered.

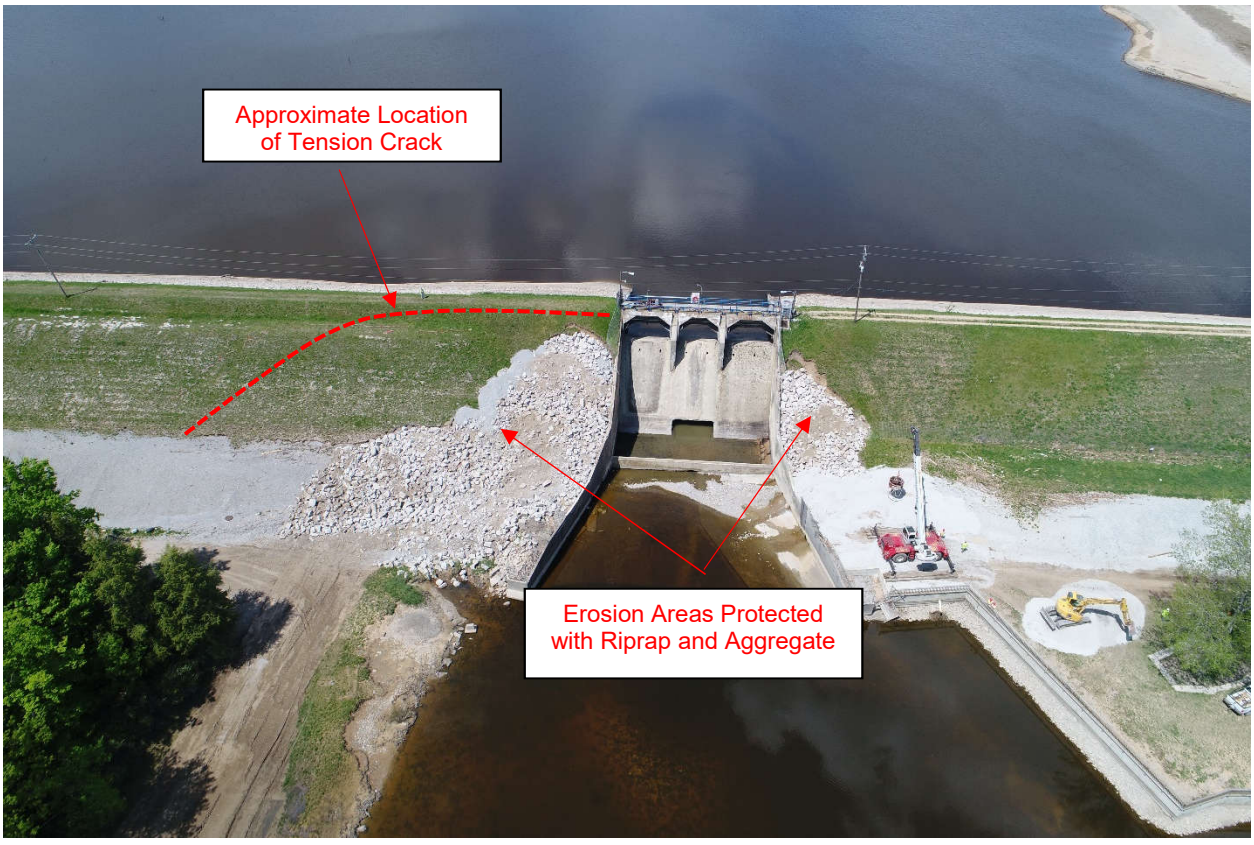


Photo 45:Approximate location of tension cracks and eroded area previously remediated by Boyce Hydro.

Photo 46:Boyce Hydro installed crack gauges to monitor the tension cracks.

4.0 Recommendations

To assist Boyce Hydro in prioritizing the recommendations presented in this Report, the remedial actions presented in the previous section have been categorized into three levels of risk:

- ***Critical Action*** are items that have potential high risk to dam stability and public safety and should be addressed immediately.
- ***Recommended Action*** are items that have medium risk to dam stability and public safety and should be addressed as soon as feasible.
- ***Non-critical Action/Maintenance*** are items that have low risk to dam stability and public safety and should be addressed as part of routine maintenance.

4.1 Critical Action

C-1 Remove the debris and establish a new drainage/river channel within the Left Embankment - Tittabawassee section to properly control and pass drainage through this area. An extensive hydraulic model will need to be developed for the drainage basin so that a new river section, flow capacity, and alignment can be determined.

C-2 Remove debris from the Tittabawassee Spillway that could potentially move downstream.

C-3 Shore the left side of the Tittabawassee Spillway against further loss of soil to prevent total collapse of spillway.

C-4 Until the Left Embankment – Tobacco can be repaired to satisfactory condition, as an interim measure it is recommended that a temporary sheet pile wall be installed from the existing fishing pier located approximately 275 feet east of M-30 to protect the embankment from further erosion by moving the floodway away from the dam by reestablishing the original path of the stream. Continue to monitor the rate of erosion of the embankment.

C-5 Until a slope stability analysis can be performed and repairs made to the Tobacco Spillway and adjacent slopes to satisfactory conditions, it is recommended that survey monitoring hubs be installed along the downslope (at the crest, toe, and midslope) portion of Right Embankment – Tittabawassee to monitor the slope for additional movement. If the slope experiences significant displacement and further analyses indicate global instability, the dam may need to be breached to the right of the spillway area so that the loading on the spillway and embankment is reduced by lowering the reservoir water level and passing the flow to the original Tobacco River alignment.

C-6 The tension cracks that have developed to the right of the Tobacco Spillway should be backfilled with soil or bentonite to “seal the voids” to prevent water from entering the cracks and potentially weakening the embankment.

4.2 Recommended Action

R-1 Remove loose soil and regrade the edges of the remaining sections of the Left Embankment – Tittabawassee to maximum 3H:1V slopes. Establish vegetation along the disturbed portions of the embankment.

R-2 Shore and stabilize the access to the Powerhouse and perform an interior inspection.

R-3 Backfill and repair the erosion washout immediately to the right of the retaining (side) walls on the upstream slope of the Tittabawassee Spillway to prevent progressive failure of the slope that could potentially impact the upper portion of the structure.

R-4 It is recommended that Boyce Hydro personnel continue to perform inspections of the dam embankment on a weekly basis to determine if conditions as described above worsen.

R-5 As the Tobacco Spillway is already under construction, there is nothing structurally that would be an immediate threat to public safety, however the retaining (side) wall should be repaired as soon as possible to better contain the earthen embankment.

R-6 Continue to monitor the gauges previously installed along the tension crack observed to the right of the Tobacco Spillway to determine if the tension cracks are widening.

4.3 Non-critical Action/Maintenance

M-1 Due to the age of the embankment (almost 100 years old), it is expected that some settlement of the embankment has occurred. Any low spots along the crest were not apparent based on visual inspection alone. Therefore, it is recommended that a survey of the dam crest be performed to ensure the top of dam is at the appropriate elevation.

M-2 Repair the eroded areas at the toe drain outlets along the Right Embankment – Tittabawassee.

M-3 The upslope portion of the Right Embankment – Tittabawassee is in poor condition as it appears a small portion of the toe has been eroded, tension cracks have formed at the crest, and the riprap needs replaced. However, based on the conditions at the time of the site inspection this is not a critical item at this time under current conditions as the edge of water was a safe distance away from the dam. Reestablish the river channel and continue to maintain the water's edge a safe distance away from the dam to minimize the loading until this section of embankment can be repaired to satisfactory conditions.

M-4 Removed sediment and repair the downslope ditch slopes repaired for the Left Embankment – Tobacco River.

M-5 Continue to remove vegetation and weeds within the toe drain ditches so the pipe outlets do not become clogged.

M-6 Perform maintenance of the vegetative cover throughout. Removal of improper vegetation is necessary for the proper maintenance of a dam. All vegetated embankment slopes should be maintained with a maximum grass height of 12 inches. Reasons for proper maintenance of the vegetal cover include unobstructed viewing during inspection, maintenance of a non-erodible surface, discouragement of burrowing animal habitation, and aesthetics. Common methods for control of vegetation include the use of weed trimmers or power brush-cutters and mowers. Chemical spraying to kill small trees and brush is acceptable if precautions are taken to protect the local environment. It is important to remember not to mow when the embankment is wet.

M-7 Maintain proper rodent control throughout. Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and impoundments, and can be dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers can plug spillways and raise the pool level. Consequently, rodent control is essential in preserving a well-maintained berm and spillway. They are usually discouraged from inhabiting the embankment if the vegetative cover is kept mowed as previously discussed. The rodents can also be controlled by fumigants, trapping or shooting during the appropriate season – local laws and regulations should be checked before trapping and/or hunting. If a burrow or den is observed, it is recommended that it be backfilled by mud-packing - pour a mud-pack mixture (i.e., a slurry consisting of 90% soil and 10% cement mixture) with the aid of a pipe into the hole with dry soil tamped into the entrance and vegetation re-established.

5.0 Limitation

The evaluations, conclusions, and recommendations presented in this Report are based on our limited scope of work and on information disclosed by our visual observations, the conditions of the site at the time of the inspection, the design and as-built information available at the time of this investigation, and only apply to Edenville Dam. This work has been performed in accordance with our authorized scope of work and is based on the level of effort and investigative techniques

using that degree of care and skill ordinarily exercised under similar conditions by reputable members of the profession practicing in the same or similar locality at the time of service. No other warranties, expressed or implied, are made or intended by this Report. These services were intended to provide an indication of the current, observable conditions of the dam at the time of the visual observations on the date indicated in this Report, and this Report is not a comprehensive analysis of the safety of the structures. Such a limited visual review does not account for other non-visible, hidden, subsurface or material condition analyses, and the professional services rendered are not guaranteed to be a representation by TRC of inaccessible and unobservable site conditions or actual conditions subsequent to the date of TRC's site visit. Therefore, the evaluations, conclusions, recommendations and opinions provided in this Report are subject to change as a result of future natural or manmade processes and as a result of an additional comprehensive, intrusive investigation and engineering analyses beyond TRC's visual observations. TRC did not perform a review or evaluation of past or present compliance with federal, state, or local environmental or land use laws or regulations, and TRC was not involved in any previous maintenance, design, construction, or modifications to the dam and associated structures. In addition, TRC makes no guarantees on the conditions of the dam or changes in site records after the date of this Report. The evaluations, conclusions and recommendations presented herein are subject to change based on additional information provided to TRC. TRC is not responsible for any conclusions or opinions drawn by others from the data included herein nor are the recommendations specifically presented in this Report intended for use or reliance as construction specifications. This Report is intended for use with regard to the specific project discussed herein and any changes in the observable conditions should be brought to TRC's attention so that we may determine how they may affect TRC's evaluations, conclusions and recommendations. An attempt has been made to provide for normal contingencies but the possibility remains that unexpected conditions may be encountered. If this should occur, or if additional or contradictory data are revealed in the future, we should be notified so that modifications to this Report and our recommendations can be made, if necessary. TRC is not responsible for any problems that may arise from the misunderstanding or misinterpretation of this Report, or failures to comply with our recommendations.

Furthermore, this Report is prepared and made available for the sole use of Boyce Hydro, LLC and their assigns for the specific purposes mentioned above. The contents thereof may not be used or relied upon by any other person or entity, without the express written consent and authorization of Boyce Hydro, LLC and TRC.

Appendix A: Tittabawassee Spillway and Powerhouse Schematic

10210-2

10210
No. 10210.

2
Note added as to Acreage for H.W. El. 671.5.

3 9-25-44

Water Surface El. 671.5 = 3658 Acres (Estimated)

UPSTREAM

Section Thru Spillway

Section Thru Power House

RIGHT (WEST) WINGWALL

LEFT (EAST) WINGWALL

DOWNSTREAM

Tittabawassee River

N

Southwest Wing Wall See Dwg.# 10230

Southeast Wing Wall. See Dwg.# 10230

117'-2"

50'-7" Power House

68'-7" Spillway

23'-7" | 2'-6" | 20'-0" | 2'-6" | 20'-0" | 2'-6" | 20'-0" | 2'-6" | 23'-7"

Bay 4 | Bay 5 | Bay 6

Sluiceway

Spillway Walk

Tainter Gate

PIER

SPILLWAY

Top of Concrete Cap El. 673.5
North Wall

RIGHT WINGWALL

Steel Sheet Piling

℄ Crest

N. & S. Reference Line

℄ Embankment

Top Concrete Cap El. 673.5?

80'± LEFT WINGWALL

Steel Sheet Piling

South Wall & Embankment

Air Shaft

Trap | Trap | Trap | Trap

6" Vent to Roof

Units

Switchboard

Trap

Transformers

POWERHOUSE

Stilling Pool

Pool Weir

WIER

Division Wall

Northwest Wall See Dwg. 10272

Flexible Paving

Future Flash Chute if desired

0 5 10 20 30 35 40
Scale in feet

Sluiceway Bay #1 Only

Temporary Sluiceway

This area to be filled with concrete when temporary sluice is closed

Ladder Rungs

Floor Bay #1 Only

Head Water El. 677.0

Head Water El. 671.5?

Crest El. 682.0?

Spillway Walk

Head Gates

Tainter Gates

Substation and Switching on Roof 37,800 Volts

Transformers 2300 Volts 3,000 K.V.A.

Embankment Line

Tail Water El. 628.5

Head Water El. 671.5

Rocks

Gravel Fill 5'-6"

Bypass

Drain

73" Francis Turbine 145 Rated 3300 H.P. 138 K.P.H.

Draft Tube

Generator 3 Phase 60 Cycle 2300 Volts 3000 K.V.A.

Switch Room

El. 677.0?

El. 672.0

El. 671.5

El. 667.5

El. 658.5?

El. 651.0

El. 643.0?

El. 643.0

El. 640

El. 621.0

El. 614.0

El. 623.5?

El. 622.5

El. 622.5?

El. 667.5

El. 640

El. 628.5

El. 623.5?

El. 622.5?

41'-6"

29'-0"

38'-6"

28'-0"

53'-0"

30'-3"

35'-7"

49'

12"

111'-0"

65'

38'-6"

24'-6"

10'-0"

37'-0"

15'-0"

49'-0"

88'-0"

13'-6"

10'-0"

MEC 6/23/44 6
MEC 6/5/44 4
MEC 6/5/44 3
MEC 6/5/44 2
MEC 6/5/44 1
MEC 6/3/44 5
MEC 4/23/44 3
MB 8/15/43 2
MB 8/11/43 1

WOLVERINE POWER CORPORATION.
EDENVILLE PLANT

GENERAL PLAN

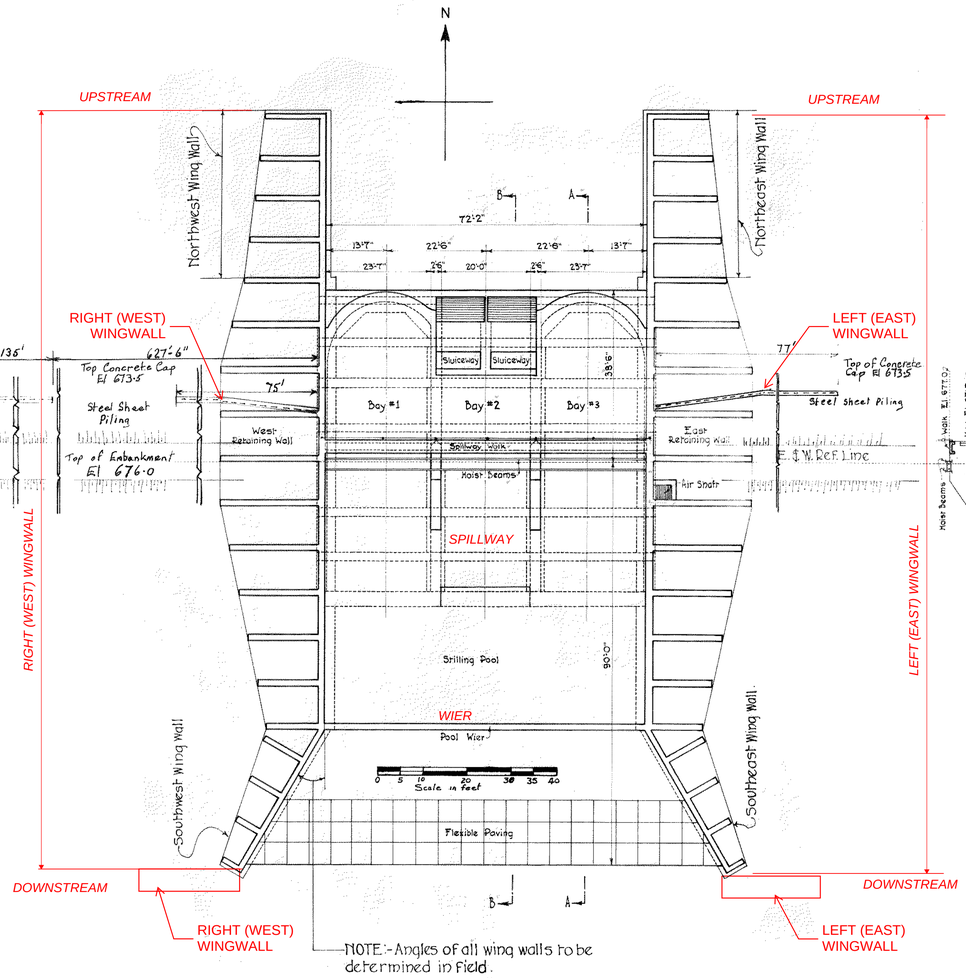
HOLLAND, ACKERMAN & HOLLAND
Consulting Engineers
Ann Arbor CHICAGO
Scale: 1/8" = 1 Ft. Aug. 1923

10210-2

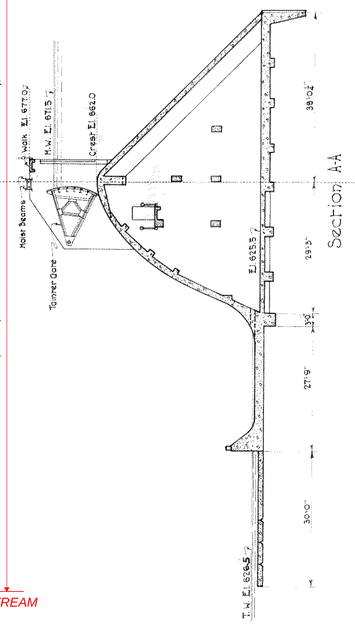
Appendix B: Tobacco Spillway Schematic

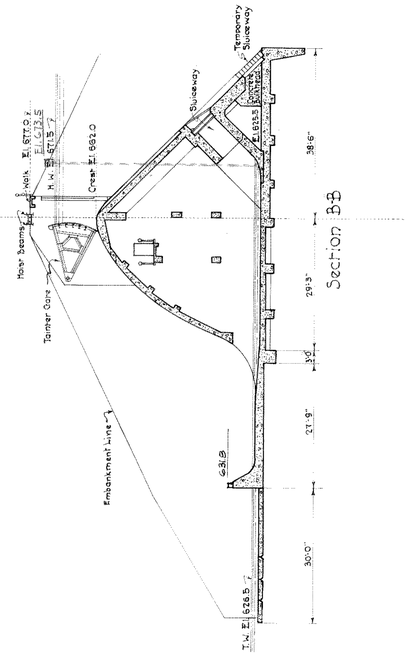
10310-2

CHECKER



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





(See Edenville Dwg. 10210)

WOLVERINE POWER CORPORATION.
TOBACCO DAM

GENERAL PLAN

HOLLAND, ACKERMAN & HOLLAND
Consulting Engineers
Ann Arbor CHICAGO
Scale:- 1in- 1 Ft. Aug. 1923.

10310-2