

BOARDMAN RIVER FEASIBILITY STUDY

Preliminary Engineering Evaluation of Existing Structures

DRAFT

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**US Army Corps
of Engineers®**

Submitted by:

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This report has been a joint effort by Environmental Consulting and Technology, Inc. (ECT) and the U. S. Army Corps of Engineers (USACE) to establish the baseline conditions and to document collect available engineering data on the existing dams on the Boardman River, inspect each dam, and to document issues that may positively or negatively affect the identification of alternatives for future evaluation.

The ECT effort, and this report, is an integral part of the engineering feasibility study being performed for the Boardman River Dams Committee (BRDC) to evaluate a full range of alternatives for the Boardman River considering environmental, economic, engineering, and societal impacts. We would like to acknowledge the Grand Traverse Band of Ottawa and Chippewa Indians (GTB) for funding this important work in support of the BRDC effort, through a Tribal Wildlife Grant provided by the U.S. Department of Interior, Fish and Wildlife Service .

The USACE effort, and the information contained in this report, is an integral part of the Feasibility Study on the Boardman River Dams, being conducted under the Great Lakes Fisheries and Ecosystem Restoration (GLFER) Program. This program enables the Corps to utilize its planning, design, and construction expertise for projects to restore the Great Lakes fishery and ecosystem.

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1.0 INTRODUCTION

The Boardman River is located in the northwestern portion of Michigan's Lower Peninsula and originates in central Kalkaska County, flows southwest into Grand Traverse County where it turns north and flows into West Grand Traverse Bay, Lake Michigan in Traverse City, Michigan. The Boardman River watershed drains a surface area of approximately 291 square miles and includes 179 lineal stream miles and 12 natural lakes. The Boardman River is designated a Natural River and is considered one of the top ten best trout streams in Michigan, containing nearly 36 lineal miles of Blue Ribbon Trout Stream. The project area is a 20-mile plus section of the Boardman River's main stem, located in Grand Traverse County, and contains four dams: Union Street Dam, Sabin Dam, Boardman Dam, and Brown Bridge Dam.

The upper three dams were constructed and operated for hydropower generation; however Traverse City Light and Power has relinquished its licenses to generate hydroelectric power at the Sabin, Boardman, and Brown Bridge dams. The owners of the dams, the City of Traverse City and Grand Traverse County are now fully responsible for the operation and maintenance of these facilities. They are committed to involving the public to help determine the fate of these dams. The Boardman River Dams Committee has been formed for this purpose and has retained the services of Environmental Consulting and Technology, Inc. (ECT) to conduct an engineering feasibility study of the Boardman River for the long term disposition of the four existing dams: Brown Bridge Dam, Boardman Dam, Sabin Dam and Union Street Dam on the bases of environmental, engineering, economic, and societal impacts.

Also, at the request of the City and County, the U. S. Army Corps of Engineers (USACE) is conducting a Feasibility Study on the Boardman River Dams under the Great Lakes Fisheries and Ecosystem Restoration (GLFER) Program. The GLFER program enables the Corps to utilize its planning, design, and construction expertise for projects to restore the Great Lakes fishery and ecosystem.

ECT and USACE continue to work cooperatively to maximize efficiency and effectiveness of their efforts and to avoid duplication of effort. This report is a joint effort, utilizing the expertise of both organizations and leveraging both direct Federal appropriation to the USACE and local funding to ECT, to evaluate the constructability of potential alternatives for the fate of the four dams.

2.0 PURPOSE OF THIS REPORT

The purpose of this report is to summarize information gathered to date on each of the dams, and document the conditions observed during the onsite inspection conducted on September 5th – 7th, 2007. The inspection was conducted with two USACE engineers, and two ECT engineers. Structural and Geotechnical disciplines were represented. Owner representatives with knowledge of the sites were also present. The purpose of the onsite inspection was to visually inspect each dam, and document issues that may positively or negatively affect viable alternatives to be considered, including the establishment of the baseline condition, or 'conditions without project', for each structure which will be the bases from which various alternatives will be evaluated. The inspection was not a dam safety inspection, nor a complete engineering evaluation of the dams; it served solely as a preliminary engineering evaluation of the existing conditions of the structures.

Representatives from the Grand Traverse Conservation District, and Grand Traverse Band of Ottawa and Chippewa Indians also participated in the inspection. The Traverse City Light and Power representative was consulted during the inspection.

This report includes a brief discussion of the constructability, including site restrictions for general categories of alternatives at each dam. This is not intended to limit future alternatives, but to identify the structural and site constraints that will have to be considered in the identification of alternatives. The general categories include:

- Existing Operations. This category includes observed or documented conditions that would impact the ability to provide for continued control of water in a safe and reliable manner. Any required modifications or major rehabilitation would have to be addressed in establishing the baseline conditions.
- Breach or Removal. Observed or documented conditions, and additional data requirements, that would have an impact on alternatives to restore a free flowing river.
- Modifications to enhance fisheries habitat. This category would include observed or documented conditions that would impact the construction of a fish bypass, or modifications to outlet systems for temperature control.

This report is meant to evaluate the constructability of the alternatives posed at each site. It does not evaluate the impacts of numerous other factors that are being/ will be considered later in the Feasibility Study.

All references to "left" and "right" in this report are based on the observer facing downstream.

3.0 OVERALL PROJECT REGULATORY HISTORY

The Brown Bridge, Boardman, and Sabin Dams were all originally constructed with power generation capabilities. Power was generated at the dams until 1969, at which time, the turbines and generators were removed from Boardman and Sabin Dams. In 1983, both Boardman and Sabin Dams were renovated and hydroelectric power generation re-commenced in 1985. Brown Bridge Dam continuously generated power during this time. In November 2006 Brown Bridge and Sabin Dams were de-commissioned, and in January 2007 the Boardman Dam was decommissioned. Power generation operations were terminated upon decommissioning at all dams.

While the Brown Bridge, Boardman, and Sabin Dams were generating hydroelectric power, they were regulated by the Federal Energy Regulatory Commission (FERC) under Part 12 of the Commission's regulations. FERC requires all hydroelectric dams regulated under Part 12 of the Commission's regulations to pass the Inflow Design Flood (IDF). The IDF is defined as the flood flow above which the incremental increase in water surface flood elevation due to failure of a dam or other water impounding structure is no longer considered to present an unacceptable threat to downstream life and property.

FERC guidance sets the upper limit of the IDF at the Probable Maximum Flood (PMF). The PMF is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the drainage basin under study

Under FERC regulations, Traverse City Light and Power was required to conduct a Probable Mode of Failure Analysis (PMFA) for Brown Bridge, Boardman, and Sabin Dams. These studies were conducted by Gannet and Fleming, Inc. and presented in reports dated 2005.

Now that these dams have been de-commissioned, the Michigan Department of Environmental Quality (MDEQ) has assumed full dam safety regulatory authority under Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act 451 of 1994, as amended. Under the State's statute, a dam less than 40 feet in height, shall be capable of passing the 200 year flood or the flood of record, whichever is greater; a dam greater than 40 feet in height shall be capable of passing the design flood equal to ½ the Probable Maximum Flood (PMF). The height of a dam is measured from the 200-year design flood elevation to the lowest downstream toe elevation.

The Union Street Dam was constructed to supply power for a now defunct flour mill, with its current purpose being to regulate the level of the Boardman Lake. As the dam was never used for hydroelectric power, it was never regulated by FERC, and is regulated by the MDEQ.

As the four dams are currently regulated by the MDEQ, the discussions presented below for the 'Conditions without Project' for each of the dams considers that the MDEQ regulations are to be met. It should be noted here that if any of the dams are to be used for hydroelectric power generation a new FERC license must be obtained and FERC regulations must be met.

4.0 UNION ST. DAM INSPECTION



Union Street Dam, looking upstream (Not taken at time of inspection)

4.1 Description Of Dam

4.1.1 General Description

The Union Street Dam is located at River Mile 1.5, and is the first dam encountered moving upstream from the mouth of the Boardman River at Traverse Bay. The height of the structure, as measured from the principal spillway apron to the top of the embankment, is approximately 21 feet.

The existing Union Street Dam consists of approximately 250 lineal feet of earthen embankment, two spillways, and a fish ladder. A site plan presenting an overview of the dam components is included as Figure 1 of Appendix A.

The principal spillway consists of a concrete overflow section with five 10.5 foot wide bays. Each bay is connected to two-48 inch diameter corrugated metal pipe (CMP) outlet conduits that extend through the earthen embankment. Each pipe has an upstream control gate.

The auxiliary spillway consists of a concrete inlet section and overflow structure with two eleven-foot wide stop log bays. Two 48-inch diameter CMPs extend through the embankment and outlet into a separate channel that connects to the Boardman River downstream of the dam.

A six-foot wide concrete fish ladder connects to the inlet structure of the auxiliary spillway and outlets downstream to the left of the principal spillway. The fish ladder has several weir sections that step down from the lake elevation to the tail water elevation in the river (MDEQ 2000 Dam Safety Inspection Report).

4.1.2 Project History

The Union Street Dam was constructed in 1867 to supply power for a now defunct flourmill. It is owned by Traverse City and its current purpose is to maintain the water level in Boardman Lake. The dam's impoundment, Boardman Lake, is a natural lake that was originally 259 acres in size and increased to 339 acres after the Union Street Dam was constructed. The spillways were reconstructed in 1965.

4.1.3 Operation

The Union Street Dam is owned and operated by Traverse City. It is operated in a run of the river mode and to maintain a fixed water surface level of Boardman Lake.

4.1.4 Existing Spillway Capacity

The spillway capacity for Union St. Dam is noted as 2,000 cfs with approximately 1.0 foot of freeboard (2005 Inspection Report).

4.1.5 FERC Requirements

Not applicable. The Union Street Dam was never used for hydropower, and never regulated by FERC.

4.1.6 MDEQ Requirements

MDEQ has been the sole regulatory authority for the Union Street Dam. The dam is less than 40 feet in height, and thus is required to have a spillway capacity capable of passing the 200 year design flood or the flood of record, whichever is greater. The 200-year (0.5% chance) flood discharge is estimated to be 2,000 cfs (2005 Inspection), which exceeds the flood of record. As stated above, the spillway capacity is reported to be 2,000 cfs.

Therefore, the existing dam does meet MDEQ spillway criteria.

4.2 Results of most recent Dam Safety Inspection (2005)

Overall, the dam was said to be in good condition, attributable to good maintenance practices. The report made several recommendations, and listed the following actions to be taken as soon as possible:

- Repair and realign trash racks in Bay #2 of the principal spillway
- Continue weekly maintenance inspections and good maintenance practices.
- Lubricate and exercise all principal spillway gate operator stems on an annual basis.
- The Emergency Action Plan (EAP) should be reviewed and updated on an annual basis. A copy of the updated EAP should be provided to the MDEQ Dam Safety Program when significant changes to the EAP occur.

- Consider constructing a toe drain system on the downstream slope of the embankment near the downstream headwall.

4.3 Onsite Observations From Joint Inspection

General observations of the condition of the dam observed on the 7 September 2007 inspection are noted below. Items observed that may affect the alternatives being considered for this dam are discussed in the subsequent paragraphs.

- Seepage noted at downstream toe of the earthen embankment, near sidewalk, as observed during the 2005 Dam Safety Inspection.
- Trees/ stumps present on the downstream slope of the earthen embankment.
- A large diameter city water main is located above ground and crosses the dam.
- A city storm sewer is shown downstream of the auxiliary spillway on the 1965 construction drawings.
- Half of the discharge culverts were observed to have turbulent flow discharge while the others were observed to have laminar discharge. Turbulent flow may indicate deterioration of the culverts.
- The trash racks in Bay#2 were observed to have been repaired since the 2005 Dam Safety Inspection.

Photos taken during the September 2007 site visit are presented in Appendix B.

4.4 Impacts To Existing Operations (Conditions Without Project)

No issues observed that would result in major rehabilitation for dam safety in the immediate future or impact existing operations of the Union Street Dam. Continued maintenance of the dam would be required for this alternative.

It should be noted here that the City of Traverse City is currently pursuing a detailed inspection of the Union Street dam including a structural evaluation of the dam structure and control gates and operators together with an underwater inspection of the principal and auxiliary spillway outlets, outlet pipes and concrete headwalls. The City is also pursuing a seepage analysis of the dam embankments. The results of this inspection may identify some maintenance requirements that will have to be addressed to support continued, safe operation of the dam.

4.5 Potential Impacts To Breach/ Removal Of Union Dam

Site conditions observed that may impact to removal of the Union St. Dam:

- A large above ground water main currently crosses over the dam. If the dam were to be removed, supports for the water main would be needed.
- Control of invasive species (sea lamprey) may be required with this option.

4.6 Potential Impacts To Construction Of A Fish Passage

There is an existing fish ladder at the Union Street Dam that is in good structural condition. There were no observed or documented conditions that would impact the consideration of a modification to the existing structure to improve the functioning of the fish ladder.

It is our understanding that the existing fish ladder was constructed to allow migration of potomadromous salmon and trout while blocking upstream sea lamprey (*Petromyzon marinus*) migration. Modification or reconstruction of the fish ladder may be desired for the purpose of allowing passage of additional species, such as sturgeon, or to provide a more effective control of invasive species such as sea lamprey.

5.0 SABIN DAM INSPECTION



Sabin Dam Spillway

5.1 Description Of Dam

5.1.1 General Description:

The Sabin Dam is the second dam moving upstream from the Grand Traverse Bay, at River Mile 5.3.

The existing Sabin Dam is an earthen dam consisting of a left earth embankment, powerhouse, intermediate earth embankment, stop log spillway section, tainter gate spillway section, and a right earth embankment. A site plan presenting an overview of the dam components is shown in Figure 2 of Appendix A. A more detailed description of each component is as follows:

The left earth embankment extends approximately 60 feet from the powerhouse and was constructed of sand fill. The top of the embankment serves as an access road to the powerhouse. The crest elevation of the left embankment is 618.5 feet NGVD.

The powerhouse consists of a concrete substructure with a brick superstructure, and contains two vertical shafts; the left one is equipped with a turbine for power generation, while the right one provides for water control.

The intermediate embankment extends approximately 52 feet between the powerhouse and the spillway and was constructed with sand fill and a core wall which ties into the spillway and powerhouse structures.

The stop log spillway section is approximately 32 feet wide. The Probable Failure Mode Analysis (PFMA) report states that there are two foot high timber stop logs above the crest and three low flow outlets with wood lift gates that are not being used. These are not shown on the 1930s construction drawings. Figure 3 in the Appendix A presents a section through the stop log spillway, showing a bulkhead on the upstream end of the low flow culverts.

The tainter gate spillway section is 18 feet in length and consists of a 5.5 foot high steel tainter gate. The gate is operated with an electric cable hoist. The tainter gate is equipped with an aerator to prevent upstream ice buildup. Figure 4 in Appendix A presents a section through the tainter gate spillway.

The right embankment extends 330 feet from the spillway structure and was constructed of sand fill.

5.1.2 Project History

The original Sabin Dam structure was constructed in 1906 for the Boardman River Light and Power Company and was completely reconstructed in 1930. Various owners operated the dam until 1969 when the turbines and generators were removed from the powerhouse and Consumers Power Company sold the powerhouse to Grand Traverse County. In 1983, the powerhouse was renovated for hydroelectric power generation. Power generation re-commenced by Traverse City Light and Power in 1985, and continued until 2006.

5.1.3 Operation

In 2006, the dam was de-commissioned and Traverse City Light and Power terminated power generation operations. The power generation equipment is still in place, but it is our understanding that it will be removed at an unknown date in the future.

While Traverse City Light and Power Company used the dam for hydroelectric power, they operated, monitored and maintained the Sabin Dam. Below is a description of the procedures that were followed during power generation and what is done now that power is no longer generated.

With Power Generation:

While generating power the dam was operated in a run-of-river mode, the primary course for the water was to pass through the vertical shaft turbine and outlet from the powerhouse, discharging directly into the Boardman River. The right vertical shaft was used for water control. When required, additional flow capacity was provided by the tainter gate spillway.

Without Power Generation:

There was no documentation available regarding the operation of the dam during the time period of which power was not being generated (1969-1983).

Changes in Operation:

Currently, the water at Sabin Dam continues to pass through the right vertical shaft and outlet from the powerhouse into the Boardman River. The vertical shaft containing the turbine is currently blocked from any water flow. Additionally, the tainter gate is open, approximately 12% (according to the County representatives) and water flows through the tainter gate spillway. The stop logs at the powerhouse are manipulated to regulate water flow as well as the tainter gate. The stop log spillway continues not to be used. It is also our understanding that other associated equipment may be removed as well, such as the agitator/ bubbler system.

5.1.4 Existing Spillway Capacity

The existing spillway capacity for the Sabin Dam has been reported as 3650 cfs (PFMA 2005).

5.1.5 FERC Requirements

Prior to decommissioning in November 2006, the Sabin Dam was regulated by FERC requirements.

The IDF for Sabin Dam was established as 2,000 cfs (Mead & Hunt IDF study). At 2,000 cfs a failure of Sabin Dam would not be expected to present a hazard to human life nor cause significant damage. As stated above the spillway capacity for the Sabin Dam has been reported as 3650 cfs.

The existing spillway capacity does meet FERC criteria.

5.1.6 MDEQ Current Requirements

As of the decommissioning in November, 2006, MDEQ assumed fully regulatory authority for dam safety. Sabin Dam is less than 40 feet in height, thus the required spillway capacity shall be capable of passing the 200 year design flood or the flood of record, whichever is greater.

MDEQ has determined the 200 year flood flow to be 2000 cfs, which exceeds the flood of record. As stated above, the spillway capacity of Sabin Dam is 3650 cfs.

Therefore, the existing spillway capacity meets MDEQ requirements.

5.2 Results Of Most Recent FERC Operation Report (2006)

The most recent FERC inspection was conducted on 26 September 2006, and summarized in a report dated 8 February 2007. The report stated that the project structures were in satisfactory condition, with no action needed at the time. The following are some noteworthy observations presented in the 2006 FERC Operation Report:

- Cloudy standing water downstream of right embankment at location of original spillway. No change in condition from previous years, recommended frequent monitoring.
- Minor cracks noted in brick superstructure and the concrete divider between the two bays of the tailrace. Continued monitoring recommended.
- Minor concrete spalling on ogee sections of spillway.

5.3 Onsite Observations From Joint Site Inspection

General observations of the condition of the dam observed on the 5 September 2007 inspection are noted below. Items observed that may affect the alternatives being considered for this dam are discussed in the subsequent paragraphs.

- Rodent holes were observed at the downstream slope of the intermediate embankment.
- At the upstream side of the right end of the right embankment an area of change in vegetation was noted. It is speculated that this area had experienced erosion or a localized failure in the past and since has vegetated and stabilized.
- Concrete deterioration and spalling were noted on the downstream side of the powerhouse, as reported in the 2006 FERC Operation Report. It should be noted here that such spalling, will continue to increase with each winter season.
- The roof has been known to leak, per the Traverse City Light and Power Company. Leaking was evidenced by retrofitted gutters on the inside of the building near the downspouts.
- Deterioration of brick mortar joints and window lintels noted in many locations of the superstructure, along with minor cracks as reported in the 2006 FERC Operation Report.
- Corrosion noted on angle brackets at door and window framing.
- Cloudy standing water downstream of the right embankment at the location of the original spillway was observed, as reported in the 2006 FERC Operation Report.

No issues observed that would result in major rehabilitation for dam safety in the immediate future. Photos taken during the September site visit are presented in Appendix C.

5.4 Impacts To Existing Operations (Conditions Without Project)

No issues were observed that would result in major rehabilitation for the project in the immediate future. However, routine operation and maintenance, including roof, brick and concrete maintenance to prevent further deterioration of the powerhouse and dam structure would be required. Additionally, we recommend that when the power generation equipment is removed the flow of water through the dam be assessed. It may be necessary to make both shafts available for water flow. An alternative flow path may include closing off both shafts and routing all water through the spillway.

5.5 Potential Impacts To Breach/ Removal Of Sabin Dam

This alternative involves the complete or partial removal of the Sabin Dam. Site conditions observed that may impact this alternative are:

- Low flow culverts exist at the stop log portion of the spillway that may be useful for drawdown.
- Large tetrahedral concrete currently used as energy dissipaters may require removal or redistribution.
- Slope of intermediate embankment very steep. May impact construction access.
- The current dam was constructed in the 1930's, and was keyed into the original dam constructed in 1906. May have impacts on both construction operations and the State Historic Preservation Office (SHPO).
- Constructability issues such as the encountering of the original wood apron downstream of the dam, and the availability of the construction documents. The 1930s construction drawings are difficult to read. It may be necessary to obtain cleaner copies if they exist.

5.6 Potential Impacts To Construction Of A Fish Passage

Site conditions observed that may impact this alternative are:

- Sabin had a fish ladder, shown on 1917 map just east of the powerhouse. None currently existing.
- Potential for fish passage through old spillway location. Topography may be suitable.
- The concrete walls from the old spillway are still present. Removal or stabilization may be necessary. Coordination with SHPO would likely be required.
- There exists low flow culverts, which are currently bulkheaded. These could be investigated for use for fish passage/ bottom draw. Need opinion from fisheries expert on requirements for optimal fish passage and/ or water quality improvements.

5.7 Potential Impacts To Rerouting River And Leaving Dam In Place

This alternative involves rerouting the river around the dam, and leaving the dam in place. This would eliminate dam safety requirements without removing the dam.

- Topography at location of the old spillway east of the dam may be conducive to this alternative.
- Would require removal of the concrete walls of the old spillway. Would require coordination with SHPO.
- Hydraulic, real estate, and wetland impacts would need to be evaluated.

6.0 BOARDMAN (POND) DAM INSPECTION



Boardman Pond Dam, prior to drawdown

6.0 Description Of Dam

6.1.1 General Description

The Boardman (Pond) Dam is located at River Mile 6.1. The project consists of a detached embankment to the left of the dam, an emergency spillway in the left bank, a concrete spillway structure and the penstock intake, and a short right embankment. A short middle embankment is located between the spillway chute and the powerhouse. An excavated power canal feeds the reservoir to the intake structure. The description of project features in this section is taken from the 2006 FERC Operation Report for Boardman Dam. A site plan presenting an overview of the dam components is included as Figure 5 in the Appendix.

The detached embankment is 650 feet long and 43 feet high, and was constructed in the original river channel with compacted sand fill. A concrete head wall, which extends from the ground surface into the clay layer and into the river banks with steel sheet piling. The headwall provides upstream erosion protection and was constructed about 24 feet upstream from the crest center line.

The emergency spillway structure is located between the detached embankment and the dam/ bridge structure. A sheet pile control section is provided. The crest of the emergency spillway section is 2.1 feet lower than the crest of the detached dike. The

emergency spillway directs flow from the power canal into the area between the detached embankment and Cass Road embankment passing through an abandoned penstock and highway culvert.

The concrete (or principal) spillway is equipped with one split-leaf, 18-foot wide by 13 foot high steel roller gate operated with a fixed electric cable hoist. The gate was replaced during the 2000 construction season.

The middle earth embankment of the project is located between the spillway structure and the powerhouse.

The powerhouse has a reinforced concrete substructure and brick superstructure, and is located approximately 73 feet downstream of the intake structure. Two 10 foot diameter steel penstocks convey the flow to the powerhouse. The right penstock serves as a bypass spillway, and the left penstock is connected to the turbine. The powerhouse intake has a bubbler/ agitator system to prevent ice-buildup in winter.

The old powerhouse is shown on the 1930s construction drawings west of the existing dam, downstream of the existing detached embankment. The immediate area of the old dam was not observed.

6.1.2 Project History

The original Boardman Dam structure was constructed in 1894 for the Boardman River Light and Power Company. In 1930 the dam was reconstructed. Power was generated at the Boardman dam until 1969, at which time, the turbines and generators were removed and the dam was sold to the County. In 1983 the Boardman Dam was then redeveloped for power generation. Power generation recommenced in 1985 and continued until 2007.

6.1.3 Operation

In 2007, Traverse City Light and Power Company ceased operations of the dam for the generation of hydroelectric power. The power generation equipment is still in place, but it is our understanding that it will be removed at an unknown future date. It is also our understanding that other associated equipment may be removed as well, such as the agitator/ bubbler system.

While Traverse City Light and Power Company used the dam for hydroelectric power, they operated, monitored and maintained the Boardman Dam. Below is a description of the procedures that were followed during power generation and what is done now that power is no longer generated.

With Power Generation:

Water used for power generation traveled through the penstock to the turbine located on the left hand side of the powerhouse. Additional water discharge capacity was provided by the second penstock and the concrete spillway to the left of the penstock intake structure.

Without Power Generation:

There was no documentation available regarding the operation of the dam during the time period of which power was not being generated (1969-1983).

Changes in Operation:

Hydropower is no longer in use, and dam is being operated as a run of the river dam. All flow at time of inspection was being discharged through the right penstock (bypass spillway). The spillway was dry (excluding minor seepage). It should be noted that there is control available at the slide gates that prevents water from entering the turbine.

Upon the surrender of the operation of the Boardman Dam by the Federal Energy Regulatory Commission (FERC), the Michigan Department of Environmental Quality (MDEQ) assumed regulatory responsibility of the dam, at which time the MDEQ evaluated the dam for hazard and spillway capacity. Based on this evaluation, the MDEQ determined that the spillway capacity of the dam did not meet the MDEQ requirements for the high hazard potential rating that it have been given.

Consequently, in January of 2007, the MDEQ entered into a consent agreement with Grand Traverse County, the owner of the dam, for the required actions to be taken at the Boardman Dam. This consent agreement indicates the following:

- The MDEQ rated the Boardman Dam as a “high hazard potential dam”.
- The Boardman Dam spillway capacity does not meet the state requirements of Part 315.
- The County shall address the inadequate spillway conditions of the dam according to the following schedule
 - Draw down the water behind the dam by August 31, 2007.
 - Complete a feasibility study for options by September 30, 2008.
 - Complete design of spillway modification or removal by June 30, 2009.
 - Complete work on dam for spillway modification by December 31, 2010.
 - Complete work on dam for removal by December 31, 2012.
- The County must provide annual reports on the progress of this project.

Based on this consent agreement, during the summer of 2007 the water level behind the dam was lowered. It had been previously determined that the distance between the normal water level and the lowest outlet (invert of penstocks) is approximately 17 feet. The drawdown, however, resulted in approximately 16 feet of feasible water level lowering.

During our site visit in September, 2007, the water level behind the dam was at this drawn down elevation. It is planned that this water level will be maintained at this level until dam removal or modification to achieve compliance with the regulations is completed.

6.1.4 Existing Spillway Capacity

A spillway capacity of 9,070 cfs was reported in the 2005 PFMA Study. However, this capacity included a flow through the emergency spillway. The PFMA stated that the emergency spillway would fail by undercutting or erosion during use, due to the highly

erodible soil. Therefore the reported spillway capacity is problematic, as discussed below. The concrete spillway and both penstocks have a flow capacity of 4,550 cfs, corresponds to a reservoir elevation of 656.4 ft, National Geodetic Vertical Datum (NVGD). This elevation corresponds to the low point in the embankment at the emergency spillway.

6.1.5 FERC Requirements

Prior to decommissioning in January 2007, the Boardman Dam was regulated by FERC requirements.

The established IDF for the Boardman Dam is equal to the full PMF, or 11,600 cfs (2006 FERC Operation Report). Therefore, the spillway capacity at Boardman Dam does not meet FERC criteria.

Traverse City Light and Power has indicated that FERC had not directed modifications at the Boardman Dam, but expected FERC to do so after modifications were completed at Brown Bridge Dam, which is located directly upstream from Boardman Dam.

6.1.6 MDEQ Current Requirements

Upon the surrender of the operation of the Boardman Dam by the Federal Energy Regulatory Commission (FERC), the Michigan Department of Environmental Quality (MDEQ) assumed regulatory responsibility of the dam. The Boardman Dam is greater than 40-feet in height and has been assigned a high hazard potential rating; accordingly, the statute requires the spillway be able to pass a design flood equal to the ½ PMF, which MDEQ has established to be 6100 cfs. In their analysis, the MDEQ did not consider the flow capacity of the emergency spillway because of the documented likelihood that the emergency spillway would fail by undercutting or erosion under any significant flow, due to the high erodible soils. Under these assumptions, the total spillway capacity at Boardman Dam is 4,550 cfs, which is less than the capacity required by statute.

Therefore, the current spillway capacity does not meet MDEQ criteria.

MDEQ also routed the design flood through the facility assuming that the water surface was reduced to the maximum practical level. Considering only the flow capacity of the concrete spillway and the penstocks, MDEQ determined that the resulting water surface would approximate the top of the embankment, with no freeboard. Thus the directed lowering of the water level is considered to be only a temporary, emergency measure and not a permanent solution.

6.2 Results Of Most Recent FERC Operation Report (2006)

The most recent FERC inspection was conducted on 26 September 2006, and summarized in a report dated 6 February 2007. The report stated that the project does not meet the Commission's engineering dam safety standards and criteria due to insufficient spillway capacity. The following noteworthy observations were reported:

- Stated that remedial measures were taken in 1996 & 1997 to address seepage in the right abutment. Area was dry at time of inspection.
- Steel roller gate placed in 2000 was in excellent condition.
- Stated that repairs were made to the Cass River Road Bridge in 1997, and the supporting beams were in good condition.
- Seepage was reported in 2000 at the middle earth embankment (between the spillway structure and powerhouse). A gravity relief drainage system was installed in 2004, and was reported as draining approximately 60 gpm. In 2005, two more observation wells were added. At the time of this inspection, the area was reported to be dry and firm.
- Powerhouse noted in good condition, with a few cracks in grout noted on the downstream brick substructure of the powerhouse.
- Vertical offset and seepage were noted at the first joint from the left in the powerhouse gallery.
- Horizontal offset was noted at the second joint in the powerhouse gallery. Noted that a crack monitor installed in 1997, with no unusual trends noted.
- Noted that a drainage system was installed at the right abutment in the late 1990's, with the discharge pipe located to the right of the wing wall. It was reported that the pipe was discharging a small amount of water at the time of this inspection.
- Discussed void discovered beneath the right tailrace wing wall in July 2003. Void was approximately 1' x 1' x 1.5', with flow passing beneath it. Sandbags were placed to prevent additional scour.

6.3 Onsite Observations From Joint Inspection

General observations of the condition of the dam observed on the September 6th & 7th 2007 inspection are noted below. Items observed that may affect the alternatives being considered for this dam are discussed in the subsequent paragraphs.

- Dam is currently drawn down approximately 16 feet, as temporary risk mitigation action.
- Emergency spillway is very close to Cass River Road, and unlined. Soils are highly erodible.
- Cracking of the deck supports and beams were observed. There was also significant spalling and exposed rebar underneath parking deck.
- Roadway guard rails are in disrepair
- Structural cracking of Cass River Bridge supports.
- Posted load limitations for Cass River Road of 10-20 tons (depending on no. of axles)
- Downstream "chute" at spillway, seepage is visible at bottom of channel. 1930s construction plans show 4" drain tile located underneath slab. Could be a break in the pipe.
- Holes drilled through access deck for drainage are allowing water to erode material below deck.
- Penstock bay (downstream side of road) cracks and spalling
- Penstock bay- soil material observed in penstock bay are coming from road drain
- Corrosion of window and door frames
- Roof may need repair or replacement

- Seepage coming from left end of detached embankment and through monitoring weir
- Rodent hole noted on downstream slope of detached embankment

Photos taken during the September site visit are presented in Appendix C.

6.4 Impacts To Existing Operations (Conditions Without Project)

As previously stated, the Boardman Dam spillway capacity does not meet the MDEQ's requirements. Therefore, ultimately, action must be taken at the Boardman Dam as operating and maintaining the dam in its current state is not an option; modification alternatives for the dam must be considered. Such alternatives include, but are not limited to the following:

- Consider options for modifying the height of the dam to be less than 40-feet. With a height of less than 40-feet, the required spillway capacity would be the 200-year flood, 1,900 cfs. One such option would include lowering the crest of the concrete spillway. Studies would be necessary to determine the modifications necessary.
- Keeping the pool elevation at its current lowered level, accounting for the additional storage capacity in the impoundment and modifying the emergency spillway to provide reliable minimum additional flow capacity.
- Restoring the pool elevation to its previous level and providing modifications to the spillway to allow for the required spillway capacity.
- Keeping the pool elevation at its current lowered level, raising the dam embankments to provide required freeboard.

Additionally under this alternative, routine operation and maintenance would be required. Also, the structural integrity of the concrete access deck and Cass River Road Bridge support system would need to be evaluated, and possibly repaired.

The allowance for flow through both penstocks would also need to be addressed. Currently, only one penstock is available for flow. It should also be noted that it is understood that MDEQ's evaluation of the Boardman Dam accounted for the use of both penstocks. But, as noted above, only one penstock is currently operated.

6.5 Potential Impacts To Breach/Removal Of Boardman Dam

This alternative involves full or partial removal at Boardman Dam. Site conditions observed that may impact this alternative are:

- Wetlands exist downstream of old dam location, on west side of Cass Road.
- The Cass River Bridge is supported by the dam, and would need to be rebuilt if the dam was removed.
- The condition of the powerhouse parking deck may limit its use as a staging or access area.

6.6 Potential Impacts To Construction Of A Fish Passage

This option would require that MDEQ's dam safety concerns be addressed prior to installing a fish ladder or bottom draw to the existing dam. Therefore, costs would include those necessary under Alternative 1, as well as costs for installing fish passage or bottom draws.

- No easy option for fish passage.
- Steep topography at abutments would require significant excavation for fish passage.
- Spoil bank currently separates the Boardman River and the spillway outlet immediately downstream of the dam.
- Modifications to Cass River Road would be necessary for fish ladder
- Fish passage options would be difficult, due to the topography of the area, road crossing, and geometry of the dam.
- Passage of water is through either two 10' diameter penstocks, or the spillway immediately west of powerhouse. A modification to draw water from the bottom of the pond would likely be prohibitively expensive.

7.0 BROWN BRIDGE DAM INSPECTION



7.1 Description Of Dam

7.1.1 General Description

The Brown Bridge dam is the furthest inland of the four dams, at River Mile 18.5.

The existing Brown Bridge Dam consists of a left earth embankment, powerhouse/ spillway structure, log chute with a slide gate, and a right earth embankment. Additionally, there exists an abandoned fish ladder which intersects the right earth embankment near the powerhouse/ spillway structure. A diagram presenting a section through the powerhouse is shown in Figure 6 in Appendix A.

A more detailed description of each component is as follows:

The left earth embankment extends approximately 400 feet from the powerhouse. The lower portion of the embankment is a hydraulic fill and the upper portion is a compacted fill. There is a concrete wall along the upstream side of the embankment that is believed to serve only for wave protection and not as seepage cutoff. The top of the embankment serves as an access road to the powerhouse.

The powerhouse consists of a concrete substructure with a brick superstructure. The powerhouse currently contains two vertical shafts containing turbines. There are a total of four tainter gates, two upper and two lower. The lower gates allow for the water to bypass the turbines. Adjacent to the powerhouse is a log chute which contains a slide gate. A figure containing a section view taken through the powerhouse is included as Figure 7 in Appendix A.

The right embankment extends 1200 feet from the powerhouse/ spillway structure. The lower portion of the embankment is a hydraulic fill and the upper portion is a compacted fill. There is a concrete wall along the upstream side of the embankment that is believed to serve only as wave protection and not seepage cutoff.

7.1.2 Construction History

The original Brown Bridge Dam structure was constructed in 1921 for the Traverse City Light and Power Company. Power had been generated at the Brown Bridge dam since its construction at the time of its decommissioning in 2006.

In April 2003, the existing spillway at the Brown Bridge Dam was determined to be incapable of passing the Probable Maximum Flood without overtopping the embankments, therefore not complying with the FERC regulatory requirements. An auxiliary spillway was then proposed. This spillway was never constructed, but the construction plans are available.

7.1.3 Operation

While Traverse City Light and Power Company used the dam for hydroelectric power, they operated, monitored and maintained the Brown Bridge Dam. Below is a description of the procedures that were followed during power generation and what is done now that power is no longer generated. Traverse City Light and Power has indicated that there are no plans to remove the power generation equipment from Brown Bridge Dam.

With Power Generation:

While generating power the dam was operated in a run-of-river mode, the primary course for the water was to pass through the vertical shaft turbines and outlet from the powerhouse, discharging directly into the Boardman River. If additional discharge capacity was required, the slide gate was operated and the spillway and log chute was used. The headwater is allowed to fluctuate +/- 1.7 ft during operation. The impoundment was lowered 0.5 feet prior to spring runoff and anticipated major storm events. This was done to minimize effect on Boardman Pond. The Brown Bridge Dam was operated to discharge a continuous minimum flow of 100 cfs or the inflow to the reservoir, whichever is less, to protect fishery, wildlife and recreational resources in the Boardman River.

Without Power Generation:

Historically, since its construction, Brown Bridge has continuously generated power up to the decommissioning in November, 2006.

Changes in Operation:

Historically, the flow of water passed through the vertical shafts and exited the powerhouse directly into the river. Currently, all flow is directed through the right upper tainter gate and log chute; flow through the turbines has been halted. The tainter gate at the powerhouse is manipulated to regulate water flow. It is also our understanding that other associated equipment may be removed as well, such as the agitator/ bubbler system.

7.1.4 Existing Spillway Capacity

The July 1991 Addendum No. 1 Spillway Flood Studies for the Brown Bridge, Boardman, and Sabin Projects indicated that the Brown Bridge Dam spillway capacity is equal to 5,670 cfs. However, the two lower gates are currently inoperable. The spillway capacity without the two lower gates is equal to 2,900 cfs, per communications with FERC.

7.1.5 FERC Requirements

Prior to decommissioning in November 2006, the Brown Bridge Dam was regulated by FERC requirements.

The established IDF for the Brown Bridge Dam is equal to the full PMF, or 8,100 cfs (*Mead and Hunt, 2001*). As indicated above, the Brown Bridge spillway capacity is reported to be 2,900 cfs. Therefore, the existing spillway capacity does not meet current FERC criteria.

In April 2003, an auxiliary spillway was then proposed. This spillway was never constructed, but the construction plans are available.

7.1.6 MDEQ Requirements

Now that the dam is not being used for hydroelectric power generation, the Michigan Department of Environmental Quality has assumed full regulatory authority.. Brown Bridge Dam is less than 40-feet in height as thus required to have a spillway capacity capable of passing the 200-year flood. MDEQ has determined that the 200-year flood is equivalent to 1,100 cfs. As stated above, the Brown Bridge spillway capacity is reported to be 2,900 cfs. Therefore, the existing spillway capacity meets MDEQ criteria.

7.2 Results of most recent FERC Operation Report (2006)

The most recent FERC inspection was conducted on 26 September 2006, and summarized in a report dated 8 February 2007. The report stated that the project does not meet the Commission's engineering dam safety standards and criteria due to insufficient spillway capacity. The following noteworthy observations were reported:

- The left embankment was noted as in good condition.
- Lower two gates at the project were reported as inoperable.
- Minor spalling on concrete surface of ogee spillway.
- Powerhouse intake noted as in generally good condition, but noted several tight cracks with efflorescence.
- Seepage noted from right embankment. Flow was noted as clear (containing no visible fines). Area was noted as relatively dry.

7.3 Onsite Observations From Joint Inspection

General observations of the condition of the dam observed on September 7th 2007 inspection are noted below. Items observed that may affect the alternatives being considered for this dam are discussed in the subsequent paragraphs.

- Seepage and moist areas were observed near the toe of the downstream right embankment slope and downstream of the left and right embankment slopes.
- The drainage pipes located on the downstream slope of the right embankment showed evidence of fines being carried through the pipes. Several moist areas were noted on the right embankment. It should be noted that this appears to be a changed condition since the 2006 FERC Operation Report, in which seepage was reported at the right embankment, but the flow was noted as clear.
- Wetlands are present downstream of the right embankment. The wetlands seem to be fed from streams created from discharge of the drainage pipes. A series of weir boxes are present along the stream.
- Observations made onsite during the site visit raised serious concerns regarding the structural integrity of the concrete support piers for the slide gate of the log chute. Significant structural cracks were noted on the piers. It was recommended to the city to remove or alleviate the load on this gate until repairs to the concrete support piers could be made.
- Spalling and structural cracking of the concrete was observed at numerous locations in the downstream support piers for the tainter gates. These cracks were noted to be in the vicinity of the tainter gate trunnion pins or supports.
- The welds on the safety railing on the downstream side of the power plant deck were observed to be inadequate and in poor condition. It is recommended that no one lean on the railings, and warning signs should be posted until the rail posts are adequately attached to the deck.
- It was recommended that a thorough structural evaluation be conducted which includes testing of the existing concrete.
- Remnants of an old fish passage were visible on the right abutment.
- The City stated that old riverbed thought to be present along right abutment.
- Increased potential for scour immediately downstream of dam as a result of current water control operations consisting of release of water from the right spillway and log chute.

It should be noted here that the recommendation for structural evaluation at the Brown Bridge Dam was shared in communication between the USACE and the City. In response to this communication, the City is actively pursuing a structural evaluation of Brown Bridge Dam's structural components, an underwater inspection of the dam's interior components and spillway apron, evaluation of mechanical equipment including tainter gates, structural members, and trunnions, evaluation for power generation equipment removal, zebra mussel control, and embankment and seepage analysis.

Photos taken during the September, 2007 site visit are presented in Appendix E.

7.4 Impacts To Existing Operations (Conditions Without Project)

This alternative would require continued routine operation and maintenance of the Brown Bridge Dam, including vegetation maintenance at the embankments. Additionally, if the dam is to be retained structural repair and seepage remediation may be required based on the evaluations currently being pursued by the City. Immediate concrete repairs may be necessary to address the structural concerns for the upstream gate.

Another item that would need to be addressed under this alternative is the flow of water through the dam. Historically, the flow of water passed through the vertical shafts and exited the powerhouse directly into the river. Currently, all flow is directed through the right upper tainter gate and log chute. This current routing of the water has raised concerns that the downstream toe of the dam is experiencing additional scour and a heightened turbulence. This concern would need to be assessed under this alternative.

7.5 Potential Impacts To Breach/ Removal Of Brown Bridge Dam

A transformer box and multiple utilities are present on the left abutment.

7.6 Potential Impacts To Construction Of A Fish Passage

The location of the abandoned fish ladder is the most logical location for a new ladder. It appears that the original inlet is still present, but blocked.

This option would require that dam safety concerns be addressed prior to installing a fish ladder or bottom draw to the existing dam. Therefore, costs would include those necessary under Alternative 1, as well as costs for installing fish passage or bottom draws. These costs may make this alternative cost prohibitive.

Another item that would need to be addressed is the draw of water. During power generation water was drawn at mid pool level. Currently water is flowing through the tainter gate and log chute. It is recommended that samples be taken in Brown Bridge Pond to determine if there is a temperature gradient.

8.0 SUMMARY

8.1 Existing Spillway Capacities

The following is a summary of both the current and historic regulatory requirements for the four dams, the corresponding flows and the existing spillway capacities.

Table 1: Summary of Existing and Required Spillway Capacities

Dam	River Mile	200-year Flood	PMF	Regulatory Requirements		Flood of Record	Exist. Spillway Capacity	Meets FERC spillway criteria?	Meets MDEQ spillway criteria?
				FERC (IDF) ⁴	MDEQ				
Union Street	1.5	2000 ¹	N/A	N/A	2000 (200-yr)	1220 (9/14/61) ⁵	2000 ¹	N/A	YES
Sabin	5.3	2000 ²	11600 ³	2,000 ³	2000 (200-yr)	1220 (9/14/61) ⁵	3650 ⁶	YES	YES
Boardman	6.1	1900 ²	11600 ⁷	11,600 ⁷	6100 (½ PMF) ²	1220 (9/14/61) ⁵	4,550 ⁸	NO	NO
Brown Bridge	18.5	1100 ²	8100 ⁹	8100 ⁹	1100 (200-year)	1220 (9/14/61) ⁵	2900 ¹⁰ (5670 ¹¹)	NO	YES

All flows in cubic feet per second (cfs)
 PMF = Probable Maximum Flood
 IDF = Inflow Design Flood

¹ Union Street Dam Inspection Report, 2005

² MDEQ Correspondence

³ Sabin Dam FERC Operation Report, 2006

⁴ FERC requires uses the Inflow Design Flood (IDF) for the required spillway capacity. See paragraphs 4.1.5, 5.1.5, and 6.1.5 for full discussion.

⁵ Report of Inspection, 1994. The flood of record was obtained at a stream gage near Mayfield, upstream of the dams. The value reported at this stream gage on 9/14/61 is the value indicated in this report.

⁶ Sabin Dam PFMA, 2005.

⁷ Boardman Dam FERC Operation Report, 2006

⁸ Boardman Dam PFMA, 2005.

⁹ Brown Bridge Dam FERC Operation Report, 2006

¹⁰ Spillway capacity, accounting for inoperable lower gates (FERC Correspondence)

¹¹ Spillway capacity, with lower gates in operation, Brownbridge Dam PFMA, 2005

It should be noted that the Boardman Dam is the only structure that does not have sufficient spillway capacity to meet the requirements of Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act 451 of 1994, as amended. However if there continues to be a system of two or more dams on the Boardman River, we recommend that in addition to the state statute, spillway capacities be based upon a risk assessment of the functioning of the entire system of dams in an extreme flood event.

8.2 Required Action for Conditions without Project

As indicated in the above table and in our discussions in this report, the Boardman Dam does not meet the MDEQ spillway capacity requirements. Therefore, action must be taken at the Boardman

Dam to comply with the regulations. Additionally, there are dam safety issues that would need to be addressed.

Even though the Brown Bridge Dam complies with the MDEQ spillway capacity requirements, as discussed above, there are some dam safety concerns at Brown Bridge that need to be addressed.

For all the dams, continued routine operation and maintenance will need to be performed.

8.3 Recommendations

Based on our observations of the dams, information gathered on the dams from existing documentation, and discussions presented in this report, we offer the following recommendations for next steps for each of the dams.

8.3.1 *Union Street Dam*

The City of Traverse City is currently pursuing additional evaluation of the Union Street Dam. We recommend that any concerns or issues that arise as a result of this evaluation be addressed as necessary.

8.3.2 *Sabin Dam*

As indicated above in this report, no immediate action is recommended at Sabin Dam aside from routine operation and maintenance.

We also recommend that preliminary engineering cost estimates for the following alternatives be established:

- Long term operation and maintenance with dam left in place.
- Modifications to operation of dam.

8.3.3 *Boardman Dam*

As indicated above in this report, the Boardman Dam currently does not comply with the MDEQ regulatory requirements. Action must be taken in order to meet compliance. It is recommended that preliminary engineering cost estimates be established for the following alternatives that will result in the Boardman Dam be in compliance with the regulations:

- Modification to the existing spillway.
- Modification to the emergency spillway.
- Modification to the detached embankment.

We also recommend that the following preliminary engineering cost estimates be established:

- Long term operation and maintenance
- Modifications to operation of dam.

Aside from the cost estimates, we recommend that a structural evaluation be conducted at Boardman Dam. As indicated in this report, there is particular concern for the Cass Road Bridge and the access deck. We would then recommend that any concerns or issues that arise as a result of this evaluation be addressed as necessary.

8.3.4 Brown Bridge Dam

The City of Traverse City is currently pursuing additional evaluation of the Brown Bridge Dam. We recommend that any concerns or issues that arise as a result of this evaluation be addressed as necessary.

We also recommend that preliminary engineering cost estimates for the following alternatives be established:

- Long term operation and maintenance with dam left in place.
- Modifications to operation of dam.

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APPENDIX A: FIGURES

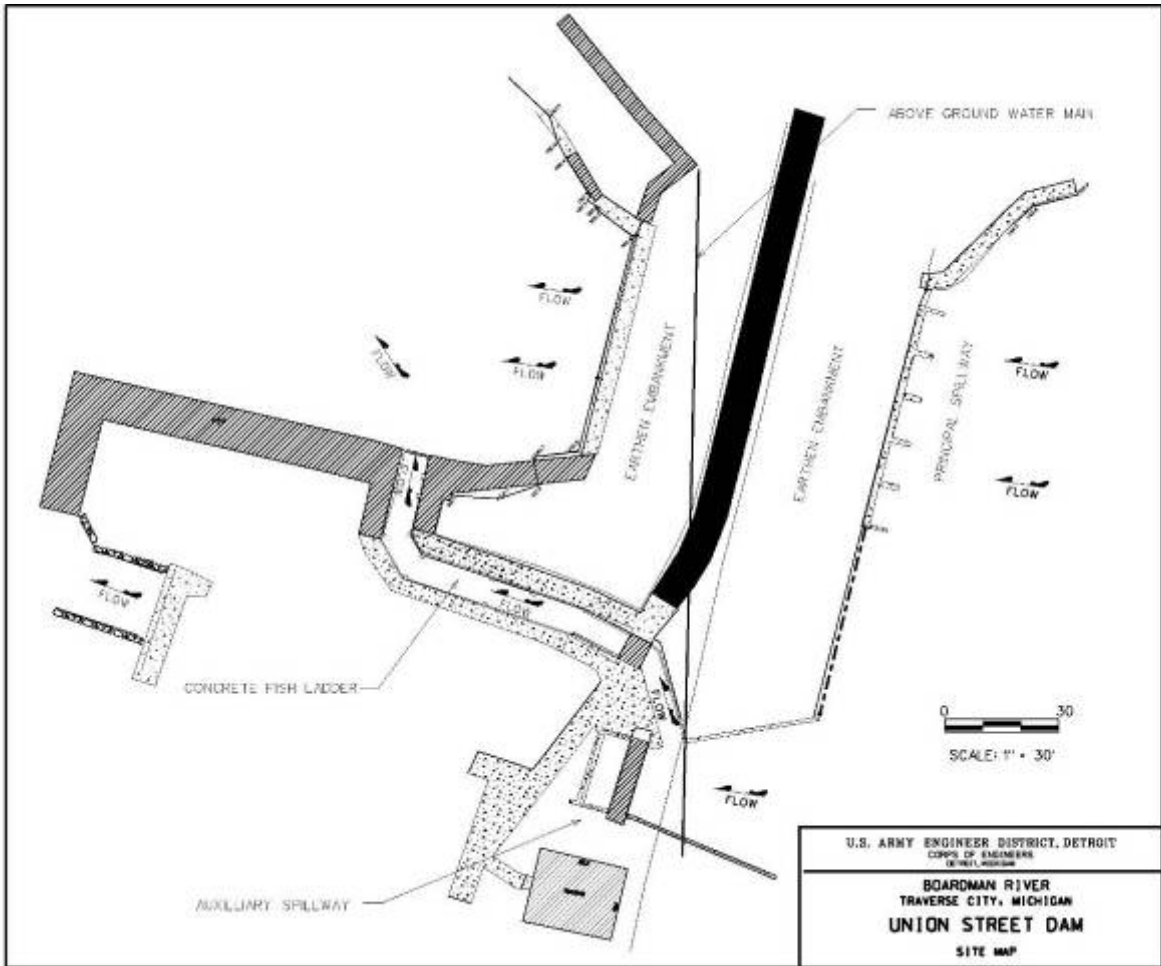


Figure 1 – Union Street Dam – Site Plan

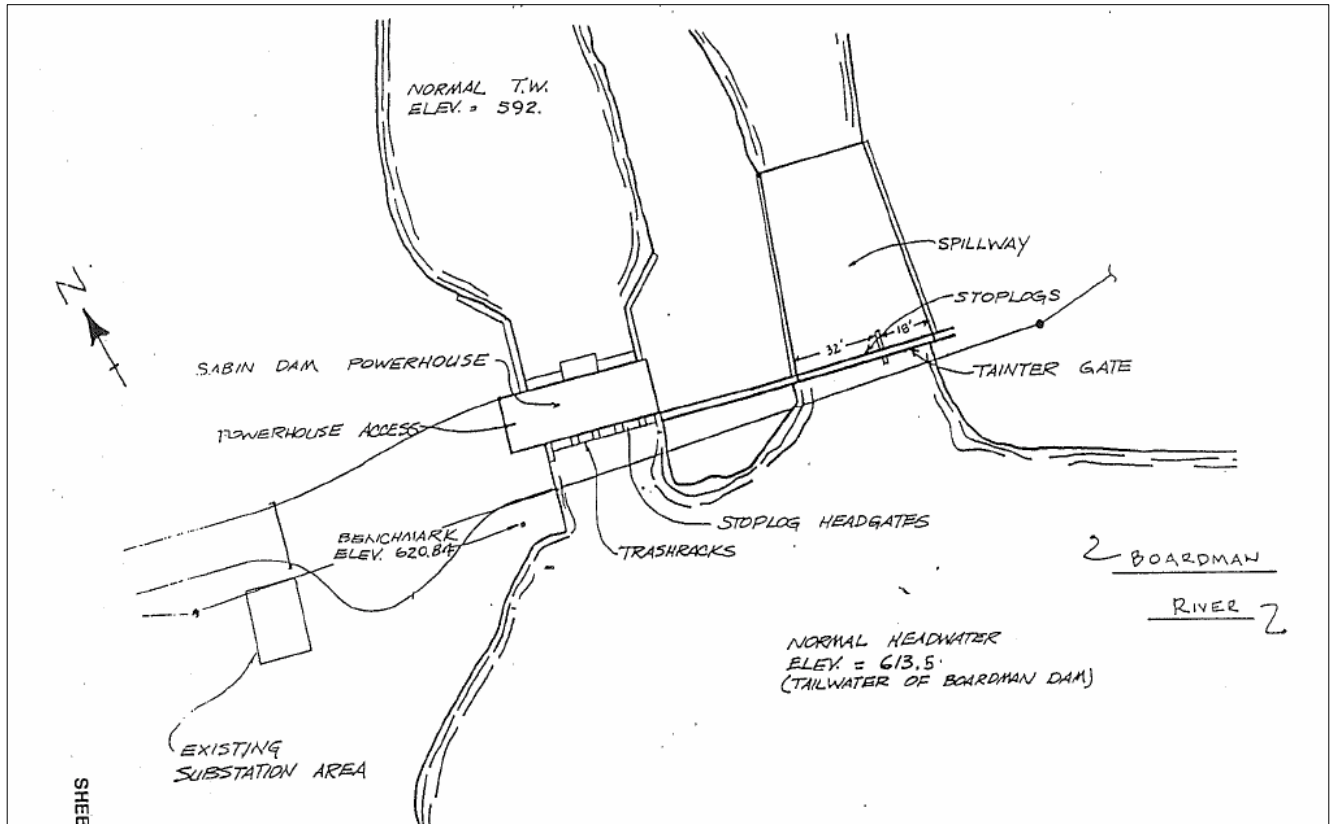


Figure 2. Sabin Dam- Site Plan (Mead & Hunt, 1999)

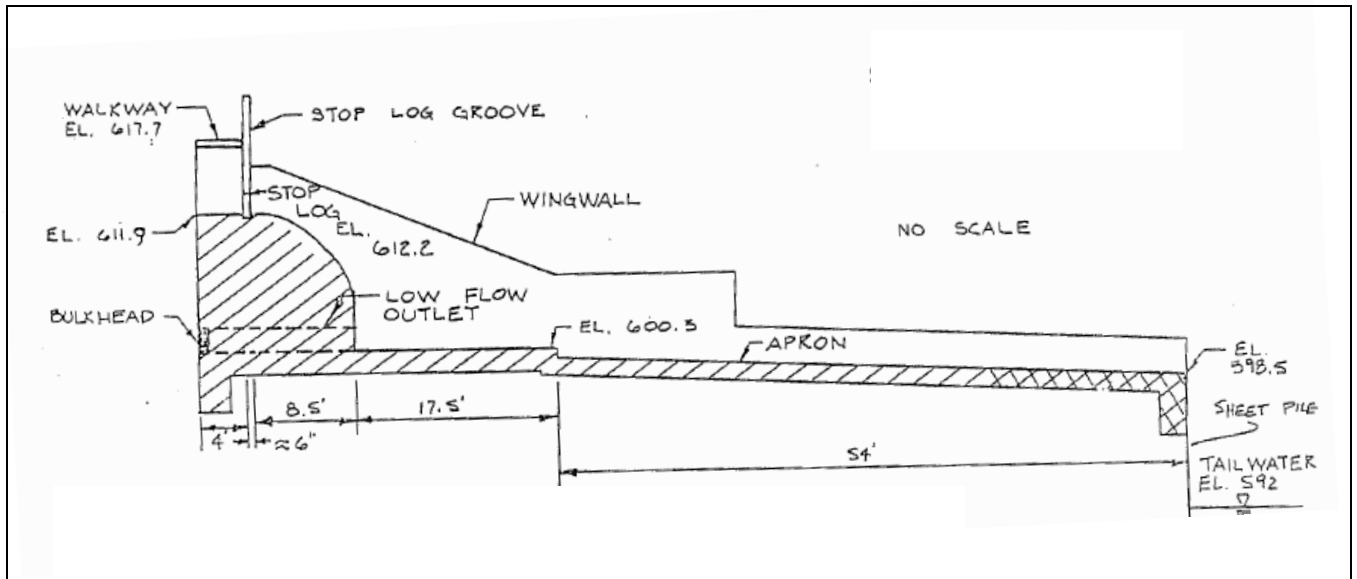


Figure 3. Sabin Dam- Section Through the Stop Log Spillway (Mead & Hunt, 1999)

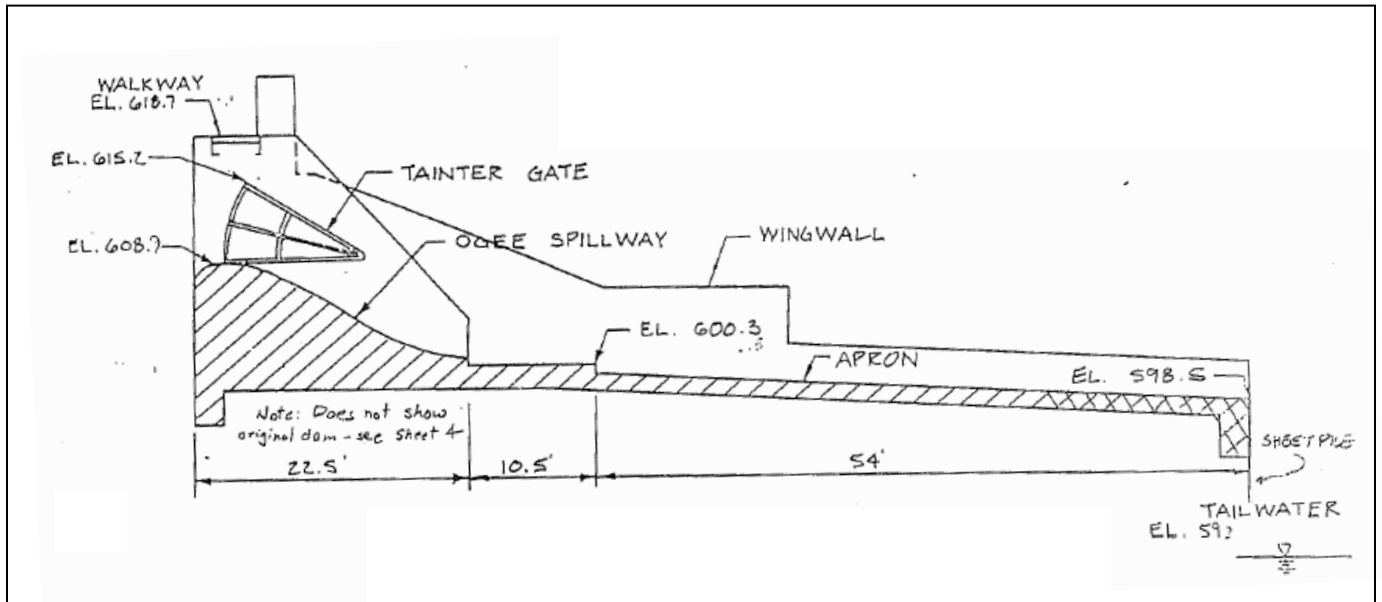


Figure 4 Sabin Dam- Section Through the Tainter Gate Spillway (Mead & Hunt, 1999)

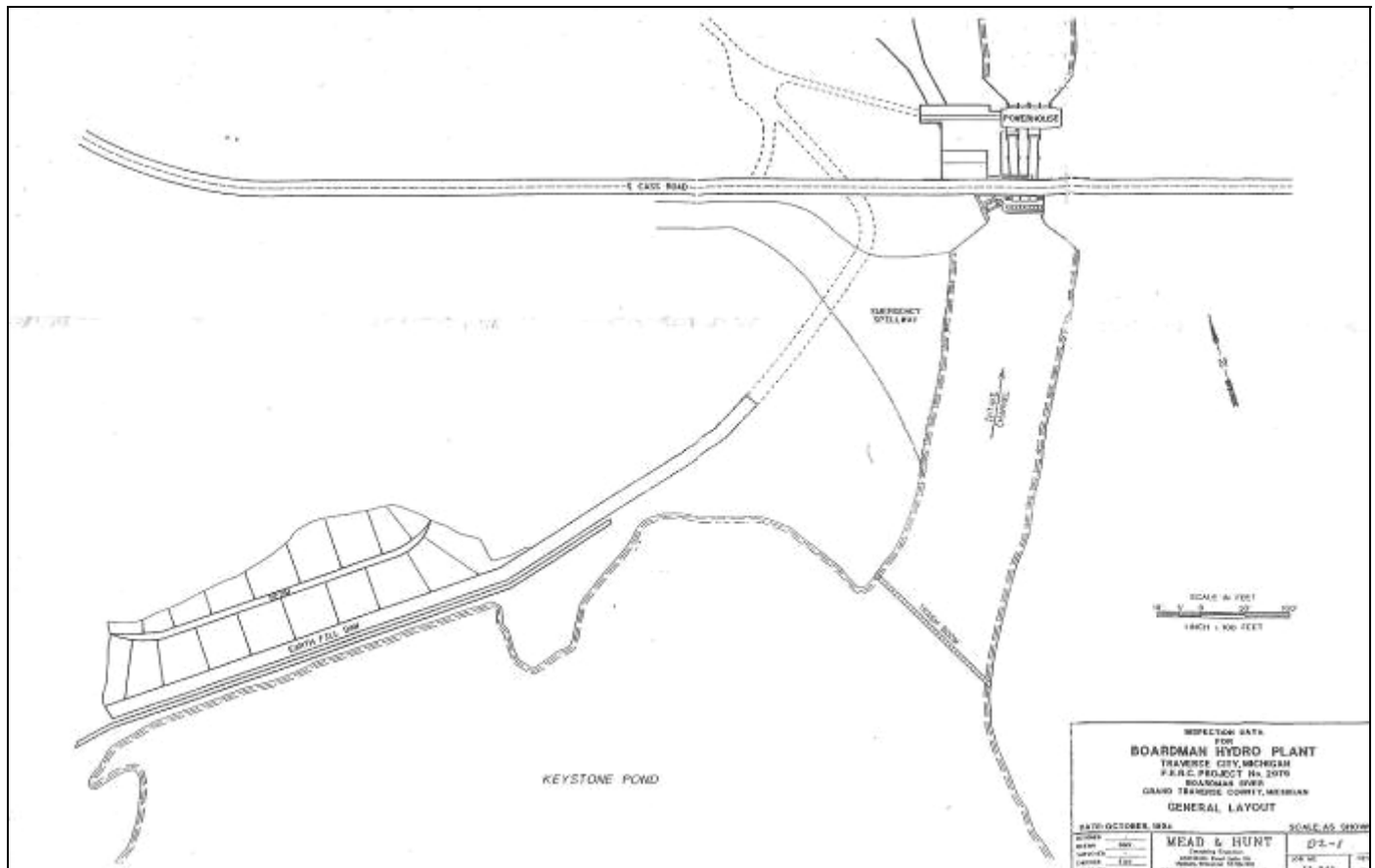


Figure 5. Boardman Dam- Site Plan (Mead & Hunt, 1999)

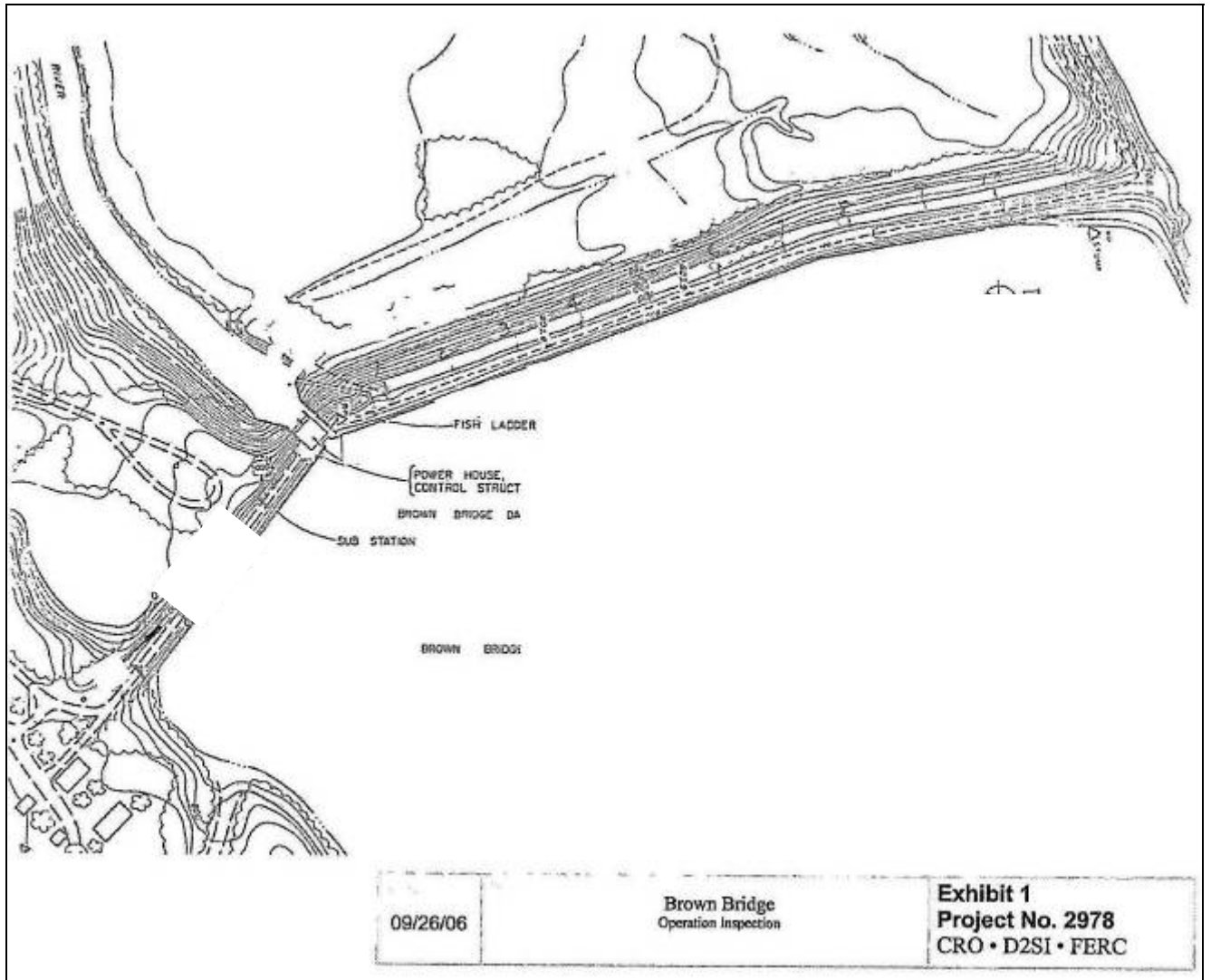


Figure 6: Brown Bridge Dam – Site Plan (FERC 2006 Report)

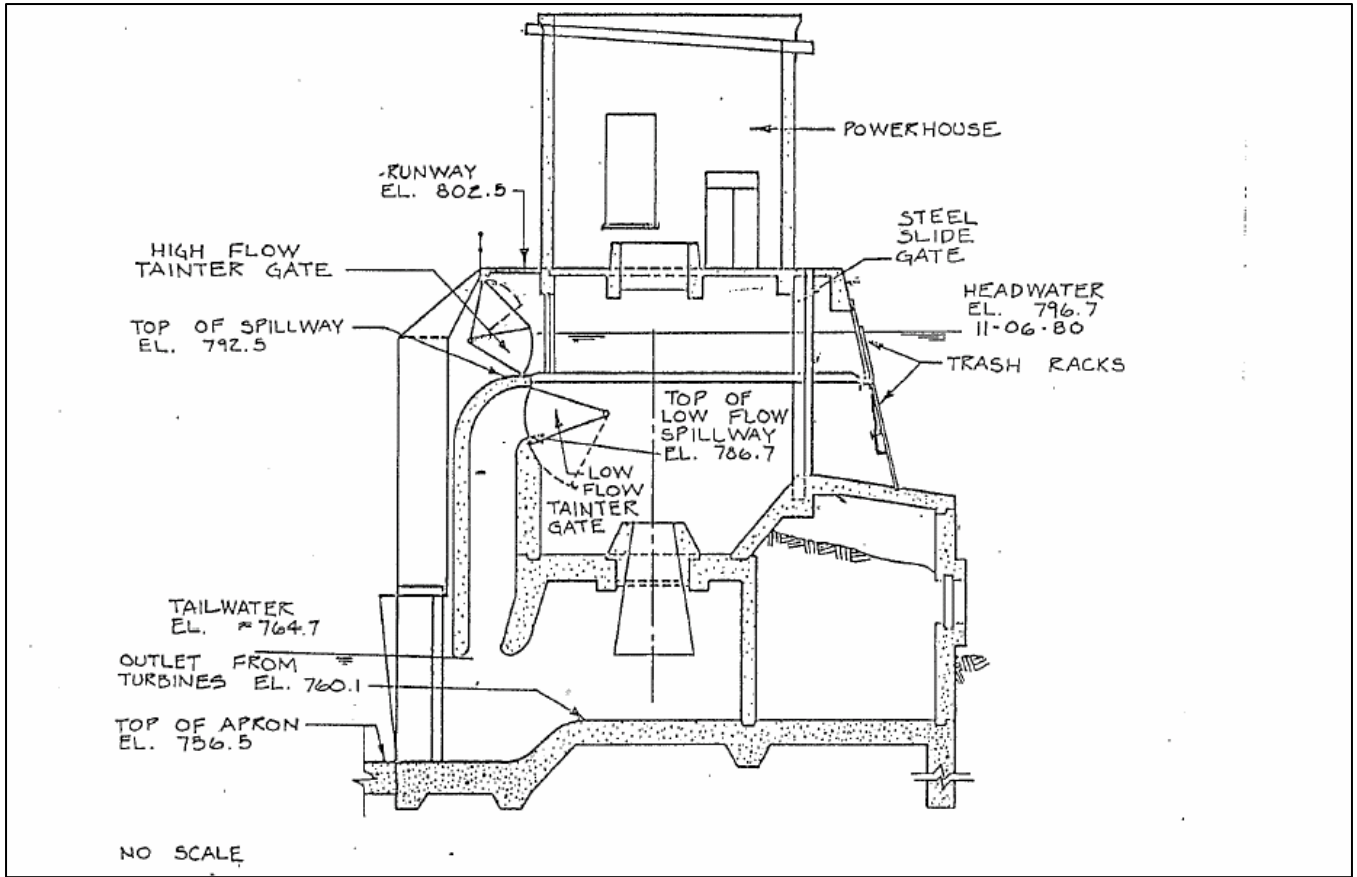


Figure 7. Brown Bridge Dam- Section Through Powerhouse (Mead & Hunt, 1999)

APPENDIX B: UNION STREET DAM PHOTOGRAPHS

Union Street Dam
09-06-07



Trash rack on upstream side of inlet section of auxiliary spillway



Upstream side of stop log overflow section of auxiliary spillway



Upstream of principal spillway, view from left embankment, looking right



Upstream of stop log overflow section of auxiliary spillway



Downstream side of stop log overflow section of auxiliary spillway



Downstream side of stop log overflow section of auxiliary spillway

Union Street Dam
09-06-07



Fish ladder, view looking upstream



Fish ladder, view looking downstream



Downstream side of principal spillway



Downstream side of principal spillway



Riprap and seepage at left embankment of principal spillway



Riprap and seepage at left embankment of principal spillway

Union Street Dam

09-06-07



Sidewalk adjacent to downstream side of principal spillway
Note seepage at edge of sidewalk



Upstream slope at principal spillway, view looking right



Left end of upstream slope at principal spillway, irregularities
In slope noted



Downstream slope at principal spillway, note irregularities in
slope



Downstream slope at principal spillway, left end, note large tree

APPENDIX C: SABIN DAM PHOTOGRAPHS

Sabin Dam
09-05-07



Interior of powerhouse



Signage of hydro electric power generation equipment



Trash racks at upstream side of powerhouse spillway.



Upstream shoreline of the intermediate embankment- note rip rap placed to control erosion.



Upstream side of stop log spillway and tainter gate spillway



Upstream side of stop log spillway and tainter gate spillway

Sabin Dam
09-05-07



Downstream side of stop log spillway



Downstream slope of intermediate embankment



Downstream slope of intermediate embankment, near power house.



Rodent holes observed at downstream slope of intermediate embankment



Downstream of tainter gate spillway



Standing water downstream of right embankment (downstream of original spillway)

Sabin Dam
09-05-07



View from right embankment, looking left



Standing water downstream of right embankment
(downstream of original spillway)



Seep at original spillway structure, right abutment wall



Seep at toe of right embankment, near standing water



Seep at original spillway structure, left abutment wall



Original spillway structure, left abutment wall

Sabin Dam
09-05-07



Downstream slope of right embankment- note, piezometers
(County continues to monitor piezometers)



Upstream side of dam, view from right embankment



Downstream side of stop log spillway



Downstream side of tainter gate spillway



Upstream of right embankment, once eroded but since
stabilized vegetated area



Downstream of right embankment, unvegetated sandy area
with unexplained hole

Sabin Dam
09-05-07



Downstream of right embankment, unvegetated sandy area



Downstream side of stop log and tainter gate spillways



Downstream side of stop log spillway, note spalling/ deterioration



Downstream of stop log and tainter gate spillways, view from intermediate embankment, looking right



Downstream side of powerhouse



Downstream of powerhouse

Sabin Dam
09-05-07



Downstream slope of left embankment, soft moist areas



Downstream side of powerhouse, view from left embankment, note spalling/ deterioration



Tail water staff gauge downstream of power house
(County reads head and tail water elevations each day)



Seep at powerhouse at left embankment



Area of seepage at powerhouse at left embankment



Left embankment, view looking right

Sabin Dam
09-05-07



View looking down at stop logs at power house spillway, concrete deterioration noted.



Right side of power house, note corrosion of window framing
Failing brick work noted



Interior of power house, note make-shift roof leak collection

APPENDIX D: BOARDMAN DAM PHOTOGRAPHS

Boardman Dam
09-05-07 & 09-06-07



Access deck to the left of the powerhouse, note deterioration



Storage bay



Underneath of access deck, note cracking and deterioration



Storage bay, note cracks



Underneath access deck, note cracking and deterioration



Underneath access deck, note cracking and deterioration

Boardman Dam
09-05-07 & 09-06-07



Downstream left of powerhouse, note water flowing



Downstream side of powerhouse



Right downstream abutment of powerhouse, note water flowing



Downstream side of powerhouse and access deck



Downstream left embankment and access deck



Downstream of powerhouse, view of right embankment

Boardman Dam
09-05-07 & 09-06-07



Downstream of spillway, note seeps in bottom of channel



Downstream of spillway, note seeps in bottom of channel



Downstream of spillway, note seeps in bottom of channel



Downstream of spillway, note seeps in bottom of channel



Downstream of spillway, view of left abutment



Downstream side of powerhouse

Boardman Dam
09-05-07 & 09-06-07



Downstream side of access deck



Downstream side of access deck



Downstream of spillway, view of left abutment



Left side downstream of powerhouse



Left side downstream of powerhouse



Right side downstream of powerhouse

Boardman Dam
09-05-07 & 09-06-07



Right side downstream of spillway, note cracking



Upstream of road and intake, note possible concrete debris



Gate at spillway



Right upstream abutment



Downstream side of road, note penstocks



Downstream side of road

Boardman Dam
09-05-07 & 09-06-07



Downstream side of road abutment



Downstream side of spillway, note seepage



Downstream side of spillway, note seepage



Downstream side of gate at spillway



Right wall at spillway, note cracks



Right wall at spillway, note cracks

Boardman Dam
09-05-07 & 09-06-07



View looking downstream at base of powerhouse and penstocks



Upstream face of powerhouse



Under deck at entrance to powerhouse, appearance of recent concrete repairs



Signage of hydro electric power generation equipment



Interior of powerhouse



Power generation equipment

Boardman Dam
09-05-07 & 09-06-07



Crack monitors in lower level of powerhouse



Downstream of spillway, note seepage



Supports for access deck



Underneath of access deck, downstream of powerhouse



Lower level of powerhouse, location of "leak" earlier this year



Upstream face of dam

Boardman Dam
09-05-07 & 09-06-07



Upstream side of dam



Upstream side of dam, right side



Upstream side of intakes



Upstream side of spillway and intakes



Detached earth embankment, view looking left



Detached earth embankment, view looking right

Boardman Dam
09-05-07 & 09-06-07



Detached earth embankment downstream slope



Detached earth embankment, downstream slope, note standing water at toe of slope



Detached earth embankment downstream slope, right end



Detached earth embankment downstream slope, left end



Seepage at left end of detached earth embankment



Seepage at left end of detached earth embankment

Boardman Dam
09-05-07 & 09-06-07



Rodent hole on downstream slope of detached embankment



Downstream slope of detached embankment



Downstream of detached embankment, note stone and pipe



Downstream of detached embankment, note stone



Downstream of detached embankment, note stone



Upstream of detached embankment, note concrete wall

Boardman Dam
09-05-07 & 09-06-07



Sheet pile extending at right side of concrete wall at detached embankment



Emergency spillway, view looking left/ downstream

APPENDIX E: BROWN BRIDGE DAM PHOTOGRAPHS

Brown Bridge Dam
09-07-07



View from left end of left embankment, looking right



Upstream slope and impoundment at left embankment



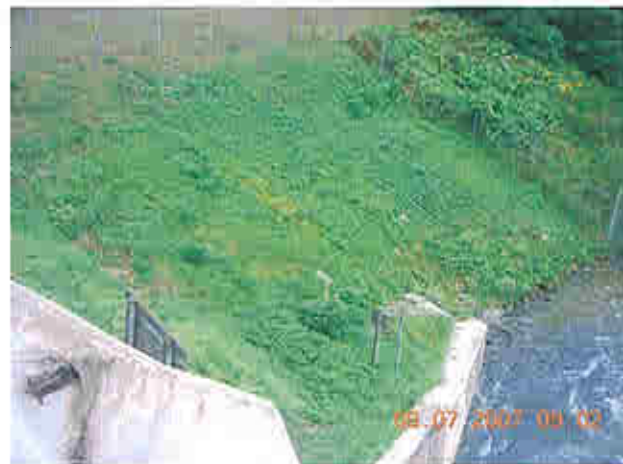
Downstream slope of left embankment at left end, note wet toe



Downstream slope of left embankment near powerhouse



Downstream of powerhouse spillway



Downstream slope of left embankment near powerhouse

Brown Bridge Dam
09-07-07



Upstream side of trash racks at tainter gate spillway



Upstream side of trash racks at tainter gate spillway



Upstream of tainter gate spillway



Downstream side of log chute gate



Downstream of log chute spillway



Downstream of log chute spillway, looking upstream

Brown Bridge Dam
09-07-07



Right downstream embankment to the right of the powerhouse



Support at tainter gate, note cracking and degradation



View from right downstream embankment slope



Left downstream abutment and embankment



Downstream right embankment slope



Downstream side of gate at log chute spillway

Brown Bridge Dam

09-07-07



Pipe at downstream slope of right embankment



Downstream slope of right embankment, note heavy vegetation near bottom quarter of slope



Pipe with flowing water and sedimentation, downstream slope of right embankment



Pipe with flowing water and sedimentation, downstream slope of right embankment



Pipe with flowing water and sedimentation, downstream slope right embankment



Downstream slope of right embankment

Brown Bridge Dam
09-07-07



Downstream slope of right embankment



Downstream of downstream slope of right embankment



Downstream slope of right embankment



Downstream slope of right embankment



Downstream slope of right embankment



Monitoring weir downstream of downstream slope of right embankment- assumed to measure seepage flow

Brown Bridge Dam
09-07-07



Monitoring weir downstream of downstream slope of right embankment- assumed to measure seepage flow



Stream downstream of downstream slope of right embankment assumed to originate from seepage at slope



Stream downstream of downstream slope of right embankment



Downstream side of dam



View of left embankment



Measurement weir- assumed to measure seepage and natural stream flow

Brown Bridge Dam

09-07-07



Measurement weir- assumed to measure seepage and natural stream flow



Area downstream of downstream slope of right embankment



Seepage downstream of downstream slope of right embankment



Right embankment, view looking right



Left face of left wall of right tainter gate spillway



Right face of left wall of right tainter gate spillway

Brown Bridge Dam
09-07-07



Left face of left wall of right tainter gate spillway



Downstream slope of left embankment, note heavy vegetation



Downstream slope of left embankment, note vegetation, irregular ground surface noted, some soft areas



Downstream slope of left embankment, note vegetation, irregular ground surface noted, some soft areas



Downstream slope of left embankment, note heavy vegetation, erosion noted along fenceline



Downstream slope of left embankment, note heavy vegetation, erosion noted along fenceline

Brown Bridge Dam

09-07-07



Roadway just left of powerhouse, view looking right
Note low area in roadway

APPENDIX F: ACRONYMS & DEFINITIONS

ACRONYMS

cfs	cubic feet per second
CMP	corrugated metal pipe
FERC:	Federal Energy Regulatory Commission
gpm	gallons per minute
IDF:	Inflow Design Flood
MDEQ:	Michigan Department of Environmental Quality
PMF:	Probable Maximum Flood
PFMA:	Probable Failure Mode Analysis
TCLP:	Traverse City Light & Power

DEFINITIONS

Inflow Design Flood (IDF): The flood flow above which the incremental increase in water surface elevation due to failure of a dam or other water impounding structure is no longer considered to present an unacceptable threat to downstream life and property.

Freeboard: Vertical distance between a specified stillwater (or other) reservoir surface elevation and the top of the dam.

Probable Maximum Flood (PMF): The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the drainage basin under study.