Consulting
Engineers and
Scientists

## DRAFT – Feasibility Study

# Flat Rock-Huroc Dam Disposition

Flat Rock, Michigan

**Submitted to:**

Huron-Clinton Metropolitan Authority
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**Submitted by:**


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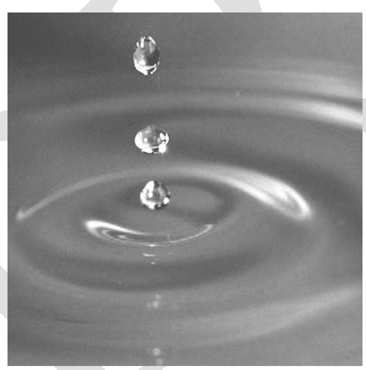
GEI Project No. 2302140

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# Definitions

**Bathymetric Survey**: A survey that measures the depths and shapes of underwater terrain. It involves mapping the underwater topography to understand the contours and features of the seabed or riverbed.[1]

**Ammocoete**: The larval stage of lampreys, characterized by an extended period of development where they burrow into sediment and filter feed.[2]

**Bankfull Flow**: The flow level at which a river or stream fills its banks and begins to overflow into the floodplain. It is often used as an indicator of the channel-forming flow.[1]

**Bottomland**: Low-lying land adjacent to a river, typically subject to periodic flooding.[2]

**Compensating Cut**: Excavation made to balance the fill needed in construction, ensuring that there is no net gain or loss of material.[3]

**Crest**: The highest point or edge of a dam or spillway over which water flows.[1]

**Dam Breach**: The failure of a dam, resulting in an uncontrolled release of water from the impoundment.[3]

**Design Flood**: The flood event used in the design of structures to ensure safety and functionality, usually with a specific probability of occurrence.[3]

**Design Flood Structural Height**: The height of a structure such as a dam designed to withstand the design flood.[3]

**Dewater**: The process of removing water from a construction site, mine, or an area for maintenance.[2]

**Efficacy-Duration Analysis**: An analysis method to determine the effectiveness of a system or intervention over a specified period.[2]

**Engineered Grade Control**: Structures designed to stabilize the slope or gradient of a stream channel to prevent erosion and maintain channel form.[1]

**Fish Ladder**: A structure built to enable fish to navigate around obstacles such as dams by providing a series of ascending pools.[5]

**Fishway**: A structure on or around artificial and natural barriers (such as dams and waterfalls) to facilitate fish migration.[5]

**Floodplain**: Flat land adjacent to a river that is subject to flooding during periods of high discharge.[3]

**Free-overfall**: The condition where water flows freely over an edge or crest without being submerged.[1]

**Hydraulic Load**: The amount of force exerted by fluid (water) flow, typically on structures such as dams or levees.[1]

**Impoundment**: A body of water confined by a barrier, such as a dam, for storage, flood control, or other purposes.[1]

**Lamprey Barrier**: A structure designed to prevent the upstream migration of invasive lampreys while allowing the passage of other aquatic species. [2]

**Lock**: A device used for raising and lowering boats between stretches of water of different levels on river and canal waterways.[1]

**Ogee Crest**: A type of spillway crest shape that resembles an S-curve, providing efficient flow control and energy dissipation.[3]

**Overbanking**: When the flow of water exceeds the bankfull capacity of a river and spills onto the floodplain.[1]

**Peak Flow Attenuation**: The reduction of the peak discharge in a flood event, typically achieved through storage or other flood management measures.[3]

**Raceway Channel**: A constructed secondary channel providing waterway access to manufacturing facilities.

**Riparian Rights**: The rights of landowners whose property is adjacent to a river or stream to reasonable use of its water.[1]

**Riverine Conditions**: The natural characteristics and dynamics of a river system, including flow, sediment transport, and ecological processes.[1]

**Rock Ramp Fishway**: A type of fishway that uses a series of rock structures to create a gradient allowing fish to navigate upstream.[4]

**Scour**: The erosion or removal of sediment from the bed or banks of a river, often around structures such as piers or abutments.[1]

**Spillway**: A structure used to provide the controlled release of water from a dam or levee into a downstream area.[1]

**Tailwater**: The water located immediately downstream of a hydraulic structure, such as a dam or spillway. [1]

**Thalweg**: The line connecting the lowest points along the bed of a river or stream, often the main navigational channel.[1]

**Water Surface Elevation**: The height of the water surface above a specified datum, such as mean sea level.[1]

**Weir**: A barrier across a river designed to alter its flow characteristics and manage water levels.[1]

1. U.S. Geological Survey (USGS): USGS Water Resources Glossary: https://water.usgs.gov/glossaries.html

2. Environmental Protection Agency (EPA): EPA Terms

3. Federal Emergency Management Agency (FEMA): FEMA Floodplain Management Glossary: https://www.fema.gov/about/glossary

4. US Fisheries and Wildlife Services (FWS): Glossary: https://www.fws.gov/policy-library/e1710fw2
5. National Oceanic and Atmospheric Administration (NOAA): NOAA Fisheries Glossary, https://repository.library.noaa.gov/view/noaa/12856

# 1. Executive Summary

## 1.1 Background

The changes in energy generation needs, scientific knowledge, and the regulatory environment have prompted a reevaluation of the viability of dams across Michigan by dam owners, resource agencies, and the communities where dams are located. Moreover, many dams have exceeded their 50-year design life and can pose hazards to human life and property. The century-old Flat Rock Dam and the smaller 60-year-old Huroc Dam on the Huron River are the subject of a feasibility study to assess this aging infrastructure.

The Huron-Clinton Metropolitan Authority (Huron-Clinton Metroparks) and the City of Flat Rock as owners of the Flat Rock Dam and the Huroc Dam, respectively, bear significant responsibilities. Both owners are liable for public safety at the dams and their impoundments. The larger Flat Rock Dam also must meet state dam safety requirements, including maintenance and regular safety inspections by credentialed inspectors. Huron-Clinton Metroparks also needs to stay abreast of future state permitting requirements and budget accordingly.

The dam owners partnered with Michigan Department of Natural Resources (MDNR), Great Lakes Fishery Commission (GLFC), and Huron River Watershed Council (HRWC) to seek funding for this feasibility study. In 2023, the partners secured a NOAA Fisheries Regional Partnership Grant funded through the Great Lakes Restoration Initiative (GLRI) for this project as it aligns with the GLRI's goals of protecting and restoring native species, providing a barrier to sea lamprey, and focuses on improving habitat connectivity for vital Great Lakes species.

## 1.2 Purpose of the Feasibility Study

The feasibility study is an information-gathering exercise designed to help the dam owners understand current conditions and explore various alternative scenarios for the Flat Rock and Huroc Dams and the associated impoundments. This study does not make any determinations or recommendations regarding the best course of action; rather, it is meant to provide conceptual-level (10%) designs of dam alternatives and assess the challenges and benefits of each alternative in relation to flooding, environmental considerations, ecosystem function, economics, public safety, and constructions costs.

The feasibility study addresses aging dam infrastructure while also focuses on enhancing fish passage, reconnecting critical tributary habitats, reducing the Huron-Clinton Metroparks' liability associated with the Flat Rock Dam, and minimizing sea lamprey risks. Additionally, the study seeks to address secondary objectives: reveal unique bedrock substrate behind the

Flat Rock Dam; remove a hazardous portage to improve the Huron River Water Trail; replenish coastal wetlands and sediment in Lake Erie at Pointe Mouillee; and expand habitat for endangered freshwater mussels downstream from the dams.

This study is the initial phase of a multiphase process that will ultimately lead to a decision on the future of the dams by the dam owners, which includes the option to take no action .

## 1.3 Key Findings

GEI Consultants, Inc. led the consulting team that performed the feasibility assessment. Over 12 months, all existing data were reviewed. Field research—topographic and bathymetric surveys, sediment sampling, delineation of wetlands, threatened and endangered species review, and a cultural resources review—was conducted as part of the assessment.

These data fed into a more detailed analysis of four potential alternatives for the study area:

- No action taken except for fish passage improvements
- Partial removal of Flat Rock and Huroc Dams
- Full removal of Flat Rock and Huroc Dams with active restoration
- Full removal of Flat Rock and Huroc Dams with passive restoration

## 1.4 Current Conditions

The Flat Rock Dam is in fair condition with no immediate safety concerns, according to recent dam safety inspections. The Huron-Clinton Metroparks are responsible for the monitoring and maintenance of the dam. The Flat Rock impoundment is approximately 188 acres and most of the impoundment is one to three feet deep with some sections as deep as eight to ten feet closer to the dam. The Flat Rock Dam currently prevents the passage of sediment—a natural river process—so the impoundment has accumulated a significant volume of sediment as indicated by the shallow water depths. The current impoundment is occasionally used for flatwater recreation primarily by nearby residents. The current portage route around the dam for paddlers is inconvenient and requires advanced notice to a business for the gate to be unlocked. An existing Denil fishway is located on the south side of the dam to allow fish passage. The Huron River Fishing Association constructed and maintains the fishway. Through fish surveys, the fishway appears to be an ineffective method of fish passage for most native fish species.

The Huroc Dam is about 2.5 feet tall and does not meet criteria for regulation by the Michigan Environment, Great Lakes, and Energy (EGLE) Dam Safety Unit. The dam impounds only the 6.9-acre area up to the Flat Rock Dam.

## 1.5 Proposed Conditions

### *Alternative One—No Action: Fish Passage Improvements*

The Flat Rock and Huroc Dams remain but fish passage is improved by replacing the Denil fishway with a new, nature-like rock ramp. The new fishway would be built in the same area as the old Denil fishway and the unused boat lock on the south side of the Flat Rock Dam.

### Benefits and Drawbacks

**Benefits**: This option continues current recreational (i.e., flatwater) activities, maintains current impoundment levels to adjacent properties, and improves fish passage for native fish species.

**Drawbacks**: This option perpetuates ongoing sediment buildup, potential water quality issues within the impoundment, disrupts the river ecosystem, does not holistically solve fish passage concerns, and requires ongoing maintenance costs.

### Cost Estimates

**Estimated one-time costs**: Implementation costs are estimated at $3.35 million, including 30 percent for unexpected costs, 10 percent for design and permitting, and 10 percent for construction oversight.

**Estimated life cycle costs:** In 2024 dollars, the 50-year life cycle cost (including initial construction) ranges from $5.85 million to $9.35 million, depending on dam safety regulatory changes. With inflation, life cycle costs could be $17.18 million to $25.21 million.

### *Alternative Two—Partial Removal of Flat Rock and Huroc Dams*

The Flat Rock and Huroc Dams are partially removed while maintaining a similar reservoir level and tailwater conditions. Rock arch rapids are added at both dam sites.

### Benefits and Drawbacks

**Benefits:** This option continues current recreational (i.e., flatwater) activities, maintains current impoundment levels to adjacent properties, holistically improves fish passage for native fish species, reduces the risks associated with the Flat Rock Dam, and removes the hazardous portage for paddlers.

**Drawbacks:** This option perpetuates ongoing sediment buildup, contributes to potential water quality issues within the impoundment, disrupts the river ecosystem, and requires ongoing maintenance costs.

## Cost Estimates

**Estimated one-time costs:** Implementation costs are estimated at $12.58 million, including 30 percent for unexpected costs, 10 percent for design and permitting, and 10 percent for construction oversight.

**Estimated life cycle costs:** In 2024 dollars, the 50-year life cycle cost (including initial construction) ranges from $15.07 million to $15.67 million. With inflation, life cycle costs could be $26.41 million to $28.34 million. Alternative Three—Full Removal of Flat Rock and Huroc Dams with Active Restoration

### *Alternative Three—Full Removal of Flat Rock and Huroc Dams with Active Restoration*

The Flat Rock and Huroc Dams are fully removed, and the river is actively restored. The dams are demolished in stages and sediment is excavated and redistributed within the project area outside the proposed river channel and floodplain. The restoration includes creating new habitats, stabilizing riverbanks, realigning the river, and reconnecting the floodplain to the river channel.

### *Alternative Four—Full Removal of Flat Rock and Huroc Dams with Passive Restoration*

The Flat Rock and Huroc Dams are fully removed but a passive approach is taken to restoration. The dams are taken down in stages to lower the water level gradually. Sediment is managed by creating a pilot channel in the river and redistributing the sediment within the project area outside the proposed river channel and floodplain, and the river is allowed to naturally restore itself with minimal human intervention.

## Benefits and Drawbacks: Alternatives Three and Four

**Benefits:** These options improve the river ecosystem, increase the potential for new parkland, eliminate future dam maintenance costs, reduce risk from dam failure, change the types of recreation, remove the difficult portage, and could be eligible for greater funding opportunities.

**Drawbacks:** These options have high one-time construction costs, change the types of recreation, and lower the impoundment levels to adjacent properties, which may generate opposition from property owners.

## Cost Estimates: Alternatives Three and Four

**Alternative three (active restoration) construction cost:** The initial cost to implement this option is $39.93 million, including 30 percent for unexpected costs, 10 percent for design and permitting, and 10 percent for construction oversight. Ongoing maintenance costs account for invasive species control after removal.

**Alternative three estimated life cycle costs:** Ongoing maintenance costs account for invasive species control after removal. In 2024 dollars, the 50-year life cycle cost (including initial construction) is $41.30 million. With inflation, life cycle costs could be $43.33 million.

**Alternative four (passive restoration):** Implementation costs are estimated at $31.30 million, including 30 percent for unexpected costs, 10 percent for design and permitting, and 10 percent for construction oversight. Ongoing Maintenance costs account for invasive species control after removal.

**Alternative four estimated life cycle costs:** Ongoing maintenance costs account for invasive species control after removal. In 2024 dollars, the 50-year life cycle cost (including initial construction) is $32.92 million. With inflation, life cycle costs could be $35.0 million.

### *Sea Lamprey Barrier Options*

Sea lamprey is a parasitic invasive species that attach to other fishes, often killing them. The United States Fish and Wildlife (USFWS) and Great Lakes Fishery Commission (GLFC) monitor and consider control measures throughout the Great Lakes to prevent sea lamprey migration. The Flat Rock Dam currently acts as a barrier to the passage of sea lamprey to upstream reaches of the Huron River. Sea lamprey have been observed in the Huron River downstream of the Flat Rock Dam in relatively low population numbers and generally the risk of sea lamprey infestation in the Huron River is low.

For alternatives two, three, and four, which consider removal of the Flat Rock Dam as a barrier, three potential locations for sea lamprey barriers were explored. These locations were the existing Flat Rock Dam, the Huroc Dam, and downstream of the Telegraph Road bridge crossing.

Both physical barriers and behavioral barriers (electric barriers) were assessed and ranked according to criteria such as sedimentation, ability for non-jumping fish to pass, initial cost, maintenance, public safety, and flooding potential. Each potential approach has advantages and disadvantages.

Cost to construct an effective sea lamprey barrier, if determined necessary (i.e., upon indications of increased numbers of sea lamprey in the Huron River), range from $5.2 million to $8.84 million in 2024 dollars. Costs for a potential sea lamprey barrier would be the responsibility of the USFWS Sea Lamprey Control Program.

## 1.6 Community Engagement

The dam owners and project partners recognize the importance of the dams and impounded waters to the community. Community engagement in the various phases of the feasibility study is critical to the process and arriving at a viable future alternative. The consulting team conducted stakeholder briefings for community leaders, elected representatives, as well as two community engagement sessions. The first session was held in August 2023 and the second will occur in fall 2024 prior to completion of the final study.

## 1.7 Next Steps

The authority to make decisions about the dams rests with their owners; the Huron-Clinton Metroparks Board of Directors and the Flat Rock City Council will follow their respective processes. Once a decision is made, funding for the projects must be identified and final design services for the preferred alternative can move forward. Depending on which alternative the dam owners select, this phase could take nine to 18 months or more, depending on funding for the project. Review of the design by permitting agencies (i.e., EGLE and U.S. Army Corps of Engineers) will occur concurrent with design phase and can take six to nine months or more. Then, the project would be put out for bid to potential construction contractors, typically a two- to three-month process. Finally, construction would occur, and, depending on the selected alternative, could take nine months to two years.

Funding for future design work has been secured through the NOAA grant award, however has not been formally accepted. Additional funding would need to be secured for the construction phase.

## 1.8 Comparison Table of the Alternatives

| Consideration | Alternative 1 – No Action: Fish Passage Improvements | Alternative 2 – Partial Dam Removal of the Flat Rock and Huroc Dams | Alternative 3 – Full Dam Removal of the Flat Rock and Huroc Dams with Active Restoration | Alternative 4 – Full Dam Removal of the Flat Rock and Huroc Dams with Passive Restoration |
|---|---|---|---|---|
| **Hydrologic and Hydraulic** | No change in impoundment water levels or flood elevations. | Minimal to no change in impoundment water levels. No increase in flood elevations upstream of Flat Rock Dam; possible compensating cut needed between Flat Rock and Huroc Dam. | Decrease in water levels: 5-6.4 feet immediately upstream of Flat Rock Dam tapering to existing WSE 14,200 feet upstream, 1.3-1.4 feet decrease in water levels between Flat Rock and Huroc Dams. | |
| **Geotechnical and Structural** | Utilizes existing structures; may require elevation adjustments and structural investigation of existing lock. | Encounters bedrock; partial dam removal will not significantly increase hydraulic loads on the W. Huron Drive bridge. | Exposes unique and rare bedrock; further investigation during detailed design should be done to confirm dam and bridge structures are structurally isolated. | |
| **Economic Impact** | No long-term impact expected. | Partial dam removal boosts recreation, jobs, and local value. | Property values are influenced by proximity to water, with dam removal mainly impacting adjacent properties, while the rest of the area sees smaller effects. Long-term value trends depend on factors like water quality, recreational opportunities, and the success of the river and green space restoration. Alternative results in increased long-term labor income and recreational value. Significantly reduces economic burden on dam owner by removing dam. | |
| **Wetlands and Endangered Species** | Wetlands unaffected; mussel survey and relocation may be required within the footprint of the proposed fishway. | Minimal potential impact to wetlands in the immediate work area. Mussel survey and relocation may be required within the footprint of the proposed rock rapids. | Existing fringe wetlands may dry with lowered impoundment, but exposed bottomlands expected to form some wetlands where excavated sediment are not placed. Potential net gain of 70 acres of wetlands. | |
| **Fish Passage** | Effective for Lake Sturgeon, Walleye, and White Bass. | More effective than fish ladders or bypass channels. | Opens 19 river miles for fish habitat and migration. | |

| Consideration | Alternative 1 – No Action: Fish Passage Improvements | Alternative 2 – Partial Dam Removal of the Flat Rock and Huroc Dams | Alternative 3 – Full Dam Removal of the Flat Rock and Huroc Dams with Active Restoration | Alternative 4 – Full Dam Removal of the Flat Rock and Huroc Dams with Passive Restoration |
|---|---|---|---|---|
| **Aquatic Organism Habitat** | Little to no habitat improvement expected. | Partial dam removal improves fish and mussel habitat within the rock arch rapids area only. | Full removal provides largest habitat improvement by restoring a natural river system; active restoration mitigates temporary negative impacts and typically shows better short-term recovery. | Full removal provides the largest habitat improvement by restoring a natural river system; Passive restoration may lead to temporary negative habitat impacts until equilibrium is re-established. |
| **Sediment** | No change to existing sediment transport regime, where dam prevents sediment transport downstream and impoundment collects sediment. Sediment will continue to build up within the impoundment. | Similar sediment regime to existing conditions, where dam prevents sediment transport downstream and impoundment collects sediment. Sediment will continue to build up within the impoundment. | Over 1,000,000 cubic yards of sediment is contained within the impoundment of which 370,000 to 390,000 cubic yards is at greatest risk for mobilization; Active restoration approach will mechanically remove sediment within proposed river channel and floodplain areas. Silts and organic material may be difficult to manage but once sediment is managed all risk is removed. | Over 1,000,000 cubic yards of sediment is contained within the impoundment of which 370,000 to 390,000 cubic yards is at greatest risk for mobilization; Passive restoration approach will mechanically remove sediment within proposed channel area, leaving floodplain sediment to naturally mobilize. Channel mobility and sediment transport downstream will occur until river system reaches equilibrium. |
| **Dam Safety** | Flat Rock Dam remains a high-hazard dam. Huroc Dam remains unregulated. | Flat Rock Dam potentially downgraded to low-hazard dam. Huroc Dam remains unregulated. | Dams are removed, removing all risk and all long-term safety hazards. | |
| **Public Utilities** | No public utilities impacted. | | Additional investigations to identify existing stormwater outlets may be required and riprap stabilization incorporated into design, as needed. | |
| **Public Safety and Recreation** | Recreational access unchanged with paddlers required to use gated portage route. | In-river barrier removed allowing paddlers to pass downstream through | Barrier removed and no portages required with the project area returned to a functioning riverine system | |

| Consideration | Alternative 1 – No Action: Fish Passage Improvements | Alternative 2 – Partial Dam Removal of the Flat Rock and Huroc Dams | Alternative 3 – Full Dam Removal of the Flat Rock and Huroc Dams with Active Restoration | Alternative 4 – Full Dam Removal of the Flat Rock and Huroc Dams with Passive Restoration |
|---|---|---|---|---|
| | | rock arch rapids or utilize safer, easier to access portage route adjacent to river. | | |
| **Regulation Change Considerations** | Potential dam regulation changes may add $3.5 million to maintenance costs over 50 years. | Potential dam regulation changes may add $600,000 to maintenance costs over 50 years. | Flat Rock Dam removed and no longer regulated by EGLE. No long-term maintenance costs anticipated. | |
| **Initial Cost to Construct Estimate** | Flat Rock Dam – $2.6 Million<br>Huroc Dam – $750,000<br>Total – $3.35 Million | Flat Rock Dam – $11.35 Million<br>Huroc Dam – $1.23 Million<br>Total – $12.57 Million | Flat Rock Dam – $37.09 Million<br>Huroc Dam – $2.84 Million<br>Total – $39.93 Million | Flat Rock Dam – $29.57 Million<br>Huroc Dam – $1.73 Million<br>Total – $31.30 Million |
| **Additional 50-year Life Cycle Cost Estimate (2024 Dollars and Future Dollars based on annual 4% interest rate)** | *2024 Dollars:*<br>$2.5 Million (No Legislation Change) / $6 Million (Legislation Change)<br>*Future Dollars:*<br>$13.85 Million (No Legislation Change) / $21.86 Million (Legislation Change) | *2024 Dollars:*<br>$2.5 Million (No Legislation Change) / $3.1 Million (Legislation Change)<br>*Future Dollars:*<br>$13.84 Million (No Legislation Change) / $15.77 Million (Legislation Change) | *2024 Dollars:*<br>$1.37 Million<br>*Future Dollars:*<br>$3.40 Million | *2024 Dollars: $1.62 Million*<br>*Future Dollars: $3.70 Million* |

# 2. Introduction

The Flat Rock and Huroc Dams are located on the Huron River and are 9 miles upstream of Lake Erie. The Flat Rock Dam is owned by the Huron-Clinton Metropolitan Authority (HCMA) and the Huroc Dam is owned by the City of Flat Rock. Through an existing partnership, HCMA, the Michigan Department of Natural Resources (MDNR), the Great Lakes Fishery Commission (GLFC), Huron River Watershed Council (HRWC), and the City of Flat Rock submitted for a National Oceanic and Atmospheric Administration Fisheries Regional Partnership Grant funded through the Great Lakes Restoration Initiative. This grant was used to develop a feasibility study (this report) that considers alternatives for the Huroc and Flat Rock Dams. Each alternative considered within this study focuses on improving fish passage and reconnecting important tributary habitat to Great Lakes species while also minimizing the risk of sea lamprey infestation. The project boundary for this study includes the upstream and downstream areas influenced by the dams (Figure 1).

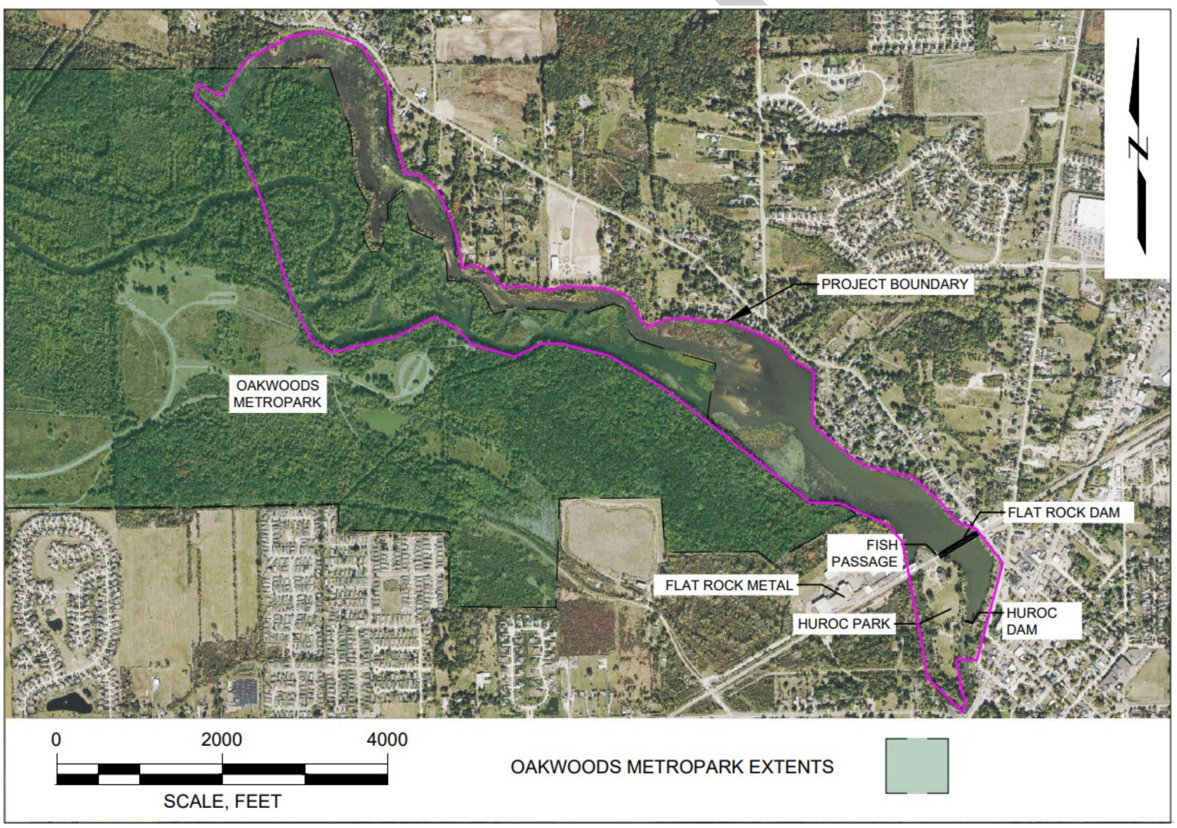


Figure 1: Project Overview

## 2.1 Background

The Ford Motor Co. built the Flat Rock Dam in the 1920s to generate hydroelectric power for its Headlamp Factory, but it ceased power generation in 1950. In 1951, the company sold the dam and adjoining land (approximately 349 acres) to the HCMA for recreational use. Currently, HCMA's Oakwoods Metropark, located in New Boston, MI, includes the dam and the impoundment behind it. Spanning 1,756 acres, Oakwoods Metropark offers various recreational activities including boat rentals, canoeing, kayaking, and fishing on the Huron River and within the impoundment.

Communication between MDNR and HCMA began in 1980 regarding construction of a fish ladder at the dam site. In 1984 and 1988, the MDNR Fisheries Division requested HCMA consider removing the dam due its blockage of fish passage on the Huron River. Both times MDNR’s request was denied, citing the dam and impoundment as crucial parts of Oakwoods Metropark. In 1995, the Huron River Fishing Association installed a fish ladder to address ecological issues posed by the dam, particularly fish passage. Repairs to the fish ladder were recently completed by the Huron River Fishing Association in 2023.

Several significant events have occurred since HCMA has gained ownership of the Flat Rock Dam. In 1956 the City of Flat Rock constructed a water intake in the lock portion of the dam until 1980 when the city connected to Detroit City water and abandoned the previous water intake. The City of Flat Rock prohibited portaging around the dam from 1977 - 1983, partially in response to a fatal boating accident for which the City of Flat Rock was found liable.

HCMA has preserved and maintained the structural integrity of the dam through two large rehab projects in 1990 and 2008. A 1987 inspection found severe cracking of the crest along the left[1] half length of the dam and severe separation of the gunite from a portion of the original concrete dam. In 1990 Saturn Construction completed the repairs at a cost of $363,825. In 2007, a Stantec Engineering inspection report indicated cracking and spalling of the right retaining wall and abutment as well as areas of erosion and concrete deterioration in the left spillway abutment, and deterioration of areas of the spillway crest. Following the inspection report, Stantec was retained by HCMA to provide design and construction of the repairs needed for the dam. Construction cost of the repair project was estimated at $1,600,000. A written history of the dam from the early 1800s to 2007 is included with available historic drawings of the Flat Rock Dam in Appendix B.

Currently, the dam maintains a recreational impoundment, supporting lacustrian fish and wildlife habitat, fishing, and boating activities. In 2023, HCMA, in partnership with

[1] Directional notations are from the perspective of looking downstream.

GLFC, MDNR, HRWC, and the City of Flat Rock, secured grant funding from NOAA and contracted GEI Consultants of Michigan, P.C. (GEI) to develop a feasibility study that considers no action – fish passage improvement, partial dam removal and full dam removal alternatives for the Huroc and Flat Rock Dams.

The City of Flat Rock owns the Huroc Dam, located directly downstream of the Flat Rock Dam. The Huroc Dam was constructed in 1954 with a truss bridge built in conjunction with the weir crest. In 1995 the truss bridge was replaced with a covered pedestrian bridge that exists at the site today. This bridge utilized the existing bridge piers. No information regarding the original purpose or use of the dam has been found during the feasibility study.

## 2.2 Purpose

This study considers alternatives for the Huroc and Flat Rock Dams that will address long-term planning for aging infrastructure, improve fish passage, and reconnect important tributary habitat to Great Lakes species while also minimizing the risk of sea lamprey infestation. This feasibility study will explore multiple options for accomplishing these goals.

The goals defined at the start of this project include:

- Minimize the risk of sea lamprey- a parasitic invasive fish species-infestation to the extent possible and necessary.
- Allow for the improved passage and travel of native species, such as lake sturgeon (***Acipenser fulvescens***), walleye (***Sander vitreus***), and white bass (***Morone chrysops***).
- Improve and connect natural habitats along the Huron River.
- Reduce future risk of dam failures and possible downstream damage that could occur in the event of a failure.
    - The current EGLE dam safety rating has classified the Flat Rock Dam as a high hazard potential dam. "High hazard potential" indicates a dam located in an area where a failure may cause serious damage to critical infrastructure, critically harm the environment, or where failure could cause potential loss of life.
    - The Huroc Dam is not regulated by the EGLE Dam Safety unit due to its small size and minimal impoundment.

Several other secondary goals have been considered; this list is not all inclusive:

- Uncovering unique and rare high gradient bedrock substrate that is inundated by the Flat Rock Dam (MDNR, Huron River Assessment, 1995).
- Enhancement of the Huron River Water Trail through the removal of a challenging portage at the Flat Rock Dam.
- Replenishment of sediment and coastal wetlands along Lake Erie and Point Mouillee as these coastal areas provide critical habitat for migratory waterfowl, dissipate energy at the confluence of the Huron River with Lake Erie, and provides recreation opportunities for fishing, bird watching, and waterfowl hunting.
- Increase suitable habitat for freshwater mussels including, but not limited to the federally endangered Snuffbox (***Epioblasma triquetra***) and their primary host fish species Logperch (***Percina caprodes***) that have been documented in the Huron River a short distance downstream of the project site.
- Reduce HCMA's liability associated with the Flat Rock Dam.

## 2.3 Scope of Work

To accomplish the listed goals the engineering team was charged with review of all existing available information and a significant field data collection effort. New data collected as part of this study includes topographic and bathymetric survey, sampling of sediments located within the dam impoundments, wetland delineation and threatened and endangered species review, and cultural resources review.

Once the data collection phase was completed, the team developed four (4) dam disposition alternatives including:

- No removal action with provision for improved fish passage.
- Partial dam removal.
- Full dam removal with active restoration.
- Full dam removal with passive restoration.

Each alternative included development of a conceptual level hydraulic model to assess impacts to water surface elevations, scour, and fish passage. An evaluation of sea lamprey blockage was also completed by considering either maintenance of the existing Flat Rock Dam, which currently serves as a barrier (http://data.glfc.org/), or a new seasonal or adjustable barrier to maximize lamprey blockage while also providing for native fish passage.

Each dam alternative was then evaluated for challenges and opportunities, and conceptual level cost estimates were developed to help inform the dam owners.

## 2.4 Authorization

GEI and their project team performed engineering consulting services for the Huron-Clinton Metropolitan Authority – Project No. 2302140 (Project), with the work authorized by the Huron-Clinton Metropolitan Authority by means of the Professional Services Agreement dated April 15th, 2023.

## 2.5 Personnel

The following GEI personnel were primarily responsible for performing the engineering analyses for this report:

| | |
|---|---|
| Project Principal: | Troy Naperala, P.E. |
| Project Manager: | Janeen McDermott, P.E. |
| Field Investigation and Restoration: | Sam Prentice, P.E. |
| Hydraulic Engineer: | Emma Giese |
| Geostructural Engineer: | Mike Carpenter, P.E. |
| Dam Safety Engineer: | Dan DeVaun, P.E. |

## 2.6 Elevation Datum

Elevations (El.) listed herein are referenced to the North American Vertical Datum of 1988 (NAVD88).

## 2.7 Limitation of Liability

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

# 3. Site Description

## 3.1 Location

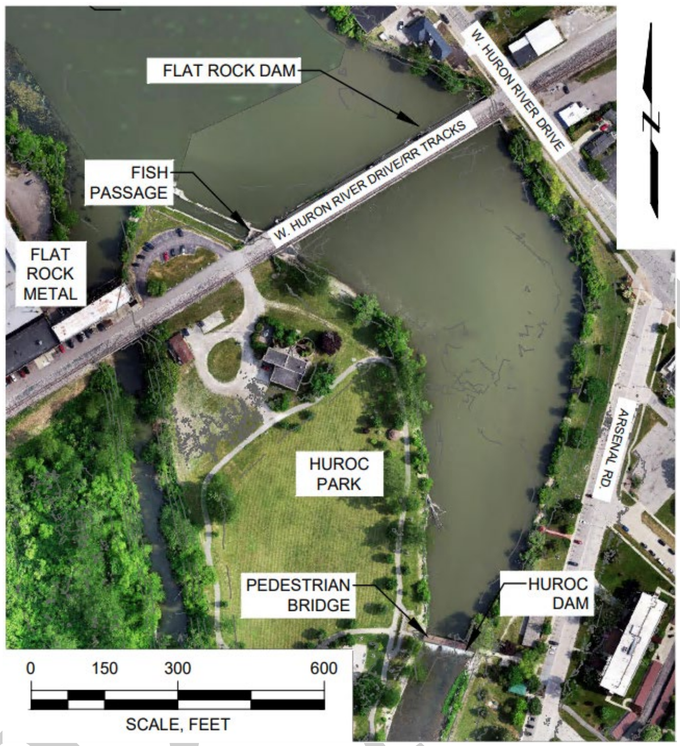


Figure 2: Site Location Map

The Flat Rock and Huroc Dams are located within the city limits of Flat Rock, MI. The Flat Rock Dam is located directly upstream of W. Huron Drive/CN Railroad Tracks on the Huron River. Flat Rock Metal is southwest of the Dam and owns the decommissioned powerhouse. The Huroc Dam is approximately 960 feet downstream of the Flat Rock Dam. Huroc Park lies directly west of the Huroc Dam connected to Arsenal Rd by a pedestrian bridge directly over top of the Huroc Dam (Figure 2).

## *Flat Rock Dam*

The Flat Rock Dam is approximately 492 feet long featuring a continuous ogee-shaped crest. The top crest elevation is 590.5 feet (Appendix B). The Dam has a structural height of 16.5 feet, a design flood hydraulic height of 18 feet, and maintains 9 feet of head with 4.5 feet of freeboard. There is an abandoned lock system immediately to the right of the spillway. The abandoned lock now serves to control flow to a fish ladder constructed under the W. Huron Drive vehicular bridge. A raceway channel, formerly used to direct river flow through the non-operational powerhouse, is approximately 67 ft wide and begins 250 ft upstream of the Flat Rock Dam, rejoining the Huron River approximately 1,000 ft downstream of the Huroc Dam.

| FLAT ROCK DAM | |
|---|---|
| Type of Dam | Continuous Ogee Concrete Spillway |
| Hazard Potential Rating | High |
| Normal Pool Surface Area (acres) | 188 |
| Dam Crest El. (feet) | 590.5 |
| Dam Crest Width (feet) | 492 |
| Normal Operating Headwater El. (feet) | 591 |
| Dam Structural Height (feet) | 16.5 |
| Dam Hydraulic Height (Normal Flow) (feet) | 15.9 |
| Dam Hydraulic Height (Flood Flow) (feet) | 18 |
| Head (feet) | 9 |
| Freeboard (feet) | 4.5 |

The former powerhouse is 90 feet into the raceway and approximately 250 ft to the right of the spillway. The powerhouse is currently not in operation and is now owned by Flat Rock Metal, a local metal manufacturing plant. The vehicular bridge immediately downstream of the dam was constructed concurrently with the Flat Rock Dam with design plans dated 1922. While the dam and bridge are indicated to be structurally separate, the bridge piers extend into the dam spillway and contribute to the dam's foundation, which is anchored into bedrock.

## *W. Huron Vehicular Bridge*

The W. Huron vehicular bridge is approximately 8 feet downstream of the dam and is 47 feet wide including 2 railway tracks and 2 vehicular lanes. The bridge itself appears to be owned by the Canadian National Railroad (CN Rail) with its primary use being for rail traffic. The bridge is also used by Flat Rock Metal as a main point of entry/exit to the manufacturing plant. The road itself appears to be maintained by Flat Rock Metal. The bridge's 20 piers/abutments appear to have been constructed into existing bedrock. During visits to the site over the course of the feasibility study, engineers noted significant concrete deterioration of the bridge faces and decking. Reportedly, the bridge was inspected during the Summer of 2023, however, the GEI team was not able to review this report. Record drawings for the bridge are included in Appendix B.

## *Impoundment*

Under normal flow conditions, the Flat Rock Dam forms a 188-acre impoundment. Approximately 129 acres is wetlands and 59 acres is open water. The drainage area contributing to the Huron River at the Flat Rock Dam is approximately 876 square miles. Currently, the dam maintains a recreational impoundment, supporting lacustrine fish and wildlife habitat, fishing, and boating activities. The land directly adjacent to the impoundment includes residential homes, a commercial factory, Flat Rock Metal, and HCMA's Oakwoods Metropark.

## *Huroc Dam*

The City of Flat Rock owns the Huroc Dam, which falls outside the regulation of the EGLE Dam Safety Division due to its small size. The dam was constructed in 1954 with a truss bridge built over top of the dam. The dam's structural height is approximately 2.5 feet with a hydraulic height of 4.5 feet during normal conditions. From site observations, aerial photographs, and site survey, the dam is approximately 110 feet long with a continuous ogee-shaped crest. The top crest elevation is approximately 582.2 feet, and directly above the dam is a pedestrian bridge 8 feet wide. The Huroc Dam currently impounds 6.9 acres of water.

| HUROC DAM | |
|---|---|
| Type of Dam | Continuous Ogee Concrete Spillway |
| Hazard Potential Rating | Low |
| Normal Pool Surface Area (acres) | 6.9 |
| Dam Crest El. (feet) | 582.2 |
| Dam Crest Width (feet) | 112 |
| Normal Operating Headwater El. (feet) | 584 |
| Dam Structural Height (feet) | 2.5 |
| Dam Hydraulic Height (feet) | 4.5 |
| Head (feet) | 1.5 |
| Freeboard (feet) | 8.3 |

# 4. Existing Data Review and Compilation

## 4.1 Dam Safety Report Review

Several documents were reviewed to better understand the condition of the existing Flat Rock Dam structure. EGLE dam safety inspection reports from 2014, 2017, 2020 and 2023, Flat Rock Dam and West Huron River Drive /Railroad bridge as-built drawings from 1922 and Flat Rock Dam Rehabilitation as-built drawings from 2007 were reviewed in this evaluation. Photo logs from site visits were also referenced to evaluate the surrounding area of the dam. The Huroc Dam was not included in this review because it is not a regulated dam.

The last four dam inspection reports indicated the Flat Rock Dam is in Fair Condition. Dam safety inspection reports from 2014 to 2020 recommendations focus on maintaining and monitoring the surrounding site with no concern regarding the structural integrity or the hydraulic capacity of the dam itself. The latest dam safety inspection report (2024) recommends more significant action be taken in the short term to maintain the condition of the dam. These recommendations are listed below:

- Remove debris from the principal spillway weir wall as soon as possible.
- Remove and replace deteriorated concrete with high-strength concrete, ensuring a minimum patch thickness of 3 inches at the bridge and right wall of the principal spillway.
- Reshape and stabilize depressions by removing unsuitable material, regrading to the original level, and installing matching surface protection on the embankment slopes and the abandoned conduit of the fish ladder. Monitor for further depressions and notify the Dam Safety Unit if observed.
- Completely fill the sink hole with MDOT Class II sand at the abandoned conduit of the fish ladder, ensuring all voids are filled. Notify the Dam Safety Program if water flow is detected.
- Repair erosion damage by regrading to the original condition with suitable material and installing surface protection at the downstream section of the auxiliary spillway.
- Inspect monthly for increased seepage or erosion and prepare for future maintenance to seal the fish ladder chute. Notify the Dam Safety Program if changes are observed at the Chute.

- Conduct monthly inspections for increased water flow from seepage at the downstream slope of the embankment and notify the Dam Safety Program of any changes.

- Develop a comprehensive operation and maintenance plan to extend the dam's service life and maintain its hydraulic and structural integrity.

Several of these recommendations include maintenance required in the short term to the dam and the surrounding structure. This maintenance will protect the structural integrity of the dam and continue to extend the life of the dam.

The Flat Rock Dam also underwent major rehab efforts in 2008 to repair cracking and spalling of the right retaining wall and abutment, concrete deterioration on the left spillway abutment and deterioration on the spillway crest.

These documents and activities indicate the dam is in fair condition and though maintenance is recommended, the dam does not pose any immediate or long-term safety concerns at this time.

While HCMA is not directly responsible for the vehicular bridge directly downstream of the Flat Rock Dam, site photos and site visit notes indicate the bridge is in poor condition. The bridge has concrete spalling and cracking, exposed rebar, and concrete deterioration throughout. Additional deterioration of the bridge could affect the integrity of the dam. Once an alternative is selected, additional evaluation of the bridge structure and coordination with the bridge owner (CN Rail) will be required.

## 4.2 Topographic Survey

A topographic survey was conducted covering the Flat Rock Dam, Huroc Dam, the upper end of the impoundment, and surrounding features. Extents surveyed include the Flat Rock Dam, the Huroc Dam, W Huron River Bridge and Huroc Pedestrian Bridge and surrounding infrastructure. Stream cross sections were surveyed downstream of the Flat Rock Dam, downstream of the Huroc Dam, and at Oakwoods Park at the upstream extent of the impoundment. Other key components surveyed include Water surface elevations (WSEs), the raceway, the fishway lock and infrastructure in Huroc Park. The collected data has been incorporated into all existing conditions drawings and used for designing the alternatives.

## 4.3 Sediment

LimnoTech collected sediment data, including a bathymetric survey and depth of refusal survey of the impoundments, along with sediment core collection and analysis for legacy contamination such as metals, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). This data is crucial for understanding the current conditions of the site and will guide future design processes. It will also be essential for developing sediment management and restoration plans for exposed floodplains if a dam removal alternative is selected. A Sediment Sampling Summary Memo is included in Appendix D.

### *Sediment Quantity*

LimnoTech conducted a bathymetric survey and collected depth of refusal measurements to establish existing sediment quantities within the impoundment. Four separate areas of the impoundments have been classified based on their geomorphic characteristics within the overall study area.

*Main Impoundment*: from the downstream end of the braided channel sections to the dam.

*Upstream channels*: the active channel and meander bends in the braided channel section of the river upstream of the main impoundment.

*Bayou*: The old meander bend that is located to the northwest of main impoundment.

*Lower impoundment*: located downstream of the Flat Rock Dam and upstream of the Huroc Dam.

The estimated sediment volumes in each of these areas are listed below.

| Project Area | Estimated Soft Sediment Volumes (CY) | Mean Soft Sediment Depth (ft) |
|---|---|---|
| Main Impoundment | 875,000 – 1,030,000 | 4.9 |
| Upstream Channels | 130,000 – 150,000 | 3.2 |
| Bayou | 260,000 – 360,000 | 5.1 |
| Lower Impoundment | 7,000 – 10,000 | 0.7 |
| **Total** | **1,272,000 – 1,550,000** | **4.6** |

These areas are shown on the map in Figure 3.

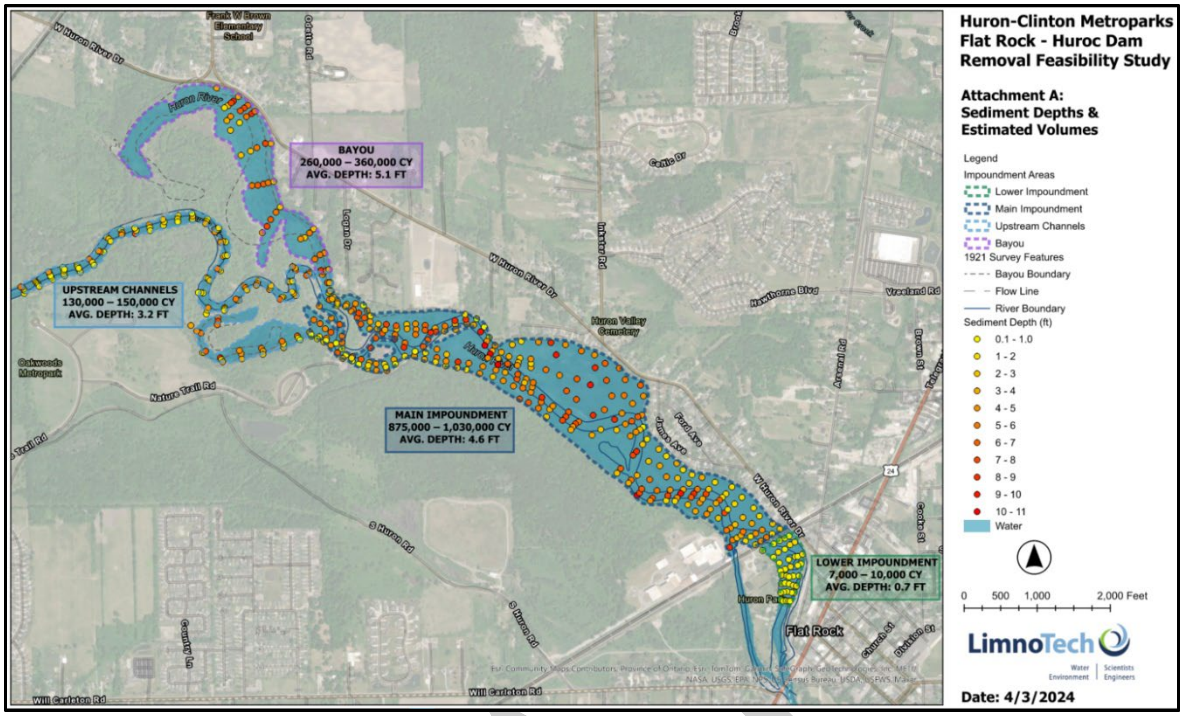


Figure 3: Sediment Depths and Estimated Volumes

Sediment volume estimates include some uncertainty based on the extrapolation of the survey data to the water's edge of the impoundment. However, these sediment volumes are appropriate for use in planning and design efforts.

The total estimated sediment volume within the surveyed limits is 1,272,000 to 1,550,000 cubic yards of material. Of this volume, 882,000 to 1,040,000 cubic yards of material is contained within the main upper impoundment upstream of the Flat Rock Dam and the lower impoundment area between the Flat Rock and Huroc Dams and has the most potential to mobilize. The majority of remaining sediment volume is found within the bayou and is not likely to remobilize if the Flat Rock Dam was removed. The estimated sediment volume in the upstream channels are not necessarily considered impounded sediment and may be mobilized to further downstream into the impoundment under future high flow conditions. Each dam disposition alternative, discussed in detail in further sections, includes a discussion of the implications of the quantity of sediment stored behind the dam.

### *Sediment Quality*

As part of the feasibility study a screening level analysis of the existing impounded sediment was completed by collecting a total of ten (10) sediment cores in the Flat Rock and Huroc Dam impoundments. Figure 4 shows the locations of the ten samples. Each sample was analyzed for the Michigan 10 Metals, PAHs, and PCBs.

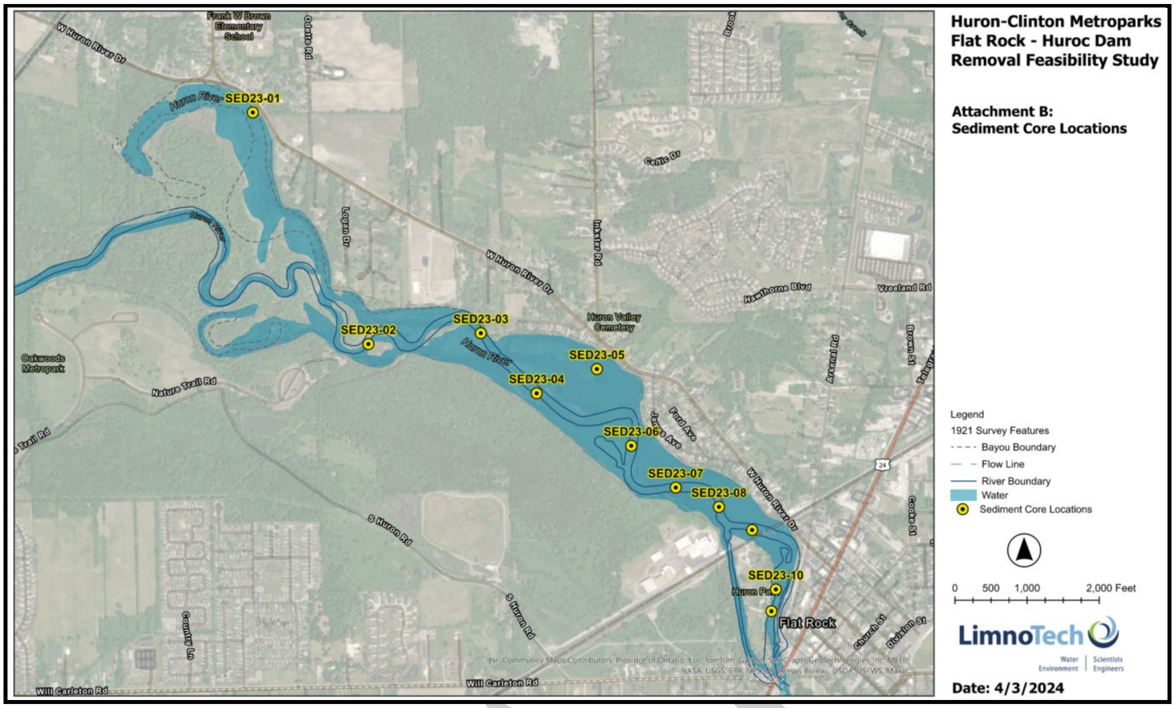


Figure 4: Location Map of Sediment Cores

The sediment sampling results show that none of the sampled locations in the Flat Rock and Huroc Dams impoundment had pollutants that exceed the sediment quality goals for public health. There were three locations (SED23-01, SED23-09, SED24-10) where the measured arsenic levels exceeded the Michigan EGLE Part 201 Residential Direct Contact Values (7.6 mg/kg), but all were below the levels identified in the Michigan Background Soil Survey Criteria as meeting background soil concentrations for this region (22.4 mg/kg).

None of the sediment sampling locations had pollutant levels that exceed the guidelines for aquatic ecosystem protection for metals, PAHs, or PCBs.

## 4.4 Wetland Delineation

Wetland ecologists evaluated the project site for wetlands and identified associated wetland regulation requirements. Wetland delineation and boundaries are shown in Figure 5 with the complete *Wetland Delineation & Protected Species Report* available in Appendix E.

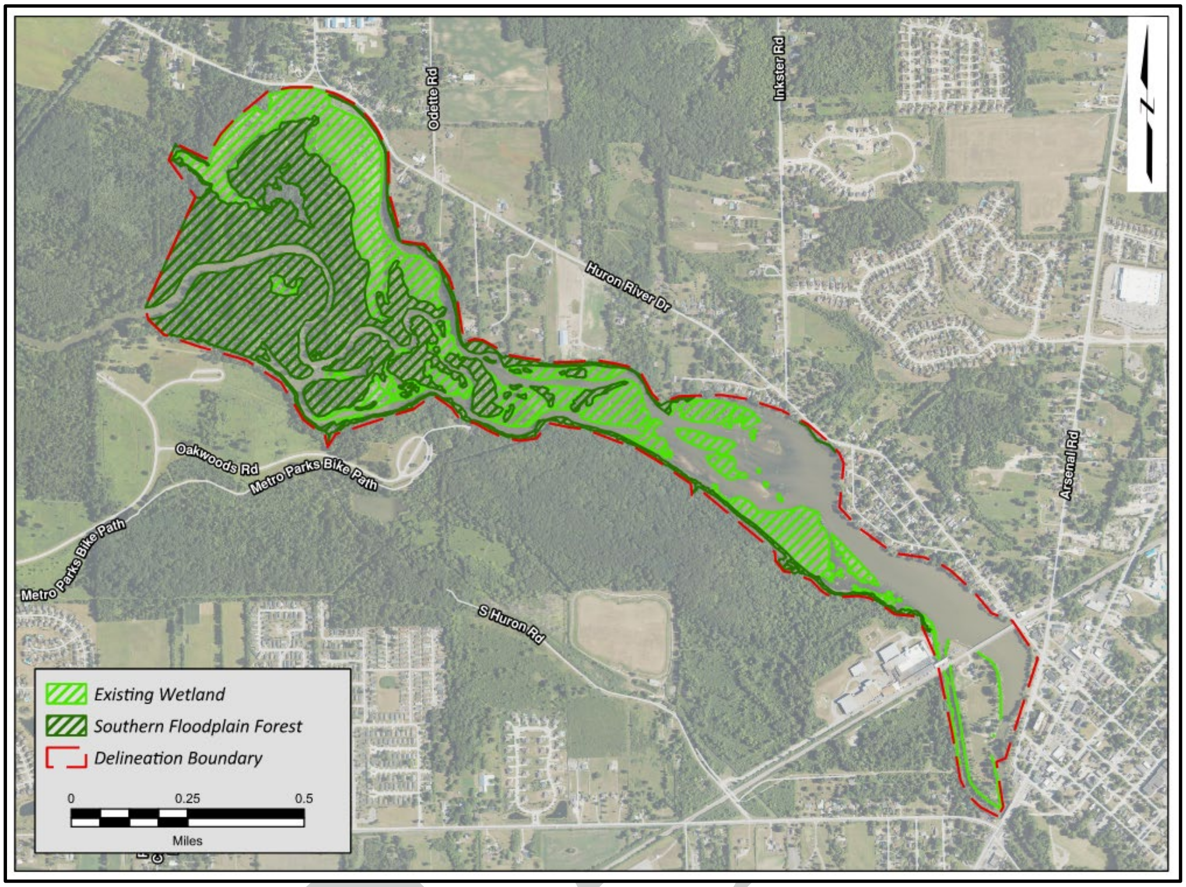


Figure 5: Existing Wetlands and Delineation Boundaries

The presence of wetlands is primarily determined evaluating the following factors:

- dominance of wetland rated plants,
- soils with field indicators of hydric soils,
- visual signs of hydrology at the surface or within the soil profile.

All delineated wetlands found on site either exceed five acres in size or are within 500 feet of the Huron River and are therefore regulated by EGLE, per Part 303 of NREPA. Wetlands in the upper impoundment were identified as potential classification as Southern Floodplain Forest wetlands based on the presence of a natural levee feature and several indicator plant species. Classified as “rare and imperiled” by EGLE, these wetlands are subject to heightened mitigation requirements, necessitating a 5:1 mitigation to impact ratio compared to the standard 2:1 ratio for forested wetlands. Based on preliminary wetland mapping, the existing site has 92 acres of wetlands and 133 acres of southern flloodplain forest.

## 4.5 Threatened and Endangered Species

Rare and protected plant and animal species regulated by the MDNR were identified through the request of a Michigan Natural Features Inventory (MNFI) and onsite field investigations. One protected species, water-willow, occupies the site and a suitable habitat possibly exists for five (5) other Threatened and Endangered (T&E) species. A table of identified T&E species are listed in Table 1.

Table 1: State Protected Species Found Onsite or Suitable Habitat Exists

| **Protected Plant and Animal Species Found Onsite** | |
|---|---|
| water-willow *(Justicia americana)* | T |
| **Suitable Habitat Exists Within the Site*** | |
| mullein-foxglove (*Dasistoma macrophylla*) | E |
| red mulberry (*Morus rubra*) | T |
| cup plant (*Silphium perfoliatum*) | T |
| eastern fox snake (*Pantherophis gloydi*) | T |
| cerulean warbler (*Setophaga cerulea*) | T |
| T = threatened species, E = endangered species<br>*Protected plants and animals observed within 1.5 miles of the project site within the last 20 years. | |

Federally protected (T&E) species with potential to occur at the project site were identified by a search of the Information for Planning and Consultation (IPaC) website. Of the 11 federally listed species whose ranges are known to overlap with the site, suitable habitat may exist at the site for three bat species and three mussel species listed in Table 2 below.

Table 2: Federally Protected Species with Potentially Suitable Habitat Onsite

| **Protected Bat Species with Potentially Suitable Habitat** | |
|---|---|
| Indiana bat *(Myotis sodalis)* | E |
| northern long-eared bat (*Myotis septentrionalis*) | E |
| tricolored bat (*Perimyotis subflavus*) | PE |
| **Protected Mussel Species with Potentially Suitable Habitat** | |
| northern riffleshell (*Epioblasma rangiana*) | E |
| rayed bean (*Villosa fabalis*) | E |
| snuffbox (*Epioblasma triquetra*) | E |
| T = threatened species, E = endangered species | |

Trees located on-site could act as roosts by protected bat species, including the federally protected species listed in Table 2. The T&E desktop review did not indicate any known occurrences of protected bat species near or within the project area. However, the range of both Indiana bat and northern long-eared bat overlap the site. Both species could roost in trees near the site, especially in mature silver maple and shagbark hickory trees whose exfoliating bark make them attractive as bat roost trees. Any construction activities near the dams could require tree clearing which may remove potential roost trees. A bat tree survey or mist-net survey may be necessary if trees must be cut for construction activities. This desktop and field review reflects the known state of the T&E species population within the project area as of July 2023. Field surveys for aquatic T&E species, including mussels, were not conducted in 2023.

## 4.6 Aquatic Biological Community

The State of Michigan retains survey records for all of its water bodies, regardless of the surveyor or reason for survey. The available records for the Huron River within the project area are from 1998 through 2017 and consist of a combination of angler surveys, formal population surveys for non-wadable rivers, and surveys in the immediate vicinity of the Denil Fishway on Flat Rock Dam constructed by the Huron River Fishing Association (HRFA). All surveys were performed by the MNDR, but some were also supported by the HRFA. These surveys were reviewed to determine the fish assemblage in the project area.

A total of eight surveys were performed between 1998 and 2017. The data from these surveys show that the Huron River supports at least 38 species of fish from 14 families (Appendix F). Large game fishes such as Walleye, Northern Pike, and Smallmouth Bass were common, and multiple species of panfish (e.g., Bluegill and Pumpkinseed) and catfish (Channel Catfish and Black Bullhead) were also collected. Nongame fishes included seven species of sucker and multiple small-bodied minnow and darter species. These small species often serve important ecological roles ranging from forage for larger species to mussel hosts. Because of the size of the river, the limited number of surveys (n=8), and the fact that some surveys were specifically designed to detect game fish and/or game fish passage through a fishway, there may be many species in the project area that have not been detected. Nevertheless, the species that have been documented are adequate to allow for holistic fishway or rock arch rapid design, as they exhibit diverse body forms/sizes and swimming abilities.

The Michigan Mussel Mapper (https://mnfi.anr.msu.edu/resources/michigan-mussels) was accessed in March 2024, to evaluate for publicly-available occurrence data for state and/or federally listed mussel species in the project area. Regardless of chosen project alternative, fishway and/or constructed riffle designs must incorporate known swimming abilities of fish hosts to prevent further impact to imperiled mussels and to facilitate their recovery. Common species and/or state species of special concern were not considered in fish passage design because the Michigan Mussel Mapper does not provide mussel species occurrence information for common species and based on the assumption that a fishway designed to allow passage of host fish of imperiled mussels would benefit more common ones as well. The Michigan Mussel Mapper output contained Huron River observation records for 10 mussel species listed as threatened or endangered in the State of Michigan, three of which are also Federally listed as threatened or endangered. An additional nine species categorized as special concern in Michigan were also reported (Appendix F). Known or probable fish hosts have been identified for the majority of these mussel species – these fishes include multiple species of perch, sunfishes, catfishes, and sculpin (Watters, G.T., Hoggarth, M.A. and Stansbery, D.H., 2009. *The freshwater mussels of Ohio*. Ohio State University Press). Lake Sturgeon, which are native to the Huron River but were not documented in any of the fishery surveys, have been identified (thus far) as the only suitable host for one mussel, the state endangered Hickorynut.

Doubtless, the fish assemblage in the Huron River has been profoundly affected by the presence of the Huroc and Flat Rock dams; major declines in populations of Great Lakes fishes such as Lake Sturgeon, Walleye, and Atlantic Salmon have been attributed to the presence of dams. However, these dams also had the unintended benefit of preventing upstream migration and reproduction of Sea Lamprey (Walter et al. 2021). Balancing the benefits of increased stream connectivity with the risks of facilitating expansion of invasive species is a major consideration of this feasibility study.

## 4.7 Fish Passage at Existing Fishway and at Huroc Dam

This section focuses primarily on the function of the existing fishway at Flat Rock Dam. However, free passage to the downstream end of Flat Rock Dam is highly unlikely for many species as they would have to move past Huroc Dam first. While this structure is significantly smaller than Flat Rock Dam, it appears to be sufficiently tall to prevent upstream movement of non-jumping species when it is not backwatered on the downstream side by flood events.

The existing fishway structure is a Denil fishway consisting of two sections with a resting pool between them. Its cross section is 4 ft high by 3.2 ft wide. The 0.6-ft wide vanes create 0.8 ft of dead space (i.e., low to zero-velocity water) between the fishway floor and the bottom of the vane; the vanes are spaced 4.5 ft apart. Drawings of the existing structure are included in Appendix B.

This section contains a brief literature review of fish passage success/efficiency for Great Lakes fishes (and the target species of Lake Sturgeon, White Bass, and Walleye in particular). It also contains an evaluation of the function of the existing Denil fishway at the Flat Rock Dam and an evaluation of the effects of Huroc Dam on fish passage. Recommendations for the replacement/modification of the existing fishway and modifications to Huroc Dam were also developed and are discussed in the 'No Action – Fish Passage Improvement' alternative in Section 6.

The efficacy of Denil fishways to pass a large number of fish species has been addressed in a number of studies, but results were somewhat equivocal. A 9.5-m long Denil fishway with a slope of 12% successfully passed White Sucker, Northern Pike, Walleye, and Sauger (Katopodis et al. 1991). All fish were greater than 212 mm, but this may have been attributable to the mesh size of the traps used to capture fish exiting the upstream end of the fishway; smaller fish may have successfully used the structure then escaped through the mesh. A three-section Denil fishway with two resting pools and a 10% slope on the Grand River, Ontario allowed passage of 29 species from five (5) families. Roughly one-third were small-bodied species such as darters or short-lived minnows (Bunt et al. 2001). These studies suggest that Denil fishways will facilitate passage of a variety of fish species. However, studies of other Denil fishways did not necessarily report successful passage of the same species despite overlap of the fish assemblages between study sites, and some of the studies indicated exclusion of at least some of the studied fishes. For example, a 3.0-m long Denil fishway with a slope of 10% passed whitefish/cisco, Northern Pike, Burbot, Longnose Sucker and White Sucker, and Spottail Shiner. However, it appeared that at high flows, many fish moved over a backwatered weir, and the fishway did not seem to work well for Walleye or Goldeye (Schwalme et al. 1985). A Denil fishway constructed on the Grand River in Ontario to facilitate Walleye Passage resulted in 0% successful passage for this species (Bunt et al. 1999). Denil fishways are not recommended for sturgeon (ASMFC 2010), because of this species' close association with the benthos/substrate (Webber et al. 2007). The number of studies that have evaluated fish passage through Denil fishways is too small to allow a concrete description of which fish species can consistently use them.

A single meta-analysis of the passage efficiency of different fishway types was performed in 2021. While fishway type was not a major predictor of fish passage success, the analysis was limited due to a small sample size and a lack of standardization of study methods (Hershey 2021). Despite these limitations, the study mentioned above included six fishways from the Great Lakes Region, and vertical slot and nature-like fishways tended to have higher attraction and fish passage efficiency than the Denil fishways (Zielinski and Freiburger 2020).

Huroc Dam can be considered a partial or total barrier to movement for most of the fishes in the Huron River. This structure is referenced in a 2000 assessment of Walleye in the Huron River (Leonardi and Thomas 2000). Based on MDNR data from 1993, Huroc Dam is considered a barrier to upstream movement of Walleye. Huroc Dam also probably prevents upstream movement of other non-jumping species (or species with limited jumping ability) for much of the year. Jumping performance experiments are rare, and most species in the Huron River have not been tested. However, most of the species tested to date, many of which are native to the Midwest, have maximum jump heights of one body length or less. Further, small-bodied species with well-developed jumping abilities may not be able to move past Huroc Dam if it is not backwatered, simply because of their small size. Species potentially affected would include large-bodied Northern Pike (Cubbage 2022), White Sucker (Gardunio 2014), multiple sunfish species (Prenosil et al. 2015), and a myriad of small-bodied species (Garvey 2024).

The weir at Huroc Dam is subject to a backwater condition that causes it to be submerged at higher flows (i.e., between 600 and 700 cfs). These flows occur almost annually – an analysis of daily flow data for the Huron River indicated that flows of 700 cfs are exceeded 65% of the time in April. A fully submerged crest at Huroc Dam would allow at least some spring-migrating fishes such as Walleye to move upstream during high flows. However, all non-jumping fishes would be prevented from moving upstream at lower flows. Also, weirs that are fully submerged may still prevent upstream movement of benthic fishes, particularly if they are small (e.g., Ficke et al. 2011).

### *Fishway slope and length.*

The Denil Fishway at Flat Rock Dam has two sections. The top section is 35 ft long with an 8.25% slope, and the bottom section is 35-40 ft long with a 9.57% slope. While many of the Denil fishways that successfully pass fish appear have higher slopes than the Flat Rock Dam fishway, many of them are shorter. Increasing fishway length may discourage fish passage – this was documented in a study that compared performance of a 25-ft, 50-ft, and 66-ft Denil fishway. Passage success of American Shad, Common Carp, Chiselmouth, Northern Pikeminnow, and multiple species of sucker decreased with increasing length of the Denil fishway placed at slopes of 23 to 29%. However, fishway length did not affect passage success for salmonids (Slatick and Basham 1985).

### *Attraction Flow and Vertical Drop at Downstream Entrance of Fishway*

The attraction flow is the flow from the downstream entrance of a fishway with appropriate volume, velocity, and location to attract fish to migrate into a fish passage. Attraction flow from the Flat Rock Dam fishway would be extremely small relative to the flow of the Huron River, as the fishway is approximately 5 ft wide and the existing dam crest is approximately 492 feet wide. The downstream entrance to the fishway is also situated so that a vertical drop exists at the downstream entrance of the fishway at low flows – this has the potential to exclude a majority of the resident fishes in the Huron River from the fishway between June and November when flows are typically lower and the vertical drop is created, as many of them have poor or nonexistent jumping abilities.

### *Denil Fishways May Not Prevent Lamprey Passage*

One potential function that should be considered in the design is a sea lamprey barrier if USFWS detects sea lamprey colonization in the river in the future Appendix L). A study of three Denil fishways at slopes from 23% to 29% showed that Pacific Lamprey passage was not prevented (Slatick and Basham 1985). Denil fishways lack plunging flows, which tend to deter lamprey passage (e.g., Lewandoski et al. 2020). Sea Lamprey have not colonized the Huron River despite 20 years of operation of the Denil fishway (Appendix L) suggesting other factors (e.g., temperature, flow, sediment load) have impacted colonization. However, if they were located at the base of the fishway, a closure would have to be considered during their migration period.

### *Flat Rock Dam Denil Fishway Documented Fish Passage*

The various fishery surveys performed by the HRFA and the MDNR have documented passage of eight fish species (Steelhead, Gizzard Shad, Common Carp, Walleye, Bluegill, and multiple sucker species) through the Denil fishway, but there are 39 fish species present in the Huron River. Some of the discrepancy may be due to timing of surveys, as many were conducted during the Steelhead run in the spring. Furthermore, the large fyke nets used during the surveys would not necessarily capture small fishes. Despite the limitations of the surveys, the data suggest that the fishway cannot be used by all of the resident fishes in the Huron River. Because the existing fishway provides upstream passage opportunities for a limited number of species (and individuals), provisions for modification and/or supplementation of fish passage at Flat Rock Dam have been included in all alternatives, including the No Action – Fish Passage Improvement Alternative (see Section 6).

## 4.8 Site Utility Mapping Investigation

The location of utility lines within a project site has the potential to greatly affect the feasibility of design and construction of a project. A preliminary map of known utility lines has been developed based on initial data collection from survey files, site visits, online resources, and local authorities (Figure 6).

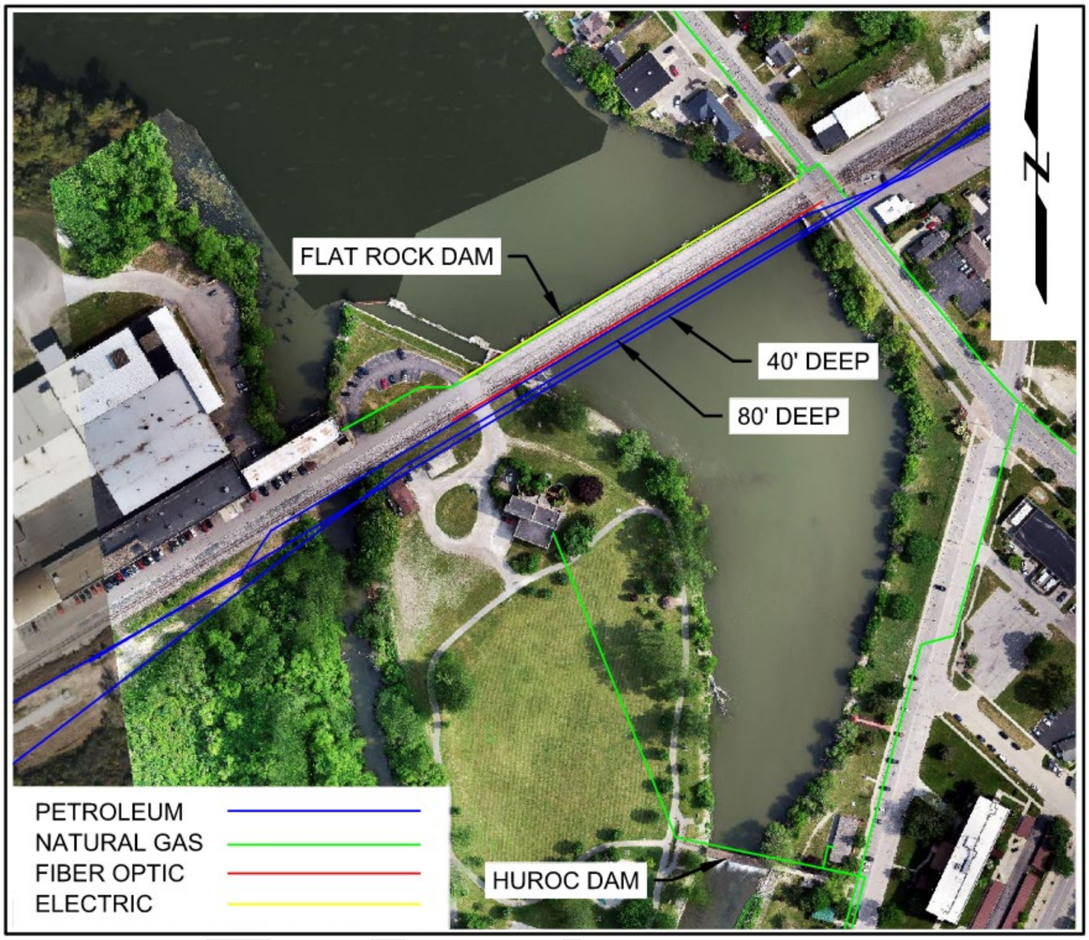


Figure 6: Location of Known Utility Lines

All utilities identified are located outside the area of project disturbance for all alternatives discussed within this report. Most utilities are fastened along the girder of the Flat Rock Railroad bridge as well as the pedestrian bridge in Huroc Park. Two petroleum lines are approximately 20 – 30 feet downstream of the Flat Rock railroad bridge dam horizontal directional drilled 40 feet and 80 feet below the existing grade. Based on these findings, it is probable no utilities will require relocation regardless of the alternative selected. A full site investigation including coordination with Miss Dig will be required with any alternative selected.

The City of Flat Rock noted there may be other stormwater outfall pipes on the north side of the impoundment and an outfall on the south side of the impoundment from a former quarry site. These were not identified as part of this study, but should be located within the potential project area for any alternative that is selected to move forward into more detailed design.

## 4.9 Real Estate Evaluation

As part of the feasibility study, a licensed surveyor completed a desktop review of property parcels within or immediately adjacent to the study limits. In total, 88 parcels were identified within or immediately adjacent to the study area. The majority of private parcels give no mention of 'water edge' as a defining property limit, with the exception of the HCMA owned parcels which call out ownership "along the north shoreline." Generally, the parcels are consistent in written language either referencing Huron River Subdivision lots or metes and bounds, which references specific measurements of distance, angles, and directions.

The review of property deeds indicates that HCMA, as owner of the dam, appears to own the bottomlands and riparian rights to the Flat Rock impoundment and Huron River area immediately downstream. There is one parcel downstream of the Huroc Dam, at 26425 Atwater Street that indicates riparian ownership. Additionally, the City of Flat Rock and Flat Rock Metal own properties with indicated riparian ownership. Figure 7 shows the results of the riparian ownership review.

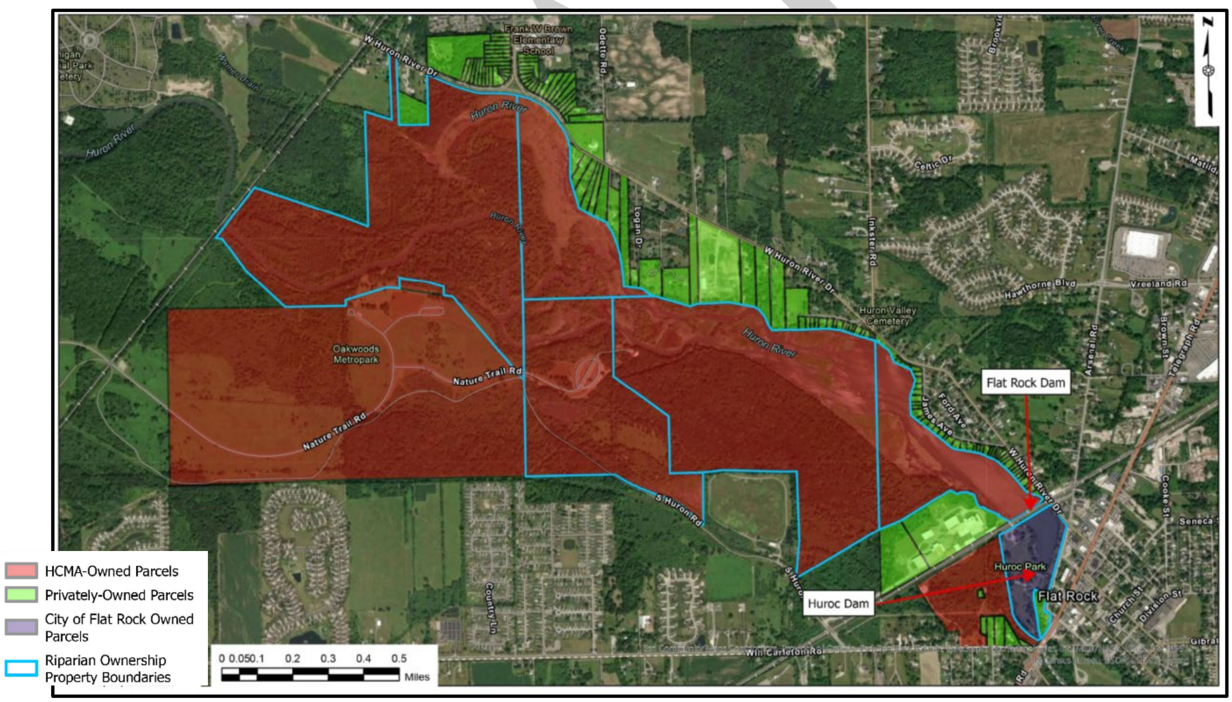


Figure 7: Map Showing Riparian Ownership Rights

Further investigation and legal consultation is recommended regarding riparian ownership and implications for the dam removal scenarios.

## 4.10 Phase I / Archeological Survey

GEI cultural resource specialists conducted a Phase I Records Review to identify known and previously recorded cultural resources on the project site and within a one-mile radius. A cultural resource refers to a historic built environment or archaeological site holding historical or social significance. Through background research, we identified seven previously recorded archaeological sites within the feasibility study area and an additional 38 known archaeological sites within the one-mile research radius. During the site visit, three additional historic-era (more than 45 years old) architectural resources were identified within or in close vicinity to the study area: the Flat Rock Dam, the Huroc Dam, and the Ford Motor Company Head and Taillight Assembly Plant. These historic-era architectural resources help determine which parts of the study area would require archaeological survey and recommended survey methods.

Based on these finding, a Section 106 application will be required through the Michigan State Historic Preservation Office (SHPO) for any alternative selected. This application will involve further assessments of cultural resources that may be affected by the project and will likely require more technical studies. These studies include a Phase I archaeological survey, a submerged resources assessment, and an Architectural Resources Inventory and Evaluation Report. The detailed *Flat Rock-Huroc Dam Removal Feasibility Study Cultural Resources Phase I Records Review Report* is found in Appendix G.

## 4.11 Public Engagement

[Comments from public input will be placed here upon finalizing the Feasibility Study.]

# 5. General Technical Considerations

## 5.1 Geotechnical and Bridge Structural Investigation

### *Structural Investigation*

Based on a review of the design documents and historical records, the Flat Rock Dam ogee crest was constructed concurrently with, but structurally isolated from, the downstream vehicular bridge piers. Modifications to the dam crest should therefore be achievable without compromising the existing bridge structures. Isolation of the ogee crests from the vehicular bridge piers should be confirmed if the alternative selected proposes dam crest modification. Care would still be required during demolition to limit any potential damage to the bridge piers. Consideration should be given to cofferdams to allow work to be completed in the dry increasing visibility and reducing the technical nature of the modifications, thereby reducing labor costs and the potential for damage to the bridge.

With the dam located slightly upstream of the bridge, the water retained by the dam is kept off the bridge piers, limiting the hydraulic load on the bridge. Reducing the dam height would not be expected to result in a significant increase in hydraulic loads to the bridge. Any potential impact loads from debris would be expected to impact the bridge piers at a lower elevation following any modification of the dam. Impact loads at lower elevations would result in less significant loading to the bridge piers.

From a stability perspective, any reduction in the height of the existing dam structure reduces lateral and uplift loads on the structure generally increasing the stability of the structure. The stability of any modified dam section should be reviewed for final hydraulic conditions to ensure conformance with current safety criteria and standards of practice. For the scenario of dam removal or partial dam removal, the dam structure would be removed a minimum of 1 foot below the proposed bottom of channel elevation or until bedrock is exposed. All existing rebar or other dam structures should be removed flush to bedrock.

The record drawings for the Huroc Dam are inconclusive as to any structural reinforcement ties between the Huroc Dam and the bridge piers. Should demolition or modification be necessary under the selected alternative, saw cutting the dam at the piers and demolishing the dam crest should be sufficient to prevent any structural damage to the pedestrian bridge piers. During construction, care should be taken during demolition and the bridge piers inspected throughout demolition activities.

## *Geotechnical Investigation*

Based on the original design plans from 1922, the Flat Rock Dam and vehicular bridge are anchored into bedrock. Other historic plans indicate bedrock is also anticipated to serve as the foundation directly upstream of the Flat Rock Dam (Appendix B). Based on review of record drawings for the Huroc Dam and pedestrian bridge, it appears these structures are also founded on bedrock.

The bedrock in the Flat Rock area is the middle-Devonian age Detroit River Group, a series of dolomite and limestone, with some sandstone and evaporites. The Bedrock Geologic Map of Wayne County, Michigan (Mozola, 1970) shows the bedrock to be the Detroit River Dolomite formation (now known as the Amherstburg formation) and underlain by the Sylvania Sandstone formation. The few scattered water well logs in the area show clay overlying sandstone and limestone. The overlying clay is lacustrine clay and silt, formed within glacial Lake Erie. Soil cores in the area confirm the limestone and sandstone bedrock layers are present at near the bottom of the dam are classified as dolomite, medium strong and limestone, laminated bedding, slightly weathered, weak rock with calcite veins. The bedrock foundation is suitable to continue to support the dam long term.

The banks along the impoundments are primarily soil, with some seawalls and riprap armoring observed along the north shorelines, particularly adjacent to residential property owners. Sudden changes in water surface elevation can sometimes affect the stability of soils. Under conditions where the impounded water surface elevation is not expected to change, there would be expected to be no impacts to the banks along the impoundment. Under the dam scenarios where a significant drop in water surface elevation is expected, dewatering activities would be prescribed to be incremental and methodical, which would result in minimal concern for long term sloughing or bank failure issues, however if sloughing were observed during construction/dewatering activities this could be addressed with earthen fill if necessary. Riprap grade control is established along both the right and left riverbanks from the Flat Rock Dam downstream the length of Huroc Park and is unlikely to be disturbed under the dam removal alternative of the Huroc Dam.

Given the slopes throughout the impoundments and the probable soil type, it is unlikely that any slopes are at risk of failing. During any potential dewatering activities, caution should be exercised, and the banks should be monitored for any unexpected instability. Once an alternative is chosen, additional soil boring samples may be necessary, and subsequent geotechnical evaluations may be recommended.

## 5.2 Hydrologic and Hydraulic Engineering

### *Introduction*

A hydrologic and hydraulic analysis was conducted to provide information on potential impacts to water surface elevations and velocities of each dam alternative. The site hydrology was informed by flow estimates from Federal Emergency Management Agency (FEMA), the Michigan Department of Environmental, Great Lakes, and Energy (EGLE), and by evaluation of peak flows from a nearby USGS gage. The hydraulics were evaluated by modeling the site with HEC-RAS version 6.3.1 software (USACE, 2022), as described below.

### *Hydrology*

GEI requested discharge estimates at the Flat Rock Dam from EGLE. EGLE provided flood flow (Table 3) and low flow (Table 4)estimates for the site. The FEMA Flood Insurance Study flood flows are also shown in (Table 3), vary slightly from the EGLE flood flows, due to rounding.

Table 3: Huron River Flood Flows

| Chance of Occurrence | EGLE Peak Flood Flows (CFS) | FEMA Peak Flood Flows (CFS) |
|---|---|---|
| 0.20% (500yr) | 12100 | 12100 |
| 0.50%(200yr) | 11700 | -- |
| 1% (100yr) | 10400 | 10390 |
| 2% (50yr) | 8800 | 8750 |
| 4% (25yr) | 7900 | -- |
| 10% (10yr) | 6500 | 6480 |
| 20% (5yr) | 5300 | -- |
| 50%(2yr) | 3700 | -- |

Table 4: Huron River Low Flows Provided by EGLE (cfs)

| Exceedance | Jan | Feb | Mar | Apr | May | June | July | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 1840 | 2650 | 2880 | 2590 | 2100 | 1380 | 1010 | 730 | 760 | 850 | 1040 | 1590 |
| 10% | 1210 | 1610 | 2210 | 1950 | 1540 | 980 | 680 | 490 | 520 | 600 | 830 | 1110 |
| 15% | 960 | 1210 | 1860 | 1620 | 1250 | 830 | 530 | 370 | 410 | 500 | 720 | 900 |
| 20% | 790 | 980 | 1580 | 1440 | 1110 | 710 | 440 | 320 | 350 | 440 | 650 | 790 |
| 25% | 670 | 810 | 1440 | 1330 | 980 | 610 | 390 | 290 | 320 | 400 | 600 | 710 |
| 30% | 610 | 720 | 1270 | 1220 | 850 | 550 | 350 | 270 | 290 | 370 | 570 | 640 |
| 35% | 540 | 630 | 1150 | 1120 | 760 | 500 | 320 | 250 | 270 | 330 | 520 | 590 |
| 40% | 480 | 560 | 1050 | 1040 | 690 | 450 | 290 | 210 | 240 | 290 | 470 | 550 |
| 45% | 440 | 490 | 950 | 970 | 640 | 410 | 240 | 180 | 210 | 250 | 440 | 510 |
| 50% | 400 | 430 | 870 | 880 | 570 | 360 | 210 | 170 | 180 | 230 | 400 | 470 |
| 55% | 350 | 400 | 820 | 800 | 530 | 320 | 190 | 160 | 160 | 220 | 360 | 430 |
| 60% | 320 | 370 | 760 | 740 | 480 | 280 | 180 | 140 | 140 | 200 | 330 | 390 |
| 65% | 290 | 340 | 690 | 690 | 430 | 250 | 160 | 130 | 130 | 190 | 300 | 340 |
| 70% | 270 | 300 | 630 | 640 | 400 | 230 | 150 | 120 | 120 | 180 | 270 | 310 |
| 75% | 240 | 270 | 560 | 600 | 360 | 210 | 140 | 120 | 120 | 160 | 240 | 270 |
| 80% | 220 | 240 | 510 | 510 | 320 | 200 | 130 | 110 | 110 | 140 | 220 | 240 |
| 85% | 200 | 220 | 440 | 460 | 270 | 180 | 120 | 96 | 98 | 120 | 200 | 220 |
| 90% | 190 | 200 | 370 | 410 | 240 | 170 | 100 | 85 | 91 | 110 | 180 | 200 |
| 95% | 170 | 180 | 290 | 350 | 200 | 150 | 86 | 69 | 81 | 90 | 150 | 170 |

Bankfull flow, typically occurring between the 1-year and 2-year recurrence intervals, is considered the channel forming flow key to any channel restoration type designs. Given that two of the dam disposition alternatives in this study consider dam removal and river restoration, it is important to identify an approximate bankfull flow for evaluation of proposed restored river channel designs. The bankfull flow was estimated using the PeakFQ software Bulletin 17B method based on the USGS Huron River at Ann Arbor gage (04174500) with 122 years of peak flow data. The results were scaled up to the Flat Rock Dam location using a drainage area ratio of 1.20. The resulting 1.5-year return interval flow, or bankfull flow, was 2516 cfs.

### *Hydraulic Analysis*

GEI developed an existing conditions hydraulic model using HEC-RAS software and information based on 2023 topographic and bathymetric survey data, 2016 LiDAR data, site observations, and FEMA floodplain modeling information.

As discussed in Section 4.3, topographic and bathymetric survey data was collected in June and July 2023 by Metro Consulting Associates and LimnoTech, respectively. The survey data was combined with Wayne County and Monroe County 1-meter LiDAR data from USGS from 2016 for design and modeling. Survey data included bathymetric cross sections from Telegraph Road to the Huroc Dam, between the Huroc Dam and Flat Rock Dam, and from the Flat Rock Dam to approximately the upstream end of the impoundment. The survey also included the Flat Rock and Huroc Dam structures and associated bridges.

The Existing Conditions HEC-RAS model extends from just upstream of Telegraph Road to approximately the upstream end of the Flat Rock Dam impoundment (Figure 8). 1-Dimensional cross sections were spaced approximately 200 feet apart, with closer spaced cross sections near the dam structures. Survey and LiDAR data were used to define the model geometry. Upstream of the Flat Rock Dam, the upper portion of the impoundment consists of several braided channels. Ineffective flow areas in HEC-RAS define areas where water is not actively being conveyed and are therefore not included in conveyance calculations. Ineffective flow areas were used to represent the side channels and impoundment backwater areas in the model. The tailrace channel downstream of the Flat Rock Dam powerhouse was also modeled as ineffective flow since it only conveys a small portion of the overall flow.

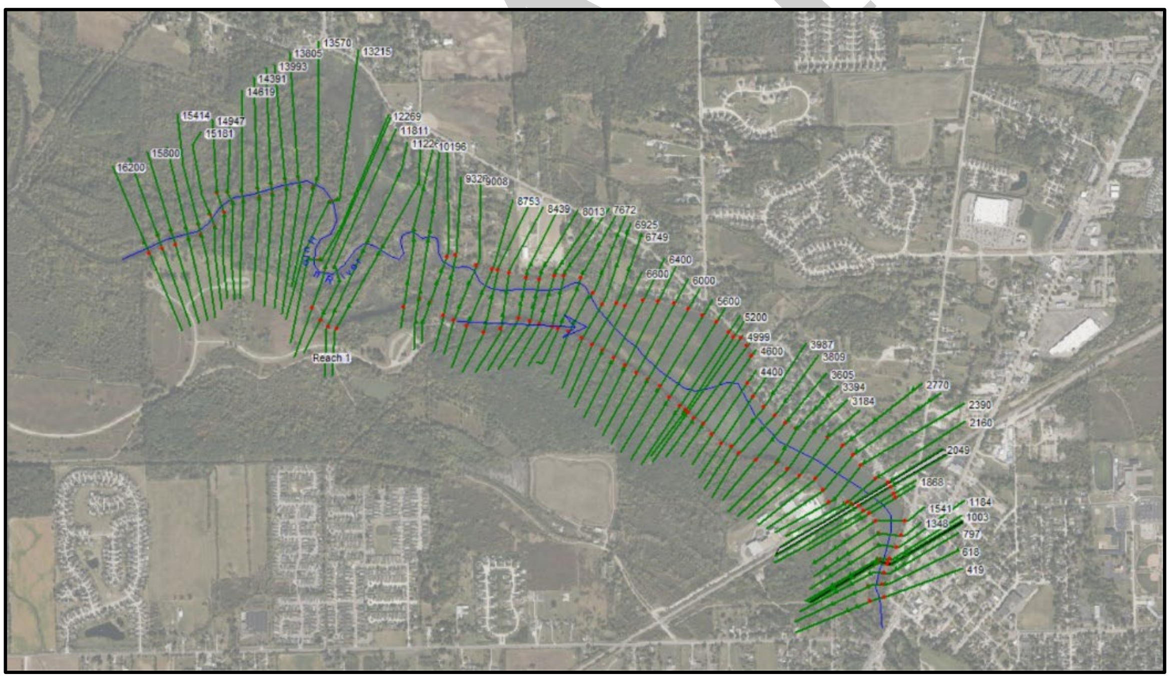


Figure 8: Plan View of Existing Conditions HEC-RAS Model Extent

Manning's *n* is the model coefficient that represents the relative roughness or resistance to flow for the streambed, banks, and floodplain. The larger the Manning's *n* coefficient, the higher the drag forces from the bed and banks, slowing water velocities and raising water surface elevations. Manning's *n* values were selected based on field observations of substrate type, bank conditions, and ground cover and subsequently appropriate adjustments to the base values to represent existing conditions. The base channel value was set as $n$ = 0.035 and represents a clean, straight natural channel with sand to gravel substrate. The floodplain value varied between $n$ = 0.08 and $n$ =0.15 (Chow, 1959) for the overbank areas and the islands within the impoundment based on the density of tree cover. Areas of the floodplain with a low density of tree cover and little undergrowth were represented with a value of $n$ = 0.08, and the floodplain areas containing very dense tree cover were represented with a value of $n$ =0.15. The changes in Manning's $n$ values were represented as horizontal variation across each cross section based on aerial imagery and site photos.

The Flat Rock Dam spillway and the railroad bridge immediately downstream were modeled as a single inline structure. Spillways and bridges in 1 Dimensional HEC-RAS models each require four cross sections (two upstream of the structure and two downstream), which are placed so that the outermost cross sections are outside of the hydraulic influence of the structure. In this case, the spillway and railroad bridge are so close together that flows in between them are influenced by both structures at the same time. This representation of the spillway and bridge as a single hydraulic structure was checked against surveyed water surfaces upstream and downstream of Flat Rock Dam to verify the model set up.

The existing fish ladder was not included in the model as it is expected to convey minimal overall flow.

The Huroc Dam and pedestrian bridge are integrated with the spillway and therefore were modeled as a single inline structure, like the Flat Rock Dam. The vertical distance between the pedestrian walkway and the roof of the Huroc Dam bridge was assumed to be blocked and unable to convey water in the hydraulic model.

The downstream boundary of the model is located between Telegraph Road and the Huroc Dam, which is approximately 1,600 feet downstream of Flat Rock Dam. The downstream boundary was set to a normal slope of 0.0002 feet/feet for flood flows, and 0.001 feet/feet for low flows, based on FEMA flood water surface elevations and calibrated observed low flow water surface elevations, respectively. The upstream boundary is located approximately 14,200 feet upstream of the Flat Rock Dam. The upstream boundary was based on a range of flows from low flows to flood flows, as provided by EGLE. The steady flow simulations were run with 1-Dimensional steady flow, using subcritical flow regimes.

The model results for the 100-year event were compared to the FEMA 100-year water surface profile. The simulated water surfaces were within 0.25 feet of FEMA elevations, except for the cross section immediately below the Flat Rock Dam, which was within 0.75 feet. The larger difference in water surface at Flat Rock Dam is likely due to differences in how the structure was modeled in the original FEMA model, which was built with HEC-2 software, an older software system. It should be noted that while the current hydraulic modeling effort follows industry standards of practice for hydraulic analysis, it is not intended to be a direct comparison with FEMA Base Flood Elevations or utilized for letter of map revision.

A suite of low flows were run as a steady flow plan, and the results were compared to surveyed water surface elevations in June and July of 2023. The simulated low flows were within 0.3 feet of the surveyed water surface elevations.

## Peak Flow Attenuation

Peak flow attenuation upstream of Flat Rock Dam was evaluated in HEC-RAS with 1 Dimensional unsteady hydrographs using the peak flows defined in Table 3. Peak flow attenuation from the upstream end of the impoundment to just downstream of Flat Rock Dam varied between 73% and 78% for all flood flows (2-year through 200-year). This attenuation is due to extensive floodplain access in the upper areas of the Flat Rock impoundment. As such, any alternatives that consider changes to the Flat Rock Dam need to consider maintaining floodplain access to the current upper impoundment area. A flow attenuation memo is included in Appendix H where discussions of the modeling and results are further explained. This is also further discussed in the full dam removal scenarios in Section 7.5.

## Hydraulic Engineering Analysis for Sea Lamprey

The US Fish and Wildlife Service (USFWS) have observed sea lamprey (*Petromyzon marinus*) in the Huron River downstream of the Flat Rock Dam in relatively low population numbers. Sampling methods have included eDNA, tagging, and reported captures over the course of 50 years of monitoring with limited positive results. The consultation memo from December 2023 (USFWS, 2023) states that while the risk of Sea Lamprey colonization in the Huron River is low, infestation is still possible at the suitable spawning grounds upstream of the Flat Rock Dam. (Appendix L ). As such, USFWS has requested the feasibility-level evaluation of sea lamprey barrier alternatives within the project area. Functional sea lamprey barriers are those that meet GLFC program standards and operate over the spawning seasons from March through June (Hrodey *et al.*, 2021).

Feasible barrier alternatives are identified and described in Section 9 of this report.

## Hydraulic Engineering Analysis for Fishes Targeted for Passage

Specifications for fishway features such as slope, depths, velocities, and boulder spacings/configurations would remain the same, regardless of whether the selected project alternative involved a channel-spanning fishway/constructed riffle (as in partial or full removal alternatives) or a fishway in the former boat lock. Therefore, a method of developing fish passage specifications in the project area is summarized below. This approach is discussed qualitatively however, because the approach to fish passage design will vary based on the selected alternative.

Design criteria performance standards would be based on published and observed hydrodynamic relationships of target species and detailed fishway hydraulics. These design criteria performance standards vary with species, body size, body shape, and behavior. There are at least 38 fish species in the project area (discussed in Section 4.6), and they have diverse body sizes/shapes, physiology, and swimming modes. Furthermore, the swimming ability of many of the species in the project area are either poorly characterized or unknown. As a result, fishes would be separated into ecomorphological "guilds" where individuals with similar body shapes and ecological niches were grouped together, and composite estimates of depth/resting pool depth, velocity, and rock spacing preferences would be developed for each group. Fishways can then be designed by using the most exacting requirements for each characteristic. For example, small-bodied fishes require low-velocity water but can tolerate shallow water and can use interstitial spaces. On the other hand, large, long-bodied fishes such as gar and Bowfin may require moderate to low water velocities because they are specialized for burst swimming, not for sustained swimming, but they cannot use shallow, low-velocity channel margins designed for passage of small-bodied species. Therefore, a fishway accommodating both guilds would contain sections of shallow, low-velocity water, as well as deep water with low to moderate velocities and frequent resting opportunities. For passage of all guilds through boulder weirs, the longitudinal length (parallel to flow) of high velocity flow is limited to balance the upstream passing ground speed with the assumed burst speed capabilities. The ground speed of an upstream passing fish is the fish's burst speed minus the river velocity, and the fish must maintain a positive ground speed long enough to pass this distance before becoming fatigued. The pools between weirs in any fish passage structure (including constructed riffles) provide resting areas for fish. Velocity and depth criteria for pools are derived using two different methods: habitat suitability indices, and sustained swimming speeds for the species. Fish can also rest in small eddies or, in the case of Lake Sturgeon, by the downward force of hydraulic vectors resulting from their wedge-shaped head; this allows them to rest even in high velocity flow areas. The target pool depth is three times the maximum body depth of the fish species to minimize the risk of fish avoiding pools that are too shallow and to decrease risk of predation from birds and other terrestrial predators.

## 5.3 Economic Impact Considerations

Public Sector Consultants (PSC) was contracted as part of the feasibility study to assess the contributions of the Flat Rock and Huroc Dams to the local recreational economy and property values and estimate the economic and housing impacts of their partial or full removal. Given the complexity of this analysis, it is highly recommended that readers go to Appendix I-Dam Economic Contribution Study to read the full economic contribution study.

This section of the report presents a summary of the results of the economic study but does not discuss the methodology or assumption associated with the study.

PSC used research literature, data from local recreational managers and organizations, and reviewed and collected information on the number and types of visitors to recreational facilities in the area. Five scenarios were analyzed for this analysis:

- Current impoundment
- Short-term partial removal (decommissioning phase)
- Short-term full removal (decommissioning phase)
- Long-term partial removal (ten years post decommissioning)
- Long-term full removal (ten years post decommissioning)

### Current Impoundment

PSC identified two main recreational activities associated with the current impoundment most likely to be impacted by a partial or full dam removal scenario: angling at Huroc Park and non-boat rental visitors at Oakwoods Metropark Nature Center (non-boat rental). Economic contributions from these two activities were a focus of the economic contribution study.

PSC found that on an annual basis, Oakwoods Metropark Nature Center, which is adjacent to the backwaters of the Flat Rock Dam, saw 2,017 visitors. Huroc Park saw 3,673 anglers annually. These counts were then applied to an inflation-adjusted recreation expenditure profile produced by an economic impact analysis of recreational activity along the Huron River. The average spending per trip for non-anglers and anglers was estimated at $15 and $42, respectively (Isley et al. 2017; U.S. Department of the Interior [US DOI] 2022).

### Short-Term Economic Impacts (Partial and Full Removal)

Short-term economic contributions associated with decommissioning or construction phases of the partial and full dam removal scenarios were also assessed. Economic contribution during the construction phase of either of alternative will consist of spending on construction materials and labor. Thus, the economic contribution is directly tied to the construction estimates provided in detail in Appendix K.

In general, construction projects of this size result in a short-term influx of jobs and labor income to the local economy. The extent of economic impact is directly related to the cost of the construction project. The higher the construction cost, the more jobs and labor income added.

### *Long-Term Recreational Economic Impacts (Full Removal)*

It is difficult to predict exactly how dam removal may affect recreation on the Huron River if the Flat Rock and Huroc dams are removed. PSC cited a number of studies that provide insight into the various areas of complexities and difficulties to predict how a project site might react from dam removal.

Angling will be impacted. While the volume of angling trips cannot be predicted beyond current observations, the type of angling can be reasonably anticipated with the removal of the dams, it is expected that angling will shift from onshore pond-like areas (e.g., Huroc Park) to more river-based fishing. This shift may lead to changes in spending patterns, as one study cited. Per angling trip expenditures increased from $42 to $96 (Hebdon et al. 2008; McKean el al. 2010; US DOI 2022).

Paddling on the river is also a recreational area that is expected to be significantly impacted by dam removal. Based on stakeholder interview and reviews of available data, PSC stated approximately 5,000 people rent canoes or kayaks in the area each year. The presence of the dams ensures nearly all trips either end before the impounded area or start below the Huroc Dam. The difficulty associated with bypassing the dams limits visitor traffic to local business in the City of Flat Rock. Dam removal is expected to open a recreational pathway for paddlers on the river. PSC projected a growth in the number of people renting canoes and kayaks over a ten-year period from an estimated 4,594 in 2023 to 25,006 ten years post dam removal.

### *Long-Term Recreational Economic Impacts (Partial Removal)*

The Partial Dam Removal alternative will result in a negligible drop in water levels and therefore we can assume only a modest shift in recreation activity is likely to occur. Annual angler trips are expected to be similar and would likely remain as onshore fishing activities.

Partial dam removal will create a more accessible boat portage for paddlers, likely leading to increased paddler activity if this alternative were to be selected. PSC estimated an increase in the number of people renting canoes and kayaks over a ten-year period from 4,594 in 2023 to 10,106 ten years after partial dam removal.

Specific results of the economic impacts during short-term and long-term scenarios for both partial and full dam removal alternatives are presented in the main economic contribution study report included in Appendix I.

### Residential Property Value Analysis

PSC conducted an analysis to estimate the current property values and tax revenue for residential properties along the current impoundment.

A hedonic analysis assessed the current impoundment's contribution to adjacent property values and tax revenue. This statistical approach isolates and measures the impact of various factors on a property's value. By holding as many factors constant as possible, the analysis identifies the individual contributions of each factor to the property's final value. PSC used the hedonic analysis to determine how proximity to the Flat Rock and Huroc Dams' impoundment impacts residential property values. These estimates only convey contribution to property value, but do not predict the change in residential property values if the dams were to be removed. The methodology of the hedonic analysis is explained in more detail in the Economic Contribution Study in Appendix I.

To gauge the impact of dam removal, PSC assessed existing relevant studies evaluating residential housing values following impoundment drawdowns.

#### Findings

The hedonic analysis indicated the Flat Rock and Huroc impoundments have minor effect on market values, except to those properties immediately adjacent to the impoundment. There were similar findings for assessed and taxable values, with adjacent properties showing higher taxable value compared to other properties within proximity to the impoundments. The full study report in Appendix I reports out specific values and tables.

### Estimated Impact on Residential Property Values Under Dam Removal Scenario

There are 56 adjacent residential properties on the Flat Rock impoundment. This study asks the question, "What might be the net effect of replacing one amenity with another?" In this case, the amenity to be replaced is the impoundment, and it is to be replaced with a natural greenway and free-flowing river.

PSC utilized a literature review to examine case studies and comparable dam removal scenarios. Studies indicate property values are strongly influenced by proximity to water. Dam removal will primarily impact the 56 properties adjacent to the impoundment, while the rest of the study area will see less significant effects. The literature suggests that property value trends after dam removal vary widely and are influenced by factors such as water quality, recreational opportunities, and the overall desirability of the new natural amenity. While some studies show that values can rebound or even increase post-removal, others demonstrate negative or neutral effects. Given these uncertainties, the study does not conclude a definitive net benefit or loss in property values but emphasizes that long-term outcomes will hinge on the successful implementation and management of the restored river and green space. Full results and further discussion is provided in Appendix I.

## 5.4 Property Boundary Survey

PEA Group was contracted to complete a property boundary survey of the properties immediately adjacent to the Flat Rock impoundment to gain a better understanding of physical property lines in relation to the current waters' edge. In general, PEA Group found that the legal descriptions for adjacent properties provide a physical description of the property limits and no properties are directly tied to the waters' edge. Most property descriptions are generally in line with the existing approximate water line, however there are some properties where the property line extends slightly into the impoundment and others where that do not extend all the way to the existing water line. The property boundary exhibits are included in Appendix J

# 6. Dam Alternative 1 – No Action – Fish Passage Improvement

The 'No Action – Fish Passage Improvement' dam alternative maintains the existing Flat Rock and Huroc Dams but improves fish passage past both structures by removing the existing Denil fishway on Flat Rock Dam and replacing it with a nature-like rock ramp fishway and adding a nature-like rock ramp fishway to the Huroc Dam. The proposed fishway on Flat Rock Dam would be constructed within the footprint of the existing Denil fishway and unused boat lock located along the right side of the Flat Rock Dam. The fishway would provide a more gradual transition from the upstream water surface elevation to the downstream normal tailwater elevation, allowing native fish species to move through a series of rock weirs and resting pools to swim up- and down-stream of the Flat Rock Dam. Figure 9 below represents the conceptual design and layout of this alternative.

Huroc Dam can be considered a partial or full barrier to upstream movement for most of the fishes in the Huron River. Therefore, the installation of a new fishway on Flat Rock Dam will not provide significant fish passage benefits unless Huroc Dam is also modified to permit fish passage. The two potential alternatives for facilitating fish passage at Huroc Dam would be the installation of a fishway or the removal of Huroc Dam. The removal of Huroc Dam is discussed in Alternatives 2, 3, and 4, and this information is not repeated here. Instead, a conceptual approach to designing and constructing a fishway for Huroc Dam is discussed.

As with Flat Rock Dam, a nature-like rock ramp fishway would be recommended for Huroc Dam under the No Action – Fish Passage Improvement Alternative. Nature-like fishways are designed to mimic the slope, substrate, and hydraulics of natural stream systems to the extent possible. A nature-like fishway design for Huroc Dam would incorporate slope, minimum width/attraction flow, substrate, and resting pool specifications to attract and successfully pass the resident fishes in the Huron River. Most fishways that would allow passage of native fishes will also allow passage of invasive Sea Lamprey; management options for this species (including barrier options) are discussed in Section 9.

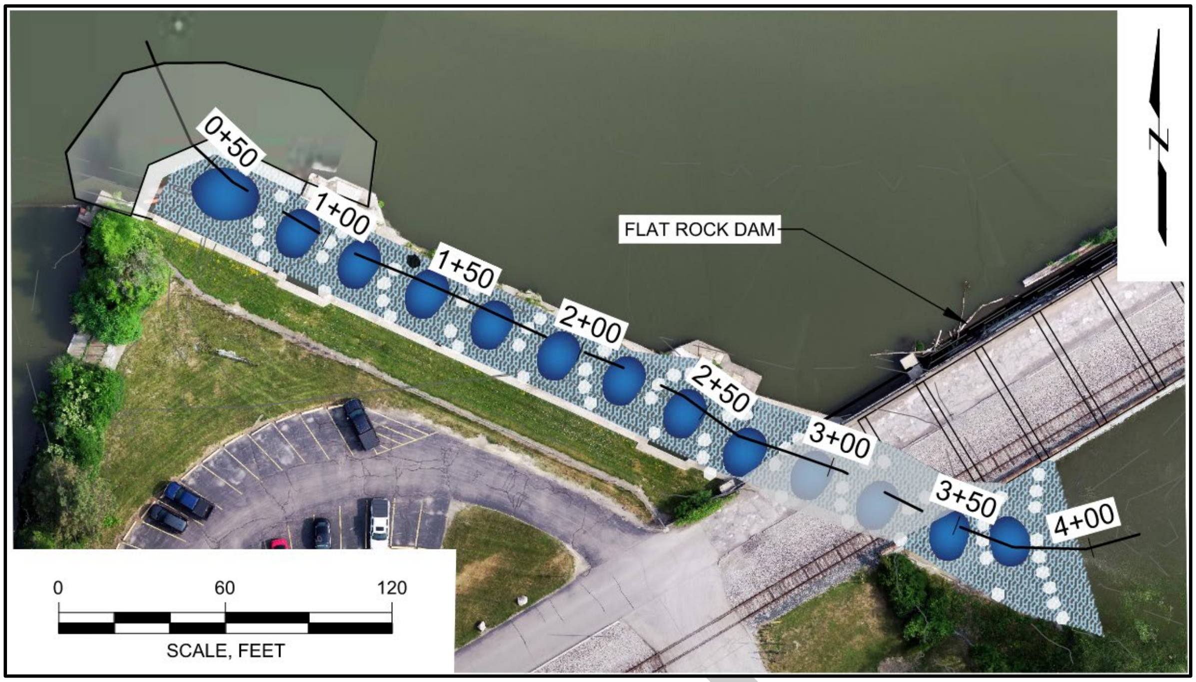


Figure 9: Alternative 1 - Fish Passage Modification at Flat Rock Dam

## 6.1 Hydrologic and Hydraulic Consideration

Under the No Action – Fish Passage Improvement Alternative, the Flat Rock Dam and the Huroc Dam would remain in place with improved fishways. There would be no change to water levels or other hydraulic parameters compared to existing conditions.

## 6.2 Geotechnical and Structural Consideration

Generally, there are expected to be minimal geotechnical concerns with this alternative. Any impacts would be limited to the footprint of the new fishway. The known underlying bedrock could potentially impact or limit the pool depths in the downstream portions of the lock.

With the proposed fishway utilizing the existing boat lock structures (i.e., retaining walls) a more detailed structural assessment of the lock would be necessary as part of a more detailed design effort. Achieving target pool depths in the lock may be limited in the downstream portions where excavation cannot occur without undermining the existing concrete walls. These potential limitations could necessitate additional modifications to the lock, in addition to the construction of the rock ramp. Significant changes to the lock, such as elevation changes to the concrete floor near the downstream end and/or structure widening may be feasible. A detailed structural assessment would provide the necessary information to guide design efforts, identify practicality of modifications to the lock area, and determine costs for those modifications. For the purposes of this feasibility study, a lump sum cost for structural modifications was included in the conceptual cost estimate as a planning mechanism for a more detailed structural assessment and potential construction considerations.

## 6.3 Economic Impact Consideration

The No Action - Fish Passage Improvement Alternative will have little to no impact to water surface elevations within the Flat Rock or Huroc impoundments. Adjacent properties will continue to have proximity to the impoundment and recreational activities will remain the same or similar to existing conditions. Therefore, there is not anticipated to be an impact to long-term economics or property values. Short-term economic impacts from construction of the improved fishway were not evaluated at this time.

## 6.4 Environmental and Ecosystem Considerations

### *Wetlands and Threatened and Endangered Species*

Fringe wetlands have been identified along the island's banks southwest of the existing fish ladder. These wetlands are dominated by non-native species with patches of a state threatened plant species, water willow (*Justicia americana*) identified in the area between the Flat Rock and Huroc Dam and immediately upstream of the Flat Rock Dam. Wetland protection measures such as minimizing land disturbance, establishing buffer zones, and erosion and sediment control will be required during the construction of the fishway. If careful consideration is taken in construction planning and land disturbance is minimized, it is likely fishway construction should have minimal to no impact on existing wetlands and T&E species.

If modifications to the existing Denil fishway are expected to impact the riverbed, a mussel survey would likely be required in advance of this alternative. The survey would be limited to areas that could safely be accessed by wading or the use of dive equipment. If state or federally listed mussels (Appendix F) were detected during the survey, a mussel relocation effort would be required prior to constructing this alternative. Mussel surveys can be conducted up to five years in advance of a project, whereas mussel relocation efforts need to occur two years or less ahead of construction. If mussel surveys detect federally listed mussels (e.g., Snuffbox) at this site, then consultation with USFWS would be required before mussel relocation efforts. As such, mussel surveys should be considered early in the project timeframe to account for potential USFWS consultation.

### *Fish Passage*

Although referred to as the No Action – Fish Passage Improvement Alternative, this alternative would include the addition of a fishway on Flat Rock Dam in the area currently occupied by a former boat lock, and a potential fishway on Huroc Dam. Because of concerns with Lake Sturgeon and Walleye passage through Denil fishways, as well as the potential for Denil fishways to exclude other resident fish species, other fishway types should be considered for Flat Rock Dam, either in addition to or in replacement of the existing Denil fishway.

If alternative 1 is selected, the following modifications are recommended. The old lock on the right side of the river looking downstream could be modified to accommodate a fishway. The lock is roughly 25 ft. wide (i.e., five times wider than the existing fishway); its increased size would accommodate a larger proportion of the Huron River's flow and would therefore improve attraction flows to the fishway. To prevent Sea Lamprey from utilizing the structure, the fishway could be construction to include accommodations for a sea lamprey barrier that could be utilized if future need arises for sea lamprey control during the lamprey spawning migration from March through June. The current cost estimate assumes full closure of the fishway during the lamprey migration period which would also prevent native fish passage and passage of desirable species such as salmonids. At this time, this would be the least expensive method of creating a lamprey barrier with this alternative, assuming the Flat Rock Dam remains in place and continues to function as a barrier.

## Fishway Improvement Alternatives

Two potential fishway types could be installed in the old lock: a vertical slot fishway (Figure 10) or a rock ramp fishway. The rock ramp fishway would have similar design characteristics to the rock-arch rapids described further as the Partial Removal option, but the location would be limited to the existing lock. However, a rock ramp fishway would likely perform better and cost less than a vertical slot fishway, as described below. A brief literature review was performed to compare the performance of vertical slot fishways and rock ramp fishways with respect to the target species of Lake Sturgeon, White Bass, and Walleye.

Slot width, slot location (i.e., center or side), and number of slots vary depending on fishway hydraulics and species targeted for passage. Photo credit: Brett Towler, available online https://scholarworks.umass.edu/fishpassage_images/1/

Figure 10: An Example of a Vertical Slot Fishway

The efficacy of vertical slot fishways to pass the target species appears to be limited. Atlantic Sturgeon use of vertical slot fishways has not been documented (ASMFC 2010), but they may be more selective than Lake Sturgeon in terms of fishway use – 36% of Lake Sturgeon confined to a net pen during experimental evaluation of a vertical slot fishway moved upstream successfully (Thiem et al. 2011). The reasons for low passage efficiency of sturgeon through vertical slot fishways is not known, but in prototype vertical slot fishways, passage efficiency was highly variable and depended on the interaction of baffle configuration and water velocity (Webber et al. 2007). Walleye also use vertical slot fishways with variable success. Successful walleye passage rates through a vertical slot fishway on the Richlieu River in Quebec were greater than 50% (Thiem et al. 2012), but multiple studies indicate that this species has difficulty in navigating this type of structure (e.g., https://www.biotactic.com/upstream-passage-of-walleye/).

On the other hand, rock ramp fishways hold significant promise in facilitating upstream passage of native species (including the target species of Lake Sturgeon, White Bass, and Walleye). Because rock ramps are designed to mimic the morphological and hydraulic structure of natural riffles, they are more likely to allow passage of fishes with a wide diversity of body shapes and swimming abilities. For example, there is evidence that these “nature-like bypasses” will work for Atlantic Sturgeon (ASMFC 2010), which tend to be selective of the fishways they utilize. Furthermore, an evaluation of seven Great Lakes Region fishways designed to pass Lake Sturgeon showed that vertical slot fishways did not pass sturgeon as efficiently as rock ramps (Bruch and Haxton 2023). Evaluations of rock ramps and their efficacy to pass Walleye and White Bass are often limited by low capture and recapture probability, but successful passage has been documented in multiple locations in the Great Lakes Region. (Wigren et al. 2019, Aadland 2010). In addition, the fishway evaluation by Bruch and Haxton (2023) also demonstrated that vertical slot fishways are an order of magnitude more expensive to design and construct than rock ramp fishways. If this alternative is selected, we recommend that the lock structure be fitted with a rock ramp fishway.

### *Rock Ramp Fishway Specifications*

Specifications for a rock ramp fishway in the existing boat lock on Flat Rock Dam and a fishway at Huroc Dam would be developed with the guild-based approach described in

Section 4.7. While retrofitting the existing lock with a fishway represents a lower-cost option to improve fish passage when compared to the other options, this alternative may lead to unique issues that would not occur with other alternatives. These potential issues are discussed briefly here.

If a rock ramp fishway were to be installed in the old boat lock, it should improve fish passage past the Flat Rock Dam. However, its small size in comparison to the width of the stream channel (25 ft versus the total channel width of approximately 490 ft) may make the fishway difficult to locate for many fish species. Furthermore, a fishway entrance that is small in relation to channel size presents risk to ascending fishes. Large numbers of fish can congregate downstream of a fishway with a relatively small entrance; this can lead to interspecies interactions such as exclusion of smaller fishes and increased predation by birds, mammals or other fish that would not occur under natural conditions. Achieving target pool depths in the lock may be limited in the downstream portions where excavation cannot occur without undermining the existing concrete walls or railroad bridge piers or where bedrock is present. Similar considerations of rock ramp width, predation risk at confined rock ramp entrances, and structural/hydraulic engineering constraints would also apply to a fishway design for Huroc Dam.

### *Aquatic Organism Habitat*

With the exception of increased aquatic connectivity between river segments upstream and downstream of the Flat Rock and Huroc dams, little to no habitat improvement would be expected under the No Action – Fish Passage Improvement Alternative. The hard substrate in the rock ramp fishway may attract small-bodied riffle dwelling species such as darters and macroinvertebrates. However, the rock ramp would be small relative to the size of the river, so improvements to aquatic habitat would be minimal.

One other potential benefit with increased fish passage may be increased mussel presence upstream of the Flat Rock and Huroc dams since the new fishway would likely increase upstream travel of fish, some of which may be carrying juvenile mussels. However, successful mussel recruitment upstream of Flat Rock Dam would require fish to move into stream reaches upstream of the impoundment, because the soft sediment in the impoundment is not suitable mussel habitat.

### *Sediment*

A sediment transport analysis was not conducted for the No Action – Fish Passage Improvement Alternative since leaving the dams in place will effectively keep sediment transport conditions the same as existing conditions. Bedload would stop and settle out within the impoundment with braided channels and islands forming near the inflection point of the impoundment's influence on the Huron River. During storm events, suspended load would be transported downstream over the fixed crest of the dam. The river channel downstream of the Flat Rock Dam is much wider than the channel upstream of the dam's influence and therefore sediment may potentially settle out in this area due to backwater from the Huroc Dam and the increase in cross-sectional area which decreases velocities and shear stresses. It is also possible this suspended load would settle out on either the left or right banks for discharges that are greater than the 2 year event. With respect to the retrofitted lock for fish passage, either the vertical slot or rock ramp would maintain a headwater similar to that of the Flat Rock Dam, so sediment transport is assumed to occur in a manner similar to current conditions. This option allows for the existing impoundment elevation to be maintained, so no bottomland exposure is anticipated.

## 6.5 Public Utilities and Safety Considerations

### *Dam Safety*

This alternative would not pose any new long-term safety concerns for the dam and surrounding area because the site conditions and structure will remain the same. The risks associated with the dam will remain. The dam will continue to undergo inspections every 3 years and HCMA will continue to be responsible for annual maintenance and upkeep and long-term rehab efforts for as long as the structure remains. The risks associated with the dam remain the same.

### *Public Utilities*

The initial utility survey found no utilities present within the lock. Most identified utility lines are fastened along the girder of the Flat Rock vehicular bridge and pedestrian bridge. Further coordination with utility providers would need to occur should this design option be selected.

### *Public Safety and Recreation*

Regarding public safety, exclusion measures such as fencing and booms like those currently in place should be considered to deter the public from entering the fishway by foot or boat. Recreational access to the dam impoundment would remain as it exists today. Paddlers on the Huron River would continue to need to use the gated portage on Flat Rock Metals property and put back in the river downstream of the Huroc Dam.

## 6.6 Potential Regulation Change Considerations

In 2021, the EGLE Dam Safety Task Force released a document outlining recommended more stringent regulatory requirements to enhance dam safety in Michigan, which align with national standards. These proposals suggest amendments to Part 315, Dam Safety

(Part 315) of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. At the time of this report, it is uncertain when or if these recommendations will be included in the Dam Safety Act. However, given the expected life span of a dam, it is in the interest of HCMA to evaluate potential long-term added costs if legislation approves more stringent measures. Table 5 highlights the major potential regulatory changes that would most significantly impact long-term maintenance of the Flat Rock Dam and HCMA obligations. These recommended changes are based on the Dam's classification as a 'High Hazard' dam by the state of Michigan.

Table 5: Summary of Potential Regulatory Changes for High Hazard Dams

| Regulatory Change | Current | Proposed |
|---|---|---|
| Engineering Inspections | 3 years | 1 year (visual), 10 years (in-depth evaluation) |
| Spillway Capacity | 200-year (1/2 PMF if over 40 feet high) or flood of record | PMF or IDF |
| Licensing Requirements | None | 15-year Registration |
| Financial Assurance | None | Required |
| Insurance | None | Required |
| Emergency Action Plan | Update Annually – No Exercise Requirements | Update Annually – 5-year Exercise Requirement |

## Dam Inspection Frequency

If dam regulations change, HCMA may be required to contract and fund yearly high-level visual dam inspections, if not provided by the State as currently done. In addition to annual inspections, HCMA also be required to perform periodic (no more than every 10 years) independent comprehensive reviews of the original design, construction, maintenance, repair, and probable failure modes conducted by a qualified and licensed team of engineers. This comprehensive assessment will likely include exploratory investigations and detailed engineering analyses.

## Spillway Capacity

Updated regulations will necessitate spillway capacity considerations for either the Probable Maximum Flow (PMF) or Inflow Design Flood (IDF) events. Both PMF and IDF events are used to assess the maximum possible flow rates in water systems. However, they differ in their scope and application. Determining the maximum IDF utilizes a risk-based approach for sizing the spillway, versus the prescriptive approach of the PMF. Aspects comparing the two methods are found in Table 6.

Table 6:Comparison of Probable Maximum Flow (PMF) and Inflow Design Flood (IDF)

| Aspect | Probable Maximum Flow (PMF) | Inflow Design Flood (IDF) |
|---|---|---|
| **Definition** | Theoretical maximum flow rate under extreme meteorological conditions. | A risk-based approach to selecting a design flood based on consequence of failure during discrete flood conditions. |
| **Purpose** | Design and assess the safety of large hydraulic structures, particularly dams. | Balance the risks of hydrologic failure of a dam with the potential downstream consequences |
| **Calculation** | Based on extreme meteorological conditions, considering factors like precipitation rates and topography. | Based on hydraulic modeling of incremental flood events and consequences of failure. |
| **Frequency** | Extremely rare with an incredibly low probability of occurrence (e.g., "1 in 10,000-year" event). | More frequent, typically with return periods ranging from 50 to 10,000 years. |

Given the minimal freeboard available with the current spillway capacity at the Flat Rock Dam, accommodating either a PMF storm event or IDF storm event could necessitate the spillway being able to accommodate double the discharge which may require significant dam modifications or replacement. This could include installation of gates as part of the dam, increasing weir length, or other dam modification. A dam breach inundation analysis, and site-specific PMF study will be necessary to establish site-specific PMF and IDF values. Regardless of which flow calculation method yields the smaller flow rate, the cost to accommodate the updated flow rate will be substantial.

## *Licensing Requirements*

Under current regulations, a dam owner only seeks a permit through the State of Michigan at the time of construction or modification. The proposed regulations may necessitate HCMA to apply for a license renewal every 15 years. During the renewal process HCMA will report on maintenance, operation, and engineering investigations, including annual inspection reports and independent comprehensive reviews. Failure to secure a license renewal could require the removal of the Dam at HCMA's expense.

The recommended licensing requirements dictate that the Dam owner must maintain adequate insurance to cover all liabilities resulting from a dam failure. HCMA currently holds an insurance policy with a limit of $325,000. This amount likely would not sufficiently cover all liabilities from a dam failure and the HCMA's insurance policy may need to be significantly increased.

As part of the licensing renewal, HCMA would also be required to provide evidence of fiscal responsibility or security to ensure the continued safe operation and maintenance of the Dam.

### *Cost Estimate Comparison for Legislation Change*

Potential regulation changes will increase the annual and long-term costs of managing the dams. Table 7 provides cost estimates for each potential change and compares them with current long-term financial responsibilities of the dam owners. These estimates consider a 50-year life cycle and include a 4% annual inflation rate. Legislative changes under Alternative 1 will add $3.5 million to the long-term maintenance costs over 50 years, based on 2024 dollars. The costs in Table 7 exclude the construction of a new fish passage. Section 6.8 provides a full cost comparison.

Table 7: Comparison of No Legislation Change/ Legislation Change 50-year Life Cycle Cost for Alternative 1

| | No Change | | Legislation Change | |
|---|---|---|---|---|
| Item | **2024 Dollars** | **Future Dollars*** | **2024 Dollars** | **Future Dollars*** |
| Inspections (annual) | - | - | $500,000 | $1.59 M |
| Increased Spillway Capacity (at 10 yrs.) | - | - | $2 M | $2.97 M |
| Maintenance and Operations (annual) | $500,000 | $1.59 M | $500,000 | $1.59 M |
| Inspections In Depth (every 10yrs) | - | - | $500,000 | $1.89 M |
| Licensing and Insurance Requirements (annual) | - | - | $500,000 | $1.59 M |
| Major rehabilitation/repairs (end of life cycle) | $1.5 M | $10.67 M | $1.5 M | $10.67 M |
| TOTAL | **$2 M** | **$12.3 M** | **$5.5 M** | **$20.3 M** |

*The cost estimates in future dollars account for a 4% annual inflation rate, based on 2024 dollars
Summation inconsistencies due to rounding.

## 6.7 Other Benefits and Drawbacks

Table 8 outlines other benefits and drawbacks of this alternative.

Table 8: Benefits and Drawbacks of Maintaining Dams with New Fishways

| Maintain Dam Alternative with New Fishway | |
|---|---|
| **Benefit** | **Drawback** |
| - Current recreational use maintained.<br>- No impact to adjacent property owners.<br>- Potential improvement of fish passage. | - Water quality issues and ecosystem disruption.<br>- Overall less efficient fish passage.<br>- Continued expense for the life of the Dam.<br>- Continued sediment buildup.<br>- Existing portage around the dam will still be required. |

## 6.8 Permitting, Schedule, and Dam Owner Considerations

### *Permitting*

Alternative 1 will require a EGLE Joint permit. A joint permit application process is a coordinated approach used to streamline the permitting process for projects that involve multiple permits. The No Action – Fish Passage Improvement alternative should require the following permits as part of the Joint Permit Application:

- **Part 315 - Dam Safety**: For constructing, repairing, or removing dams to ensure they meet safety standards.
- **Part 31 - Water Resources Protection (Floodplains)**: For activities related to water use and discharge, protecting floodplain functions, and minimizing flooding impacts.
- **Part 301 - Inland Lakes and Streams**: For activities like dredging, filling, or constructing structures in or near inland lakes and streams.
- **Part 303 - Wetlands Protection**: For activities that might alter or impact wetlands.
- **Part 91 - Soil Erosion and Sedimentation Control**: For earth changes that disturb one or more acres of land or are within 500 feet of a lake or stream.

### *Project Schedule*

Once dam owners select a preferred alternative, they will likely need to solicit proposals for design from engineering consultants. The design process will include 30%, 60%, 90%, and 100% final design documents. If selected, Alternative 1 has an expected design timeframe of 9-12 months, including permit review. If, for example, HCMA and the City of Flat Rock both decide to move forward with Alternative 1, the timeline could follow the schedule outlined in Table 9.

Table 9: Alternative 1 – Theoretical Project Schedule

| Stage | Length |
|---|---|
| Solicitation for Design | 3 mo |
| Final Design Services (30, 60, 90, 100%) | 9 mo |
| Permitting (begins at 60% design and occurs concurrent with rest of design effort) | 3 – 9 mo |
| Bidding to Construction Contractor | 2 – 3 mo |
| Construction | 6 – 9 mo |

This timeline is an estimate based on experience completing similar projects. A schedule would be further defined once a preferred alternative is selected by each dam owner and may be affected by funding availability.

### *Dam Owners*

As noted previously, the Huroc Dam can be considered a partial or full barrier to upstream movement for most of the fishes in the Huron River. The existing Denil fishway on Flat Rock Dam has the potential to exclude a majority of the resident fishes in the Huron River under low flow conditions, but studies have shown that some fish passage occurs during higher flows . Under this Alternative, improvement of fish passage past both the Huroc and Flat Rock dams would require that fishways be constructed at both structures. The fishways do not have to be installed concurrently, but if a new fishway were to be installed at the Flat Rock Dam, it would be ideal if a fishway had already been installed at the Huroc Dam. For this reason, for Alternative 1 to be successful it will be important for both dam owners to coordinate efforts to improve fish passage at the two dams.

## 6.9 Cost Estimate

The cost estimates provided are AACE Class 4 estimates which are appropriate for feasibility studies and the current level of design completed. These estimates carry an expected accuracy of up to -30% to +50% and are meant to guide future planning and decision making. Initial costs to construct this alternative were developed as well as 50-year life cycle cost estimates. Fifty (50)-year life cycle cost estimates are provided in both 2024 dollars as well as future dollars assuming a 4% inflation rate. Cost estimates were based on current day bid prices from similar projects and materials within the region and based on engineer's experience. Appendix K contains the detailed breakdown of costs associated with each alternative.

### *Initial Cost Estimate*

A construction cost estimate was prepared for this design alternative assuming no costs associated with direct maintenance or work on the existing Flat Rock Dam. Under this alternative the existing Denil Fishway would be removed, a mixture of sand, gravel, and cobble would be placed into the bottom of the lock to create the base of resting pools, and boulders would be placed as the grade controlling structures. Alternative 1 is estimated to cost $2.6 million for Flat Rock Dam and $750,000 for Huroc Dam which includes a 30% contingency for unknown items and market changes, 10% for design engineering and permitting, and 10% for construction engineering and observation.

### *50-year Life Cycle Cost Estimate*

Given the lifespan of a dam and the requirement for ongoing repairs, it is likely that maintenance over time will be needed. Over the next 50 years, the Dam will necessitate annual maintenance, operations, periodic inspections, and insurance, incurring additional costs within the evaluated timeframe. Additionally, the new fishway will likely require regular maintenance. Currently the existing Denil fishway is operated and maintained by the Huron River Fishing Association. It is unclear at the writing of this report which organization would take on regular maintenance and inspection of the proposed rock-ramp fishway. For the purposes of this cost estimating effort, we have included regular maintenance and repairs in the 50-year life cycle cost. Table 10 highlights and compares estimated long term costs of the Dam, outlining initial repairs, 50-year life cycle cost represented in 2024 dollars, and an estimation of the 50-year life cycle cost in future spending based on a 4% annual inflation rate. After this 50-year life cycle, the Dam will necessitate ongoing maintenance and repairs for its duration.

Table 10:Cost Estimate for Maintaining Dam and Improving Fishway

| | Assuming No Legislation Changes | | Assuming Legislation Changes | |
|---|---|---|---|---|
| | **2024 Dollars** | **Future Dollars*** | **2024 Dollars** | **Future Dollars*** |
| *Flat Rock Dam* | | | | |
| Initial construction cost | $2.6 M | $2.6 M | $2.6 M | $2.6 M |
| Total operation and maintenance costs over next 50 years | $2 M | $12.26 M | $5.5 M | $20.27 M |
| Total Cost (including initial construction) | $4.6 M | $14.84 M | $8.1 M | $22.87 M |
| *Huroc Dam* | | | | |
| Initial construction cost | $750,000 | $750,000 | $750,000 | $750,000 |
| Total operation and maintenance costs over next 50 years | $500,000 | $1.59 M | $500,000 | $1.59 M |
| Total Cost (including initial construction) | $1.25 M | $2.34 M | $1.25 M | $2.34 M |
| ***Total*** | | | | |
| **Initial construction cost** | **$3.35 M** | **$3.35 M** | **$3.35 M** | **$3.35 M** |
| **Total operation and maintenance costs over next 50 years** | **$2.5 M** | **$13.85 M** | **$6 M** | **$21.86 M** |
| **Total Cost (including initial construction)** | **$5.85 M** | **$17.18 M** | **$9.35 M** | **$25.21 M** |

*The cost estimates in future dollars account for a 4% annual inflation rate, based on 2024 dollars. Summation inconsistencies due to rounding.

# 7. Dam Alternative 2 – Partial Removal

## 7.1 Description

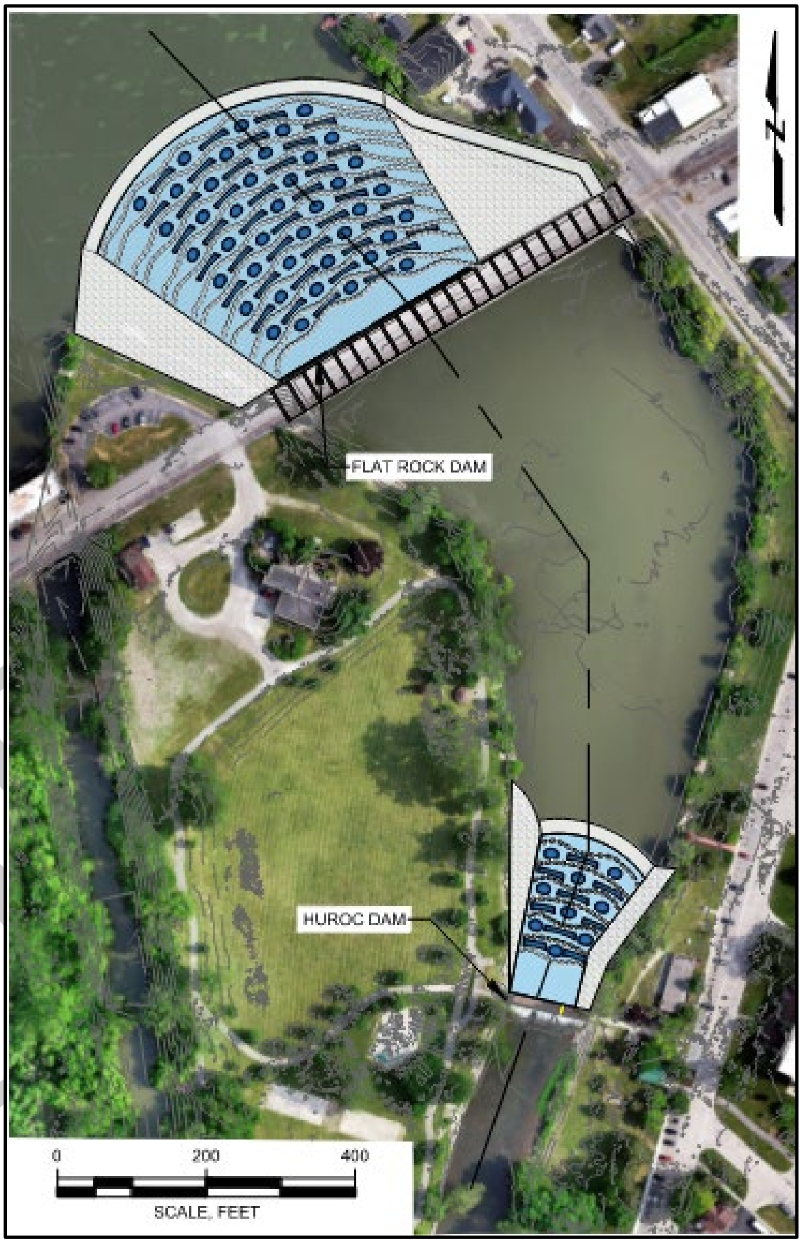


Figure 11: Partial Removal

Partial dam removal of the Flat Rock and Huroc dams was considered with the primary benefits of this alternative being to maintain a reservoir with similar water levels to the existing Flat Rock Dam and maintaining the existing tailwater through partial removal of the Huroc Dam. This alternative included investigating the feasibility of rock arch rapids at both the existing Flat Rock and Huroc dam locations (Figure 11). A rock arch rapids, sometimes also referred to as rock rapids, boulder rapids, or rock ramp, is a type of nature-like fishway comprised of a series of rock arches (i.e., weirs). At the Flat Rock Dam, each weir downstream of the first weir is designed for a maximum of 0.6 feet of head loss over a total of 13 weirs and the crest (Figure 12). Each weir, comprised of boulders 3 to 5 feet in size, has a sinusoidal plan-view shape to concentrate flow into the design pool areas and provide stability to the rapids.

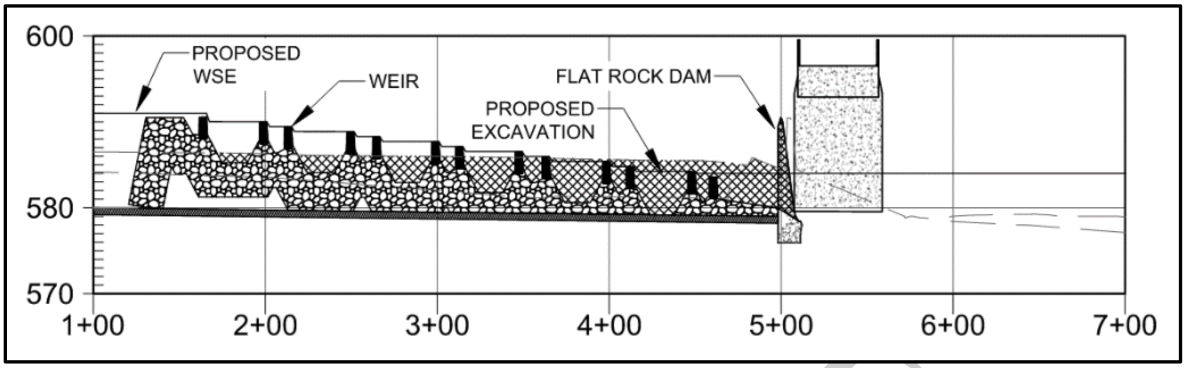


Figure 12: Partial Dam Removal - Profile View of Flat Rock

A low-flow thalweg (area of lowest elevation) and higher flow terrace is built into each weir to maximize water depth and fish passage during variable flow conditions. Terrace weirs are approximately 1 foot higher than thalweg weirs. Gaps in between the weir boulders will allow fish to burst swim through weirs and enter pools ranging from 2 to 6 feet deep providing resting locations for fish prior to approaching the next upstream weir (Figure 12).

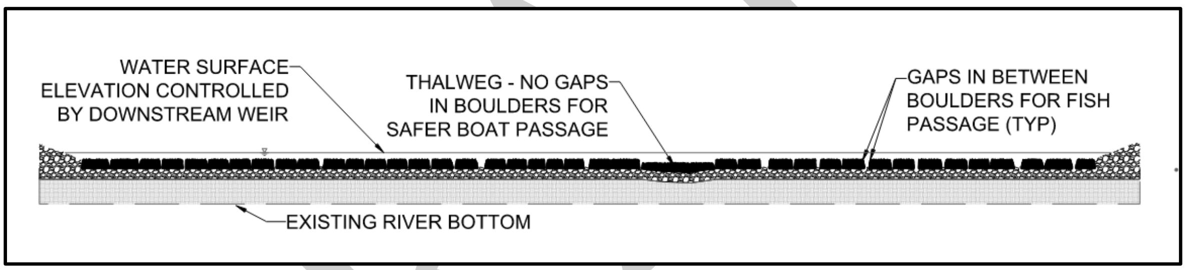


Figure 13: Partial Dam Removal - Cross Section of Rock Arch Rapids Weir

A similar design approach was used at the Huroc Dam. The need for partial removal of the Huroc Dam and construction of a rock arch rapids allows the water surface elevation in between the two dams to fluctuate in a similar manner as it does currently, while also providing fish passage from downstream of the Huroc Dam, past Huroc Park, and up to and past the Flat Rock Dam if a rapids is constructed. To accommodate a maximum of 0.6 feet of head loss across each weir and the crest, 7 weirs are proposed at Huroc Dam.

Concept plan details for this option are provided in Appendix A. If this design is selected, other key design considerations may warrant minor modifications. Design considerations may include geometry modifications to the crest (to increase hydraulic capacity and decrease velocity, maximizing fish passage and flood storage) and removal or addition of weirs at the downstream end of the proposed structure dependent upon the need for a Sea Lamprey barrier, the selected design at Huroc Dam, or changes to the tailwater conditions. Further, if a combination presented within this study is desired. Under this alternative, removal of Huroc Dam and installation of a rock arch rapids at Flat Rock Dam was not feasible given that 7 additional weirs would be required upstream of the Flat Rock site, potentially impacting upstream property owners. This would likely impact the private property owners closest to the dam.

## 7.2 Hydrologic and Hydraulic Consideration

The hydraulics through the railroad bridge structure could potentially be a challenge to this alternative as any fill within the bridge cross section is likely to negatively impact the hydraulic capacity of the bridge. However, this is only a problem if the hydraulic modeling indicates the proposed channel cannot convey the required storm without raising water surface elevations. With installation of a rock ramp/rock arch rapids, a seasonal or adjustable lamprey barrier may be considered at or near the location of the existing Huroc Dam. Sea Lamprey Barrier considerations are discussed later in this report in Section 9.

In support of this design alternative, the existing conditions HEC-RAS model described in Section 5 was modified to evaluate the impact of the proposed project on flood elevations upstream of both dams. The model includes existing and proposed condition scenarios for comparison of flood elevations along the modeled river reach.

The proposed model was developed by updating geometry and roughness coefficients to represent the proposed conditions. The proposed model was compared against the existing conditions model to verify no rise in water surface elevations during the prescribed flood events. If this alternative were to be progressed, the model will be updated to identify any rise and evaluate the need for potential compensating cut, which is excavation within the 100-year floodplain to increase flood flow conveyance, in order to have no impact to the flood elevations. Initial results showed that the area between Huroc Dam and Flat Rock Dam may need to be evaluated further for potential compensating cut in order to not increase flood elevations. Upstream of Flat Rock Dam there was no increase in flood elevations.

It should be noted that this hydraulic modeling effort was completed exclusively to compare impoundment water surface elevations and confirm whether a future no-rise in flood elevation evaluation would be achievable. If this alternative were to be selected, additional hydraulic modeling directly following FEMA processes would be needed. Due to the complex nature of the rapids design, significant additional hydraulic modeling showing velocity, depth, and shear stresses in two- or even three-dimensional modeling software is recommended to understand the fish passage potential of this design. The model review team should include a mix of engineering and fisheries biologist personnel who together can interpret the modeling results and relate these to field observations of fish passage in similar structures.

## 7.3 Geotechnical and Structural Consideration

There is known underlying bedrock at the Flat Rock Dam and immediately upstream of the dam. It is anticipated that the lower portions of the rock arch rapids will encounter this bedrock layer and will need to be a consideration during more detailed design phases and construction.

The Flat Rock Dam is proposed to be partially removed with this alternative and as such, prior to demolition activities it will be important to confirm the concrete ogee crest is structurally isolated from the vehicular bridge piers. This should be done by isolating an area of the dam, preventing flow over that section of the dam, dewatering the downstream portion, and completing a structural inspection of the dam/pier interface. Once confirmed during the final design phase, care will still be required during demolition to limit any potential damage to the bridge piers. Construction methods such as use of cofferdams to allow demolition work near the bridge piers to be completed in the dry therefore increasing visibility would be recommended.

The partial removal of the dam is not expected to result in a significant increase in hydraulic loads to the bridge. Any potential impact loads from debris would be expected to impact the bridge piers at a lower elevation. Impact loads at lower elevations would result in less significant loading to the bridge piers. Scour at the bridge is also not expected to significantly change.

## 7.4 Economic Impact Consideration

As discussed in Section 5.3, the existing Flat Rock Dam does in fact have some economic impact to the local economy as well as adjacent property values. The Partial Dam Removal scenario, while it will remove the Flat Rock Dam, seeks to largely maintain the existing impoundment water elevation and therefore is anticipated to have minimal impact on property market value and taxable values.

However, with partial dam removal and construction of a rock arch rapids, there are expected to be both short-term and long-term economic impacts. In the short-term, construction is anticipated to support an additional 32 jobs, $2 million in labor income, and $3.3 million in value-added dollars to the area.

Partial dam removal of the Flat Rock and Huroc Dams will maintain the existing impoundments while improving fish passage and recreational passage for paddlers on the Huron River. This is expected to increase recreational use of the river in the area with resulting increased jobs and labor and value-added dollars to the area

Since partial dam removal will maintain the impoundments, property market value and taxable value of adjacent properties are not anticipated to be impacted.

The Economic Impact Analysis Study in Appendix I details these contributions and impacts as well as the methodology of the analysis in more detail.

## 7.5 Environmental and Ecosystem Considerations

In general, this design alternative provides a benefit to the environment and the ecosystem. By maintaining similar water levels to the existing Flat Rock and Huroc Dams, little to no change will occur in the extents of the impoundment, surrounding wetlands, and riparian areas. Sediment transport will also remain very much the same with regard to the braided channels and islands near the upper end of the impoundment which provide slower moving water that can be used by different aquatic organisms for spawning, foraging, and other beneficial habitat for waterfowl and herpetofauna.

There will be impacts to the bottomlands within the footprint of the rock-rapids. Sand and other bottom substrate may need to be excavated to minimize scouring and undermining of the placed structure and achieve adequate pool depths for energy dissipation and resting velocities for fish. Depending on the environmental sampling results specific to this area and this excavated material, it may be able to be disposed of on-site or it may need to be disposed of in an offsite facility. Also, once the boulder rapids are constructed, the substrate will change from a sandy river bottom into a rockier substrate. While this material can be used for spawning, resting, and foraging by fish and other aquatic organisms, there may be temporary negative impacts that are outweighed by increased efficiency of fish passage.

### *Wetlands and Threatened and Endangered Species*

This design alternative does not anticipate large impacts to wetlands given water levels will remain similar to the existing dams. There may be minor unavoidable impacts to wetland areas around the proposed rapids where fill material required to construct the rock rapids is placed and where needed to facilitate contractor access to the river.

A mussel survey in the vicinity of anticipated areas of direct impact (e.g., excavation, bank armoring) to the riverbed would be required in advance of this alternative. The survey would be limited to areas that could safely be accessed by wading or the use of dive equipment. If state or federally listed mussels (Appendix F) were detected during the survey, a mussel relocation effort would be required prior to constructing this alternative. Mussel surveys can be conducted up to five years in advance of a project, whereas mussel relocation efforts need to occur two years or less ahead of construction. If mussel surveys detect federally listed mussels (e.g., Snuffbox) at this site, then consultation with USFWS would be required in advance of mussel relocation efforts. As such, mussel surveys should be considered early in the project timeframe to account for potential USFWS consultation.

### *Fish Passage*

The proposed rapids design is a functional solution to addressing fish passage and should be more effective than a fish ladder, bypass channel, or other means of attempting fish passage. It should be noted this design approach is different than the two most well-known rock ramp projects in Michigan at the former locations of the Chesaning and Frankenmuth dams. Fish passage at these sites has yielded mixed results due to a number of factors, including limited to no gaps in between boulders, movement of boulders after construction, and weirs arching across the entire channel instead of a sinusoidal pattern that is proposed for this alternative. Several of the projects constructed using Dr. Aadland's design approach have been monitored for successful passage of multiple species and age classes. This project site presents favorable characteristics for this type of design to facilitate the success of fish passage by different species and age classes throughout the year. Figure 13 shows an example of what the river could look like following removal of the dam and construction of the rapids at the Flat Rock Dam.

Figure 14: Looking Upstream at a Completed Rock-Arch Rapids Project Designed by Dr. Aadland on the Willow River of Minnesota

This design will achieve fish passage, reduce operational and maintenance costs (i.e., compared to those associated with the dam), minimize public safety concerns through the removal of aging infrastructure, and maintain or increase recreational use of the Huron River. The project will address aquatic connectivity with the goal of passing as many species and age classes of fish as possible while maintaining the normal pool elevation upstream of the rapids. However, maintaining the existing impoundment may affect fish passage success and aquatic organism habitat (see following section).

While sea lamprey will also be able to navigate this structure and move upstream, lamprey production potential in the Huron River has been determined to be low (Appendix L). If this alternative were selected, it is anticipated USFWS would continue sea lamprey monitoring efforts and determine the need for a sea lamprey barrier at a later date if an infestation were detected.

### *Aquatic Organism Habitat*

For this project, partial dam removal options would maintain the water surface elevations of the current impoundments. Fish passage would be restored within the project area (see previous section), and connectivity is an extremely important component of fish habitat and for mussel populations. However, because the current impoundments would not change under this alternative, lacustrine or "lake-like" conditions would continue to persist in the project area. River-dwelling fishes and fishes that live in lakes and spawn in rivers would be moving into or through the project area in search of river habitat, not lake habitat. Furthermore, some mussel species that inhabit the Huron River cannot survive in soft sediment or in engineered rapids that are designed not to move (they cannot move through the substrate). Therefore, the creation of 530 feet of riffle habitat at both dams, which would mimic a natural rapid (although artificially long), is the only significant local increase in fish habitat quality that would result from this alternative. Conversely, this alternative would allow at least some fish access to an additional 19 river miles of habitat, while maintaining the water surface elevation near the inlet of the impoundment behind Flat Rock Dam. This area exhibits good floodplain connectivity and likely has ecological value. Maintenance of the water surface elevation would maintain habitat for lentic fish species and mussel species that are common to lakes and impoundments.

Details on rock ramp composition are included here to demonstrate the utility of this habitat type to target fish species. The rapids will be constructed using heterogeneous materials including:

- Sand, gravel, and small cobble (chinking material and subgrade fill),
- Surface material comprised of large cobble and boulders (armor stone), and
- Larger boulders to form each weir (weir stones).

These substrate types have been documented to be suitable for most fish species known to inhabit the Huron River. It should be noted that spawning has been documented in other rapids constructed in a similar manner and is likely to occur depending on flow conditions during critical spawning timeframes.

Empirical habitat suitability criteria for spawning Walleye and Lake Sturgeon were developed in Minnesota (Aadland and Kuitunen 2006). Both species have also been documented spawning in nature-like fishways providing additional insights into suitable substrates and geomorphic habitats. Walleye typically spawn in gravel riffles but will spawn on sand, cobble, and small boulder substrates, depending on the geomorphology of the river (Figure 5-14; Aadland and Kuitunen 2006). White Suckers frequently spawn on the same riffles and substrates as Walleye. All three of the target species are known to spawn on coarse substrates similar to those proposed for use in the selected design; this habitat type is also abundant upstream of the Flat Rock Dam impoundment.

Lake Sturgeon prefer coarser substrates like rubble, boulders, and fragmented boulders associated with moderate velocities and turbulent flow (Figure 5-15; Aadland and Kuitunen 2006). Lake Sturgeon have very specific spawning requirements that extend beyond water depth, velocity, substrate, and cover (such as trees, brush, logs, etc.). Since females can carry 20% of their body weight in eggs, deposition of a thick layer of eggs can be common. Successful development of fertilized eggs requires well-oxygenated water. Glides (just upstream of riffles or weirs), pools below cascades, and eddies around large boulders in fast water can provide turbulence that drives oxygenated water into the stream bed where the sticky eggs collect in crevices or attach to rock surfaces. These were discussed in Aadland, 2010 and are illustrated on Figures 5-16 and 5-17 within that report. For the proposed rock arch rapids, flow over the weirs will form cascades that carry oxygenated water into the deeper pools, random boulders will create turbulent eddies, and glides upstream of the crest and weirs will provide habitat similar to other sites in the Midwest where Lake Sturgeon spawning has been documented. Since a mix of gravel and cobble will be used as chinking materials on a boulder and rubble base, the proposed rapids should have substrates advantageous for spawning of multiple species, including Lake Sturgeon as demonstrated in similar rock arch rapids.

A partial dam removal would increase available riffle/rapid habitat. Therefore, the partial dam removal would result in an increase in habitat quality for both fish and mussels within the project area. Furthermore, improved fish passage at these locations should result in a greater diversity and abundance of fish species available to mussels (who require fish as hosts) and potential increased dispersal of juvenile mussels through greater connectivity of areas upstream and downstream of the existing dams.

### *Sediment*

Sediment transport for this proposed design would occur in a similar manner to the existing dam. The proposed rapids would maintain a similar sized impoundment that would slow sediment transport and increase sediment deposition within the impoundment. For sediment that is transported to the crest of the rapids, the majority will be transported downstream of the rapids due to is moderate longitudinal slope of 2-3%, converging flow in between sinusoidal weir boulders into pools, and contraction flows in between each boulder gap. The material placed in the rapids is designed to remain in place during moderate flooding events and the boulders have been documented to remain in place at other project sites during floods exceeding the 100-year event. Ice flows may make minor adjustments to the boulder locations, but the angular corners of the boulders can break up ice flows as they move toward the rapids. Also, the boulder weirs are typically constructed highest on the outside of the river near the banks and lowest in the middle, creating concentrated flows and minimizing the potential for ice to form in fast-moving water.

Any existing sediment needed to be excavated to construct the rock rapids would need to be tested for chemical constituents in accordance with EGLE permitting requirements for dredge material. The screening level analysis of sediment within the impoundments was discussed in Section 4.3 and indicated no significant contamination or areas of concern. If this material was found to be clean, it is likely this material might be placed on-site, either as part of the fill material needed to construct the rock rapids or disposed of in upland areas adjacent to the immediate construction area.

## 7.6 Public Utilities and Safety Considerations

### *Dam Safety*

The use of rock arch rapids proposed in Alternative 2 to maintain current water elevations does not pose any additional dam safety concerns to the site. A dam breach, or unexpected failure of the rock arch rapids is highly unlikely because the rapids is constructed to a slope and with rock material sized to be independently resistant to erosion under a wide range of flow conditions. Additionally, dam breach formation times will likely be much longer than typical earth-fill embankment breach times and will result in much smaller peak outflows and flooding downstream. Any large storm event will likely be inconsequential to the structure. If EGLE agrees potential failure modes are insignificant, it is probable the rock arch rapids dam would be downgraded from a high-hazard dam to a low-hazard dam given the slow breach formation of the proposed structure. The change in classification would change the level of liability for HCMA. If this design were selected, further consultation with EGLE Dam Safety and engineering analysis would be needed to confirm a hazard classification reduction.

### *Public Utilities*

Most identified utility lines are fastened along the girder of the Flat Rock vehicular bridge and pedestrian bridge. Further review and communication with utility companies will be necessary if the project team decides to select this design option. Partial demolition of the dam and working near the existing railroad bridge will require effective communication with all stakeholders and responsible parties for this infrastructure but the function of the

Rail line should not be impacted by this work. Similar steps should be taken at Huroc Dam when working in the river and in close proximity to the pedestrian bridge crossing the dam.

### *Public Safety and Recreation*

The proposed design shows rock fill along both banks extending down to the proposed rapids to concentrate flows toward the middle of the river and bring the river dimensions closer to those downstream of the Huroc Dam. Placing rock fill in both of these areas allows for safer portaging around the rapids and the rock fill is designed to only flood during larger storms when recreational use is less. Within the rapids, the thalweg boulders can be installed without gaps to increase the water surface and provide a minimum water depth for adventurous paddlers to float downstream through the rapids. While this experience may not be suitable for paddlers of all skill levels, safe passage has been documented on other similarly constructed rapids. For paddlers that are not comfortable floating through the rapids, the rock fill on the side of the rapids can be used for portaging downstream. This alternative improves the portage options for recreational paddlers from the existing portage option.

## 7.7 Potential Regulation Change Considerations

In 2021, the EGLE Dam Safety Task Force released a document outlining recommended more stringent regulatory requirements to enhance dam safety in Michigan, which align with national standards. These proposals suggest amendments to Part 315, Dam Safety (Part 315) of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. At the time of this report, it is uncertain when and if these recommendations will be included in the Dam Safety Act. However, given it is likely the rock arch rapids would still be considered a regulated dam, it is in the interest of HCMA to evaluate potential long-term added costs if legislation approves more stringent measures. Table 11 highlights the major potential regulatory changes that would most significantly impact long-term maintenance of the proposed rock arch rapids and HCMA obligations. These recommended changes are based on the anticipated classification of the rock arch rapids as a 'Low Hazard' dam by the state of Michigan.

Table 11: Summary of Potential Regulatory Changes for Low Hazard Dams

| Regulatory Change | Current | Proposed |
|---|---|---|
| Engineering Inspections | 5 years | 5 years |
| Spillway Capacity | 100-year flood or flood of record | 100-year flood or flood of record |
| Licensing Requirements | None | unknown |
| Financial Assurance | None | Required |
| Insurance | None | Required |
| Emergency Action Plan | None | None |

### *Dam Inspection Frequency*

If dam regulations change, HCMA may be required to contract and fund high-level visual dam inspections every 5 years for a low hazard dam, if not provided by the State as currently done.

### *Spillway Capacity*

Updated regulations are not anticipated to impact spillway capacity requirements for dams with a low hazard classification.

### *Licensing Requirements*

Under current regulations, a dam owner only seeks a permit through the State of Michigan at the time of construction or modification. It may be possible under proposed regulations HCMA may be required to apply for a license renewal every 15 years. During the renewal process HCMA will report on maintenance, operation, and engineering investigations, including inspection. Failure to secure a license renewal could require the removal of the Dam at HCMA's expense.

The recommended licensing requirements dictate that the Dam owner must maintain adequate insurance to cover all liabilities resulting from a dam failure. HCMA currently holds an insurance policy with a limit of $325,000. This amount likely would not sufficiently cover all liabilities from a dam failure and the HCMA's insurance policy would need to be significantly increased.

As part of the licensing renewal, HCMA would also be required to provide evidence of fiscal responsibility or security to ensure the continued safe operation and maintenance of the Dam.

### *Cost Estimate Comparison for Legislation Change*

Potential regulation changes will increase the annual and long-term costs of managing the Flat Rock Dam. Table 12 estimates the cost of each potential change and compares these costs to the current long-term financial responsibilities of HCMA. These estimates account for a 50-year life cycle of the Flat Rock dam, with future values adjusted for a 4% annual inflation rate. Legislative changes under Alternative 2 will raise the long-term maintenance costs by $ 600,000 over 50 years, based on 2024 dollars. Table 12 excludes the initial construction costs of the rock arch rapids. Section 7.10 provides a full cost comparison.

Table 12: Comparison of No Legislation Change/ Legislation Change 50-year Life Cycle Cost for Alternative 2

| | No Change | | Legislation Change | |
|---|---|---|---|---|
| | **2024 Dollars** | **Future Dollars*** | **2024 Dollars** | **Future Dollars*** |
| Inspections (5 year cycle) | - | - | $100,000 | $340,000 |
| Maintenance and Operations (annual) | - | - | $500,000 | $1.59 M |
| Increased Spillway Capacity (at 10 yrs.) | $500,000 | $1.59 M | $500,000 | $1.59 M |
| Major rehabilitation/repairs (end of life cycle) | $1.5 M | $10.66M | $1.5 M | $10.66 M |
| TOTAL | **$2 M** | **$12.25 M** | **$2.6 M** | **$14.18 M** |

*The cost estimates in future dollars account for a 4% annual inflation rate, based on 2024 dollars. Summation inconsistencies due to rounding.

## 7.8 Other Benefits and Drawbacks

Table 13 outlines other benefits and drawbacks of this alternative.

Table 13: Benefits and Drawbacks of Partial Dam Removal

| Partial Dam Removal Alternative | |
|---|---|
| **Benefit** | **Drawback** |
| - Current impoundment recreational use maintained.<br>- Minimal impact to adjacent property owners.<br>- Increased ability to portage paddling boats around rock rapids and/or navigate boats through rapids.<br>- Improves fish passage potential.<br>- Lowers risk associated with Flat Rock Dam. | - Water quality issues and ecosystem disruption.<br>- Ongoing maintenance/repair/inspection costs associated with a regulated dam.<br>- Continued sediment buildup. |

## 7.9 Permitting, Schedule, and Dam Owner Considerations

### *Permitting*

Alternative 2 will require an EGLE Joint Permit. This joint permit application process is a coordinated approach used to streamline the permitting for projects involving multiple permits. The partial dam removal alternative should require the following permits as part of the Joint Permit Application:

- **Part 315 - Dam Safety**: For constructing, repairing, or removing dams to ensure they meet safety standards.
- **Part 31 - Water Resources Protection (Floodplains)**: For activities related to water use and discharge, protecting floodplain functions, and minimizing flooding impacts.
- **Part 301 - Inland Lakes and Streams**: For activities like dredging, filling, or constructing structures in or near inland lakes and streams.
- **Part 303 - Wetlands Protection**: For activities that might alter or impact wetlands.
- **Part 91 - Soil Erosion and Sedimentation Control**: For earth changes that disturb one or more acres of land or are within 500 feet of a lake or stream.

## Project Schedule

Once the dam owners have selected a preferred alternative, they will likely need to solicit proposals from engineering consultants. The design process will include 30%, 60%, 90%, and 100% final design documents. If Alternative 2 is selected, the expected timeframe for design is 12-18 months, including permit review. If HCMA and the City of Flat Rock decide to move forward with Alternative 2, the timeline could look like the schedule outlined in

Table 14: Alternative 2 – Theoretical Project Schedule

| Stage | Length |
|---|---|
| Solicitation for Design | 3 mo |
| Final Design Services (30,60,90, 100) | 12 – 18 mo |
| Permitting (begins at 60% design and occurs concurrent with rest of design effort) | 4 – 18 mo |
| Bidding to Construction Contractor | 2 – 3 mo |
| Construction | 9 – 12 mo |

This timeline is an estimate based on experience completing similar projects. The schedule will be further defined once the preferred alternative is selected by each dam owner and may be affected by funding availability.

## Dam Owners

Alternative 2 assumes both dams are partially removed and rock rapids established at both structures. If a rock rapid is constructed at the Flat Rock Dam, the Huroc Dam must either stay in place or also be removed and replaced with a rock rapid in order to maintain the necessary tailwater elevation at the Flat Rock Dam rock rapid. This would be a long term condition that must be communicated to the City of Flat Rock and ideally, a formal agreement put into place for the long term stability and function of a rock rapid structure at the Flat Rock Dam.

The Huroc Dam rock rapid presented as part of Alternative 2 could be constructed regardless of action taken at the Flat Rock Dam. From a fish passage perspective, if the Huroc Dam remains in place and a rock rapid installed at the Flat Rock dam, an improved fishway should at a minimum be considered otherwise fish passage benefits from removing the Flat Rock Dam as a barrier will be limited.

If HCMA selects Alternative 2 as their preferred alternative, ongoing coordination with the City of Flat Rock should occur.

## 7.10 Cost Estimate

The cost estimates provided are AACE Class 4 estimates which are appropriate for feasibility studies and the current level of design completed. These estimates carry an expected accuracy of up to -30% to +50% and are meant to guide future planning and decision making. Initial costs to construct this alternative were developed as well as 50-year life cycle cost estimates. Cost estimates were based on current day bid prices from similar projects and materials within the region and based on engineer's experience. Appendix K contains the detailed breakdown of costs associated with each alternative.

### *Initial Cost Estimate*

A cost estimate was generated for this design to include partial removal of both the Flat Rock and Huroc Dams, backfilling upstream of both dams with a mixture of armor and chinking stone, placement of weir boulders on top of both mixes, and placing armor and chinking stone along both banks at a higher elevation than the rapids to narrow the channel and provide safe portaging around the rapids. Alternative 2 is estimated to cost $11.35 million for Flat rock Dam and $1.23 million for Huroc Dam which includes a 30% contingency for unknown items and market changes, 10% for design engineering and permitting, and 10% for construction engineering and observation.

### *50-year Life Cycle Cost Estimate*

As outlined in Section 6.9, in the next 50 years the Dam will require annual maintenance, operations, periodic inspections, and insurance for the Dam, resulting in additional costs within the assessed timeframe. Table 15 provides a comparative analysis of the Dam's estimated long-term costs, accounting for potential legislative changes. Table 15 compares initial rock rapid construction cost, the 50-year life cycle cost with no regulatory changes in 2024 dollars, and an estimate of the 50-year life cycle cost adjusted for a 4% annual inflation rate.

Table 15: Cost Estimate for Partial Dam Removal

| | Assuming No Legislation Changes | | Assuming Legislation Changes | |
|---|---|---|---|---|
| | **2024 Dollars** | **Future Dollars*** | **2024 Dollars** | **Future Dollars*** |
| *Flat Rock Dam* | | | | |
| Initial construction cost | $11.35 M | $11.35 M | $11.35 M | $11.35 M |
| Total operation and maintenance costs over next 50 years | $2 M | $12.25 M | $2.6 M | $14.18 M |
| Total Cost (including initial construction) | $13.34 M | $23.59 M | $13.94 M | $25.53 M |
| *Huroc Dam* | | | | |
| Initial construction cost | $1.23 M | $1.23 M | $1.23 M | $1.23 M |
| Total operation and maintenance costs over next 50 years | $500,000 | $1.59 M | $500,000 | $1.59 M |
| Total Cost (including initial construction) | $1.73 M | $2.8 M | $1.73 M | $2.8 M |
| ***Total*** | | | | |
| **Initial construction cost** | **$12.57 M** | **$12.57 M** | **$12.57 M** | **$12.57 M** |
| **Total operation and maintenance costs over next 50 years** | **$2.5 M** | **$13.84 M** | **$3.1 M** | **$15.79 M** |
| **Total Cost (including initial construction)** | **$15.07 M** | **$26.41 M** | **$15.67 M** | **$28.34 M** |

*The cost estimates in future dollars account for a 4% annual inflation rate, based on 2024 dollars. Summation inconsistencies due to rounding.

# 8. Dam Alternative 3 & 4 – Full Dam Removal with Active or Passive River Restoration

Alternative 3 and 4 propose fully removing both the Flat Rock and Huroc Dams, including their spillways and associated structures. This action aims to eliminate risks and liabilities linked to the dams and restore the Huron River to a more natural state. Alternative 3 proposes dam removal coupled with active river restoration, while Alternative 4 evaluates dam removal with passive river restoration. While passive restoration can be more cost-effective, it may take longer to see desired results, meaning vegetation growth within the old impoundment can be slow while nature is allowed to take over and establish itself. Active restoration aims for quicker outcomes but may come with higher costs and environmental impacts. The choice between the two methods depends on project goals, site conditions, cost, and stakeholder preferences. Both alternatives will require long term invasive species management to prevent invasive species from propagating throughout the newly exposed impoundment and preventing native species from establishing.

## 8.1 Dam Alternative 3 – Full Dam Removal with Active River Restoration

Alternative 3 proposes fully removing the Flat Rock and Huroc Dams and actively restoring the river. Dam removal would be completed through incremental demolition of the concrete dam structure, utilizing the existing dam to slowly dewater the impoundment. During this process, typical dam demolition rates would lower the impounded water surface at a maximum of 0.5 feet per day. While dewatering and demolition activities occur at the dam, the contractor would actively manage sediment within the impoundment by mechanically excavating the restored river channel and floodplain benches, working at the upper extents of the impoundment toward the dam. Sediment removed from the river would be placed within the project area outside of the proposed river channel and floodplain. Active restoration involves direct designed interventions to enhance the ecological health, functionality, and resilience of the river and its habitats. Interventions for active river restoration can include:

- Bed Form and Habitat Creation: Constructing structures like riffles, pools, and gravel bars to improve habitat diversity and support aquatic life.

- Bank Stabilization: Using engineered solutions such as bioengineered and engineered bank protection (i.e., riprap, large wood, or constructed riverbanks) to prevent erosion and stabilize riverbanks.

- Channel Realignment: Altering the course of the river to restore its natural meandering pattern, enhancing habitat diversity and water quality.

- Floodplain Reconnection: Allowing rivers to access their floodplains by removing barriers or constructing floodplain channels, reducing flooding risk and providing valuable habitat.

Figure 15 illustrates a conceptual design and proposed restoration intervention methods following the removal of the Flat Rock and Huroc Dam. A larger version of this figure is included in Appendix A.

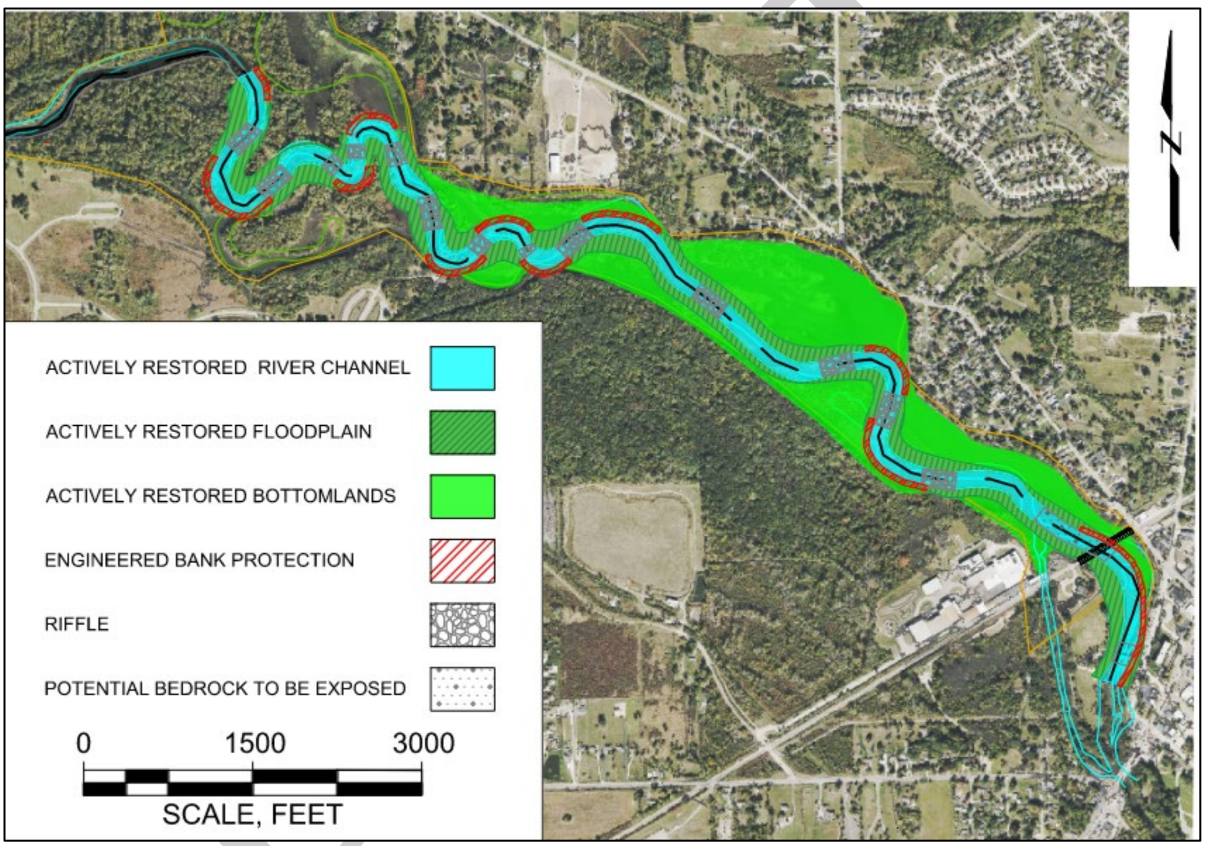


Figure 15: Full Dam Removal with Active Restoration - Plan View

## 8.2 Dam Alternative 4 – Full Dam Removal with Passive River Restoration

Alternative 4 proposes fully removing the Flat Rock and Huroc Dams and implementing passive river restoration ( Figure 16). Like Alternative 3, dam removal would be completed through incremental demolition of the concrete dam structure, utilizing the existing dam to slowly dewater the impoundment. During this process, typical dam demolition rates would lower the impounded water surface at a maximum of 0.5 feet per day. While dewatering and demolition activities occur at the dam, the contractor would actively manage sediment within the impoundment by mechanically excavating a pilot channel in the desired location of the restored river channel, working at the upper extents of the impoundment toward the dam. Sediment removed from the river would be placed within the project area outside of the proposed river channel and anticipated floodplain. Passive restoration allows natural processes to drive the recovery of degraded river ecosystems without direct human intervention or manipulation. Key principles and approaches of passive river restoration include:

- Natural Succession: Allowing vegetation and habitats to regenerate through natural processes such as colonization by native plant species, soil development, and ecological succession.
- Riparian Buffer Zones: Establishing and maintaining vegetation along riverbanks to stabilize soil, filter pollutants, and provide habitat, naturally improving river health and water quality.
- Floodplain Dynamics: Allowing rivers to naturally access and shape their floodplains during flood events, promoting sediment deposition, nutrient cycling, and habitat creation.
- Woody Debris Management: Allowing fallen trees and woody debris to accumulate in river channels, providing habitat for aquatic organisms, creating hydraulic complexity, and stabilizing banks.
- Natural Flow Regimes: Preserving or restoring natural patterns of river flow, including seasonal variation and flood events, to support ecological processes such as sediment transport, nutrient cycling, and habitat connectivity.
- Non-intervention: Minimizing human disturbance and intervention in river systems, such as limiting dredging, channelization, and bank reinforcement, to allow natural processes to unfold.

Passive restoration allows the river to self-establish its floodplain benches and the native seed bank within the impounded sediment, now exposed to air and sunlight, to grow. With this self-establishment can come channel adjustments and erosion of sediment. There are three critical areas where existing infrastructure are present where it would be important to prevent channel migration. In those areas engineered bank protection would be constructed, while the remaining river channel banks would be left to stabilize naturally over time.

Additionally, there are two areas where engineered grade control would be recommended. These areas include establishing grade control at the upstream tie-in point and at the location of the existing Huroc Dam where the soils have been significantly impacted by dam construction. Bedrock is expected to be exposed at the Flat Rock Dam; therefore, no engineered stabilization is anticipated.

Figure 16 illustrates the conceptual design and proposed restoration approach following the removal of the Flat Rock and Huroc Dams with passive restoration.

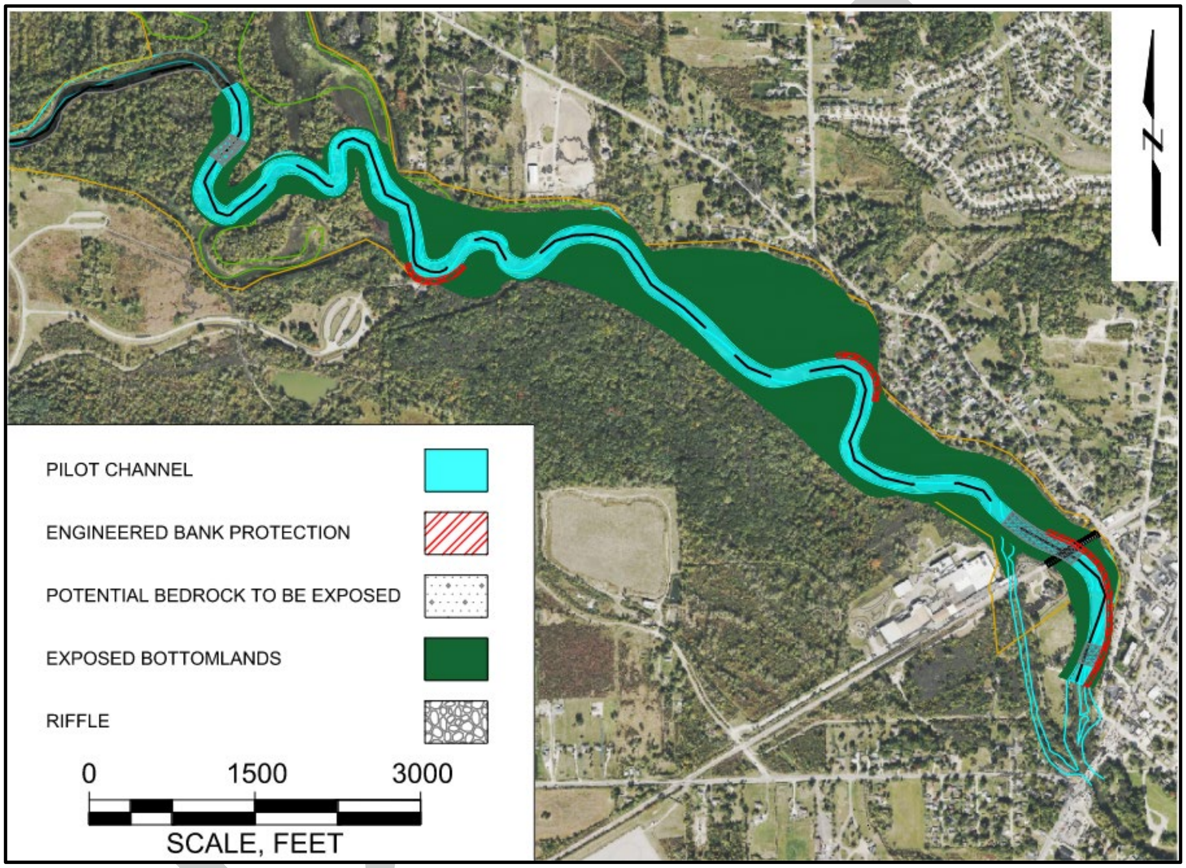


Figure 16: Full Dam Removal with Passive Restoration - Plan View

## 8.3 Channel Conceptual Design

After the Dam is removed, the river channel is restored to a more natural state, resembling the width, depth, and meandering of the pre-dam river channel. This restores the natural hydraulics of the river and reintroduces sediment transport to the restored river reach and downstream. The proposed restored river alignment for both alternative 3 and 4 closely match the Huron River surveyed in the early 1920s before the Flat Rock Dam was constructed (Figure 16).

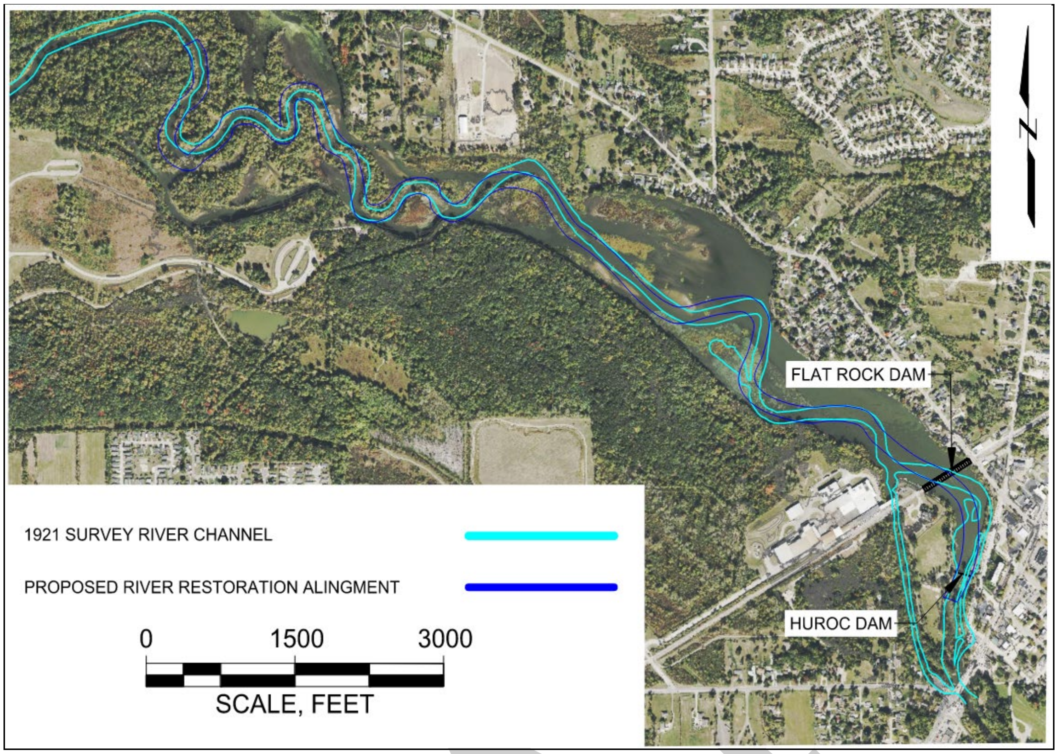


Figure 17: Proposed River Restoration Alignment Compared to 1921 Pre-Dam Historic Survey

In the proposed stream channel for both alternatives the upstream channel would connect to the existing channel 12,400 feet from the Flat Rock Dam at an existing grade elevation of 586.7 feet. The downstream connection point would be approximately 300 feet downstream of the Huroc Dam, at an existing grade elevation of 578.3. The planned stream restoration would include approximately 16,600 linear feet of new stream channel with an average slope of 0.05% percent.

The conceptual design of the river channel is based on industry accepted design criteria for rivers found in Michigan. Specific attributes estimated for this reach include bankfull width and depth, or the width and depth of the channel just before the water enters the floodplain, the width of the floodplain bench, and the sinuosity of the river. The estimated river geometry is based on observed river geometry upstream and downstream of the project site and confirmed with bankfull flow (2,516 cfs) estimated using PeakFQ software Bulletin 17B method based on USGS gage data for the Huron River. The conceptual river channel design uses a trapezoidal river channel with a bankfull width of 150 feet, depth of 5 feet, with 2H:1V side slopes.

If HCMA and the City of Flat Rock move forward with dam removal, the site-specific design will depend on river geometries gathered at an appropriate reference reach of the Huron River and verified through additional hydrologic and hydraulic analyses.

Removal of the dams is expected to expose unique and rare bedrock outcroppings at both dams and potentially upstream of the Flat Rock Dam based on record drawings of the dams which indicate the dam structures were built on bedrock foundations. These features, as exposed with dam removal would be incorporated into the restored channel design.

### *Active Restoration Channel*

Active restoration channel design and construction includes implementing all interventions discussed in Section 8. The channel and floodplain would be constructed to the appropriate bankfull width and depth and floodplain width as determined through hydraulic and hydrologic analysis and engineering recommendations. Impounded sediment would be dredged/excavated from the proposed channel and floodplain in sequence with the dewatering of the impoundment, to minimize the release of sediment downstream. Sediments dredged to create restored river channel and floodplain (Alternative 3) would be disposed in upland areas outside of the 100-yr floodplain within HCMA or City property, but ideally within the former impounded area.

### *Passive Restoration Channel*

The passively restored channel will be a mechanically dredged pilot channel within the dewatered impoundment that roughly follows the alignment of the 1920's Huron River Survey. The mechanical dredging process involves the removal of sediment, silt, and other materials from the riverbed and banks to create a preferential path for the river to return to its natural meanderings. Formation of the floodplains would be allowed to occur over time through natural sediment transport mechanisms. Similarly, the river will be allowed to naturally armor and develop bedform diversity as larger substrate and woody debris are daylighted and recruited.

## 8.4 Sediment Management

These alternatives would also allow riverine processes such as sediment transport to reestablish in the project area. The approach to sediment management and removal is determined by the specific volume and characteristics of sediment at the site. As discussed in Section 3.2, there is a large amount of sediment likely contained within the impoundment prevented from moving downstream by the Flat Rock Dam. The majority of this sediment is not expected to mobilize during dam removal, but instead would form the floodplain or upland habitat outside of the restored river channel post dam removal. Sediment data collected as part of this project preliminarily shows overall the pollutant levels in the sediment are likely low enough that most of the sediment can be managed safely, and re-used onsite, either in the restored floodplain or upland areas.

Of the 882,000 to 1,040,000 cubic yards of sediment within the main upper impoundment and the lower area between the Flat Rock and Huroc Dams, 370,000 to 390,000 cubic yards is estimated to be most likely to mobilize during dewatering and dam removal activities.

It is important to compare this sediment volume estimate to the estimated annual sediment yield of the Huron River at Flat Rock and Huroc Dams. In 2010, the U.S. Army Corps of Engineers (USACE) completed a study on the Ontonagon River to estimate the annual sediment yield, in tons. Using the trendline for annual sediment yield of the historic Ontonagon River and other Michigan rivers results in an estimated annual sediment load of 75,100 tons for the Huron River at Flat Rock and Huroc Dams.

In order to convert this mass per year to a volume per year, a sediment density needs to be assumed. According to the 1943 report published by multiple authors on the Density of Sediments Deposited in Reservoirs, sand density is 93 pounds/cubic foot and silt density is 65 pounds/cubic foot (Lane and Koelzer, 1943). Assuming the reservoir sediment is a mixture of these two materials, the annual sediment load converts to approximately 60,000 to 90,000 cubic yards per year. Using this range, the estimated mobilized sediment volume of 370,000 to 390,000 cubic yards is approximately equivalent to 4 to 7 years of annual sediment loading.

Given the important fisheries present in the Huron River downstream of the Flat Rock and Huroc Dam, sediment management throughout the duration of dam removal should be considered by use of engineered controls (such as turbidity curtains), incremental dewatering/demolition, and construction methods (such as sediment dredging). The use of all three approaches will result in the greatest capture of sediment and prevent the material from moving downstream. An estimated 370,000 CY to 390,000 CY will be mechanically dredged to create the restored river channel (both alternatives) and floodplain (for alternative 3 only). The excavated material would be disposed in upland areas outside of the 100-yr floodplain within the project area. Following the dredging of this volume, the river channel is estimated to transport the annual sediment yield of 60,000 to 90,000 cubic yards without permanent impacts to the downstream channel.

## 8.5 Hydrologic and Hydraulic Consideration

The full removal with active or passive restoration dam disposition alternatives considers the complete removal of both the Flat Rock and Huroc Dams. Development of a conceptual level hydraulic model for this alternative will allow for the assessment of potential impacts to water surface elevation and fish passage. With the full removal of Flat Rock and Huroc Dams, the current barriers to sea lamprey would be removed, therefore, further evaluation will be performed to determine whether there is a need for the inclusion of a barrier structure. Section 8 discusses this topic in more detail.

In support of this design alternative, the existing conditions HEC-RAS model described in Section 5.2.1 was modified to evaluate the impact of the proposed project on water surface elevations and velocities upstream of both dams. The model includes existing and proposed condition scenarios for comparison of hydraulic parameters along the modeled river reach.

The full dam removal scenario was modeled using the existing conditions model geometry extents, including the entire Flat Rock impoundment, with a modified channel centerline alignment that was determined based on recent depth of refusal data, as well as historic 1920's survey data, in an effort to restore the Huron River channel back to its original location where logistically feasible. The model geometry was updated to represent the proposed conditions. The inline structures were removed and replaced with existing Flat Rock and Huroc bridge data. Cross sections along the proposed centerline alignment from approximately 100 feet downstream of Huroc bridge to approximately 8,000 feet upstream of Flat Rock bridge were modified by applying a cross section template with channel specifications including a 5 feet bankfull depth, 150 feet bankfull top width, 2:1 channel side slopes, and bankfull bench widths of 90 feet. Manning's *n* values were set to 0.035 for the design channel, and 0.050 for the bankfull bench cut. All other model parameters were kept the same as the existing conditions model. The proposed model results were compared against the existing conditions model results to verify no rise in water surface elevations during the prescribed flood events.

Compared to the existing conditions hydraulic model, the full removal model resulted in an overall decrease in water surface elevation within the Flat Rock impoundment extents. Immediately upstream of the Flat Rock bridge, water surface elevation decreased 5-6.4 feet in the full removal scenario, gradually tapering down until matching with existing water surface elevation approximately 14,200 feet upstream. Within the area between Flat Rock and Huroc bridges, there is a 1.3-1.4 feet decrease in water surface elevation compared to existing conditions. Immediately downstream of Huroc bridge, the water surface elevation shows a decrease of 0.1 feet in the full removal modeled alternative before matching with existing water surface elevation approximately 500 feet downstream.

Channel velocities for the existing conditions hydraulic model ranged from 0.5-4.1 feet/sec throughout the Flat Rock impoundment. Comparatively, the channel velocities for the full dam removal hydraulic model resulted in a range of 0.9-5.4 feet/sec throughout the impoundment.

Peak flow attenuation for the full dam removal alternative was evaluated at the dams and showed minimal change compared to existing conditions, therefore suggesting minimal impact on flood potential downstream. Peak flow attenuation is generally greater than 70% for all flood flows (2-year through 200-year) for both existing conditions and full dam removal. This attenuation is likely due to good floodplain access in the Flat Rock impoundment for both existing conditions and full dam removal (Appendix H).

## 8.6 Geotechnical and Structural Considerations

There is known underlying bedrock at the Flat Rock Dam and immediately upstream of the dam. It is anticipated that this bedrock will be exposed will full dam removal. Investigating the exposure of unique and rare bedrock habitat was a secondary goal of this feasibility study.

Alternatives 3 and Alternative 4 propose full removal of the Flat Rock and Huroc dams and as such, prior to demolition activities it will be important to confirm the concrete ogee crests are structurally isolated from the bridge piers associated with each dam. This should be done by isolating an area of the dam, preventing flow over that section of the dam, dewatering the downstream portion, and completing a structural inspection of the dam/pier interface.. Once structural isolation is confirmed, care will still be required during demolition to limit any potential damage to the bridge piers. Construction methods such as use of cofferdams to allow demolition work near the bridge piers to be completed in the dry, therefore increasing visibility, would be recommended.

The full dam removal is not expected to result in a significant increase in hydraulic loads to either bridge. Any potential impact loads from debris would be expected to impact the bridge piers at a lower elevation. Impact loads at lower elevations would result in less significant loading to the bridge piers. Scour at the bridge is also not expected to significantly change but should be confirmed during more detailed design efforts.

## 8.7 Economic Impact Consideration

As discussed in Section 5.3, the existing Flat Rock Dam does have some economic impact to the local economy as well as adjacent property values. The Full Dam Removal scenarios will significantly change the landscape of the Flat Rock Dam impoundment by reducing water elevation and extents of area covered by impounded water. Property values are largely influenced by proximity to water, with the most significant impacts from dam removal affecting the 56 properties adjacent to the impoundment. The rest of the study area will experience smaller changes. Literature shows varying property value trends post-removal, influenced by factors like water quality, recreational opportunities, and the new natural amenity's appeal. While some studies suggest a rebound or increase in property values, others show negative or neutral effects. The study emphasizes that long-term property value outcomes depend on the success of the river and green space restoration.

Short- and long-term impacts from dam removal and construction are expected to significantly contribute to local employment, value-added, and taxes. In the short-term, construction is anticipated to support additional jobs, labor income, and value-added dollars to the area. Anticipated economic impacts are detailed in Appendix I.

Long-term impacts from dam removal are anticipated to result in additional jobs and labor income/value-added contributions.

Removal of the Flat Rock and Huroc Dams will create a riverine condition where recreation opportunities will change from paddling only within the impoundments and will open a larger corridor of the Huron River to open paddling without challenging portage routes. Additionally, dam removal would be expected to create desirable aquatic habitat for the 38 native species of fish in the Huron River and expose unique and rare bedrock within the restored Huron River channel. Fishing for native fishes could also potentially increase within the restored river corridor. These added recreational benefits result in the sustained employment, labor income, and value-added dollars.

The Dam Economic Contribution Study Report included in Appendix I details these contributions and impacts as well as the methodology of the analysis.

## 8.8 Environmental and Ecosystem Considerations

### *Wetlands and Threatened and Endangered Species*

Dam removal can have substantial impacts on wetlands both upstream and downstream of the dam. If water levels are reduced within the impoundment behind the Flat Rock Dam and Huroc Dam, fringe wetlands along the waterline will likely dry out as the steep slopes and loss of hydrology will gradually reduce hydric soil characteristics and support more upland plant species. However, dewatering the impoundment will also create opportunities for new wetlands to form on exposed impounded sediments within the newly created floodplain area. Based on the existing wetland inventory, it is likely new wetlands will be created because of dam removal (Figure 17). Preliminary comparison estimates a net gain of 70 acres (southern floodplain forest and wetlands) and a net loss of 10 acres of southern floodplain forest. It should be noted that Figure does not account for disposal locations for sediments excavated to create the restored river channel or floodplain so overall net gain in wetlands will be less than shown. If a dam removal alternative is selected to move forward, further design stages should evaluate the best locations for disposal areas that will minimize impacts to potential future wetland formation.

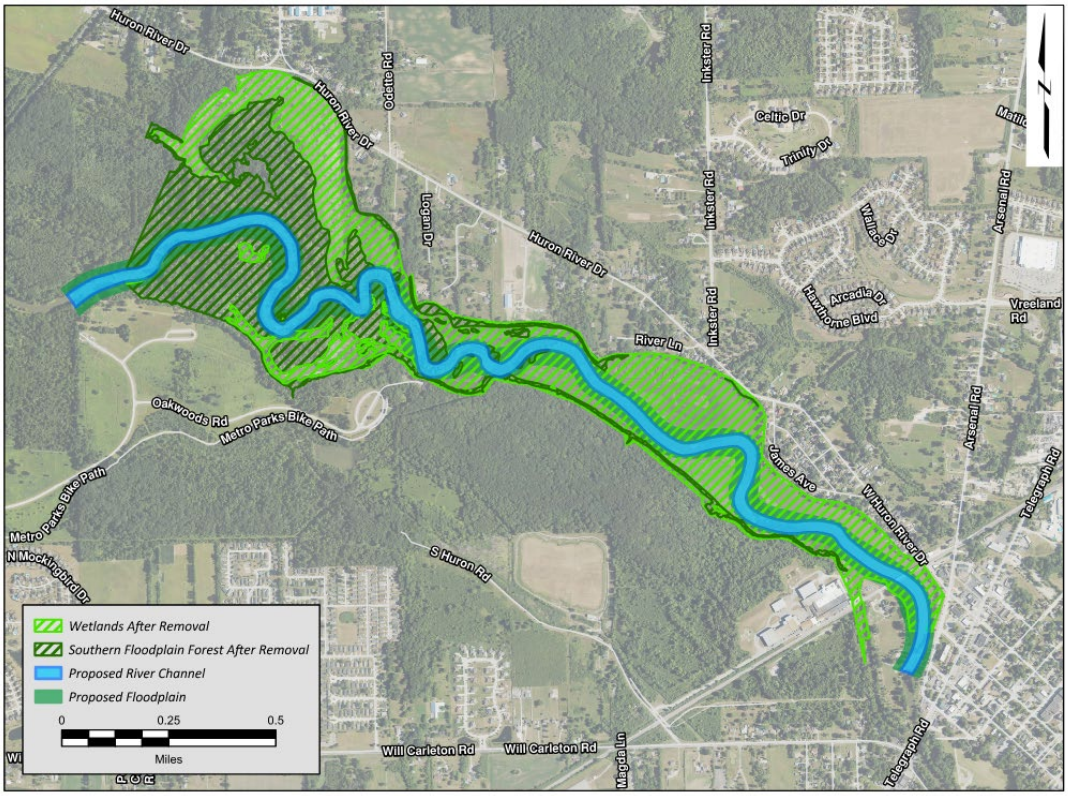


Figure 18: Possible Wetland Delineation After Removal

Alternatives 3 and 4 would require a mussel survey in the vicinity of anticipated areas of direct impact (e.g., excavation, bank armoring) to the riverbed and in areas that would eventually be dewatered. The survey would be limited to areas that could safely be accessed by wading or the use of dive equipment. If state or federally listed mussels (Appendix F) were detected during the survey, a mussel relocation effort would be required prior to constructing this alternative. Given this alternative will result in impacts to the riverbed and dewatering of some areas of the impoundment, mussel relocation efforts associated with this alternative may be greater in scope as compared to the other alternatives. Mussel surveys can be conducted up to five years in advance of a project, whereas mussel relocation efforts need to occur two years or less ahead of construction. If mussel surveys detect federally listed mussels (e.g., Snuffbox) at this site, then consultation with USFWS would be required in advance of mussel relocation efforts. As such, mussel surveys should be considered early in the project timeframe to account for potential USFWS consultation.

## Fish Passage

Full dam removal with either passive or active restoration would mimic natural river conditions to the extent possible, with more flexibility to work around existing infrastructure (i.e., grade control riffles and bank stabilization could be where they needed to be). Thus, the hydraulics in the restored river would be the most natural under these alternatives and would present the best opportunity for river reconnection. From a fish passage standpoint, this would be the most effective alternative. Removal of the dams would open approximately 19 river miles of the Huron River for fish habitat, migration, and spawning. The project will address aquatic connectivity with the goal of passing as many species and age classes of fish as possible while preventing further invasion of the Huron River by Sea Lamprey if necessary. (see Section 9).

### *Aquatic Organism Habitat*

Full removal of the Flat Rock and Huroc dams would result in the largest improvement in aquatic habitat. The entire affected area, which incorporates approximately two stream miles, would be returned to riverine conditions, and a natural channel profile would be reestablished, while also exposing unique and rare bedrock. This alternative would also allow riverine processes such as sediment transport to reestablish in the project area. The return of riverine conditions and processes would result in a gain of approximately two miles of stream habitat for native fishes and mussels. Even though the No Action – Fish Passage Improvement and Partial Removal alternatives would improve fish access to 19 river miles upstream of the Flat Rock Dam, their effects on local aquatic habitat would be less beneficial than the Full Removal Alternatives. The No Action – Fish Passage Improvement Alternative would result in negligible local habitat improvements, and the local improvements associated with the Partial Removal Alternative would be limited to the 530 feet of rock arch rapids at both dam locations.

## Active Restoration

Active restoration would help mitigate the temporary ecological and aesthetic impacts of dam removal such as exposure of lake sediments, weed establishment, invasive plants, impacts to wetlands, and disturbance to aquatic habitat associated with the transition back to a riverine environment. For example, active restoration would help maintain the valuable wetlands near the inlet of the current impoundment behind Flat Rock Dam. However, active restoration can inadvertently disrupt normal, healthy riverine processes, and human ideals of how a river should look can often overwhelm the focus on river health and river process – careful design would be necessary to prevent this.

## Passive Restoration

Passive restoration would likely result in some temporary impacts to aquatic habitat. These could include disruption of the substrate as lake habitats transitioned to riverine habitats, and exposure of formerly wetted areas. Disturbance is highly common in riverine systems, and aquatic organisms are adapted to it. However, lower abundances of fish, aquatic invertebrates, and riparian species could be expected until the project site readjusted to the absence of the Flat Rock and Huroc Dams and established dynamic equilibrium within the restored reach. The duration of adjustment of habitat from lacustrine to riverine will take longer than an active restoration approach. The duration can be highly specific to each project and site conditions but likely looking at a number of years difference.

### *Sediment*

Dam removal restores the natural riverine sediment regimes, bedload, suspended load, and wash load will no longer be stopped by the dams. These are critical natural processes that contribute to the overall health of a river ecosystem. As discussed in Section 4.3, there is estimated to be over 1,000,000 cubic yards of impounded sediment within the project area. The preliminary sediment sampling indicates this material is clean based on state specific standards. If a dam removal alternative is selected, additional sediment sampling would be required to confirm the overall quality of the sediment and meet EGLE permit requirements for dam removal projects.

Sediment management is an important aspect of dam removal projects and considerable thought, engineering control, and construction methods will need to be exercised if a dam removal alternative is selected to move forward. Prevention of significant amounts of sediment being transported downstream of the project area is critical to prevent burying riverine habitat, clogging of existing downstream river crossing, and other negative impacts to the downstream Huron River reaches. Common methods to addressing dam removal and sediment management include a multifaceted approach of incremental, or slow, dewatering of the impoundment, active management of sediment by mechanically removing sediment from the river channel, and passive controls like turbidity curtains and sediment traps. The preliminary sediment sampling indicated the majority of sediment is silts and organic material. This material having a smaller size than gravels and sands makes it more difficult to manage during dewatering. This will be a challenge for any dam removal alternative, however, given the fine grain material it is expected that any impounded sediment transported downstream would be exported out of the Huron River system by the base and peak flows.

As the impoundment is dewatered the bottomlands, or area where water currently exists, will be exposed. This material will need time to dry out. Given the material appears to be largely silts and organics, this could take weeks or months to occur. This could present challenges for large construction equipment attempting to drive over this material and should be a consideration if more detailed design progresses. The sediments meet EGLE residential direct contact criteria so there are no concerns for human contact with the material. Once the material has had adequate time to dry out and vegetation to establish it is expected the bottom lands could become additional parkland, however, there appears to be a reasonable possibility of new wetland formation in many areas of the former bottomlands.

Sediments removed in order to create the restored river channel and floodplain (Alternative 3) or pilot channel (Alternative 4) should be able to be stockpiled on site within the footprint of the existing impoundment. These areas would likely revert to upland habitat.

## 8.9 Public Utilities and Safety Considerations

### *Dam Safety*

Removal of the Flat Rock Dam will remove all long-term dam safety hazards from the site. The Huroc Dam is not a regulated structure due to its minimal size and impounded area, therefore in its existing conditions it generally poses minimal risk. During detailed design, control of water should be a significant design consideration to identify the safest methods for removing the dam and dewatering the impoundment. During construction, engineering controls will be implemented during to maintain appropriate dam safety risk management in coordination with EGLE's Dam Safety Unit. Water levels and flows will be controlled though incremental dewatering at a maximum rate of 0.5 feet per day to minimize downstream impacts and facilitate effective sediment management upstream of the dam.

### *Public Utilities*

As noted in previous sections, there no public utilities were found during this study within the project area that are expected to be impacted by dam removal and stream restoration work. However, the City of Flat Rock has noted there may be stormwater outfall pipes along the north side of the impoundment and a former quarry stormwater outfall pipe on the south side of the impoundment. Additional field investigations and record drawing searches should be conducted during design phases to locate any existing pipes. A drop in the impoundment water level may expose the pipes and require riprap stabilization be placed at the pipe outlet to prevent erosion or undermining of the pipe.

Existing utilities are primarily on the girder of the W. Huron Drive vehicular bridge, horizontally directional drilled utilities lines well below the anticipated restored river bottom or are located on the Huroc Park pedestrian bridge. If either Alternative 3 or Alternative 4 are selected to move forward to detailed design, additional public utility investigation should occur including calling MISS DIG.

### *Public Safety and Recreation*

Removal of the Flat Rock and Huroc dams removes potential hazards to paddlers and users of the Huron River. Removal of the Flat Rock Dam also removes the potential for dam failure and downstream impacts from an uncontrolled failure. Dam removal will restore a free-flowing river system which would likely increase recreational usage (i.e. canoeing, kayaking, river fishing) locally. Additionally, removal of both dams removes the need to portage around the dam structures. Dam removal would also expose over 100 acres of existing bottomlands. Some of this area may convert to upland habitat, particularly where excavated sediment is placed within the impoundment. This exposed bottomland will be owned by HCMA. While there has been no planning done to date, this land could potentially become an additional recreational land usage for the Downriver communities.

## 8.10 Other Benefits and Drawbacks

Table 16 outlines other benefits and drawbacks of the dam removal alternatives.

Table 16: Other Benefits and Drawbacks of Dam Removal

| Dam Removal Alternative | |
|---|---|
| **Benefit** | **Drawback** |
| - Improved condition of river ecosystem and surrounding natural resources.<br>- Removing all future expenses and liabilities associated with the Dams.<br>- Mitigating risk from the dam structures or a dam failure.<br>- Greater potential for outside funding opportunities to complete work. | - Overall construction cost is high.<br>- Change in recreational use of impoundment.<br>- Modest impacts to upstream adjacent property values. |

## 8.11 Permitting, Schedule, and Dam Owner Considerations

### *Permitting*

Alternative 3 and 4 will require an EGLE Joint Permit. This streamlined process coordinates multiple permit requirements. The dam removal with passive restoration and dam removal with active restoration will need the following permits as part of the Joint Permit Application:

**Part 315 - Dam Safety**: For constructing, repairing, or removing dams to ensure they meet safety standards.

**Part 31 - Water Resources Protection (Floodplains)**: For activities related to water use and discharge, protecting floodplain functions, and minimizing flooding impacts.

**Part 301 - Inland Lakes and Streams**: For activities like dredging, filling, or constructing structures in or near inland lakes and streams.

**Part 303 - Wetlands Protection**: For activities that might alter or impact wetlands.

**Part 91 - Soil Erosion and Sedimentation Control**: For earth changes that disturb one or more acres of land or are within 500 feet of a lake or stream.

## Project Schedules

Once the dam owners have selected a preferred alternative, they will likely need to solicit proposals from engineering consultants. The design process will include 30%, 60%, 90%, and 100% final design documents. This timeline is an estimate based on experience completing similar projects. The schedule will be further defined once the preferred alternative is selected and may be affected by funding availability.

### Estimated Timeframe for Dam Removal with Active Restoration

If Alternative 3 is selected, the expected timeframe for design is 12-18 months, including permit review. If HCMA and the City of Flat Rock decide to move forward with Alternative 3, the timeline could look like the schedule outlined in Table 17

Table 17: Alternative 3 – Theoretical Project Schedule

| Stage | Length |
|---|---|
| Solicitation for Design | 3 mo |
| Final Design Services (30,60,90, 100) | 12 – 18 mo |
| Permitting (begins at 60% design and occurs concurrent with rest of design effort) | 4 – 18 mo |
| Bidding to Construction Contractor | 2 – 3 mo |
| Construction | 24 mo |

### Estimated Timeframe for Dam Removal with Passive Restoration

If Alternative 3 is selected, the expected timeframe for design is 12-18 months, including permit review. If HCMA and the City of Flat Rock decide to move forward with Alternative 4, the timeline could look like the schedule outlined in Table 18.

Table 18: Alternative 4 – Theoretical Project Schedule

| Stage | Length |
|---|---|
| Solicitation for Design | 3 mo |
| Final Design Services (30,60,90, 100) | 12 – 18 mo |
| Permitting (begins at 60% design and occurs concurrent with rest of design effort) | 4 – 18 mo |
| Bidding to Construction Contractor | 2 – 3 mo |
| Construction | 12 – 18 mo |

### *Dam Owners*

Alternatives 3 and 4 assume both dams are fully removed, and a restored river channel is established within the former impoundments, tying into the existing river channel a few hundred feet downstream of the Huroc Dam. Given the owners of the dams are two separate entities, the Huroc Dam can be removed without any action required at the Flat Rock Dam. The tailwater elevation at the Flat Rock Dam would decrease, however, there is not anticipated to be any negative effect from this change given that the Flat Rock Dam was in place before the Huroc Dam and the fact that the dam was constructed into bedrock. The Flat Rock Dam can also be removed without any action required at the Huroc Dam; however, the limits of the restored river channel would need to be adjusted due to a higher water surface elevation controlled by the Huroc Dam propagating upstream. It is anticipated that this would mostly impact restoration of the river between the existing Flat Rock Dam location and the Huroc Dam.

One of the benefits of the dam removal is increased fish passage. If the Huroc Dam is not removed in conjunction with the Flat Rock Dam, some form of fish passage improvement, either a fishway or partial dam removal, should be considered at the Huroc Dam to maximize the overall project benefit from the removal of the Flat Rock Dam.

If either HCMA or the City of Flat Rock selects Alternative 3 or 4 as their preferred alternative, ongoing coordination should occur so that each entity understands how the proposed project may impact the surrounding project area.

## 8.12 Cost Estimate

The cost estimates provided are AACE Class 4 estimates which are appropriate for feasibility studies and the current level of design completed. These estimates carry an expected accuracy of up to -30% to +50% and are meant to guide future planning and decision making. Initial costs to construct this alternative were developed as well as 50-year life cycle cost estimates. Cost estimates were based on current day bid prices from similar projects and materials within the region and based on engineer's experience. Appendix K contains the detailed breakdown of costs associated with each alternative.

## *Initial Cost Estimate*

The cost estimate for removing the dams and actively restoring the impoundments (Alternative 3) is $37.09 million for Flat Rock Dam and $2.84 million for Huroc Dam. Full dam removal of both structures with passive restoration of the impoundments (Alternative 4) is estimated to cost $29.57 million for Flat Rock Dam and $1.73 million for Huroc Dam, which includes 30% contingency. The substantial difference between the dams is primarily due to the amount of sediment needed to be removed from each impoundment.

## *50-year Life Cycle Cost Estimate*

If the dams are removed, and the river channel is restored to a more natural state, long-term maintenance, and upkeep costs only include invasive species management. Table 19 compares initial dam removal costs and long term costs associated with invasive species control with and without an adjustment for a 4% annual inflation rate.

Table 19:Cost Comparison for Removing the Dam

| | **Active Restoration Approach** | | **Passive Restoration Approach** | |
|---|---|---|---|---|
| | **2024 Dollars** | **Future Dollars*** | **2024 Dollars** | **Future Dollars*** |
| Flat Rock Dam Initial Construction Cost | $37.09 M | $37.09 M | $29.57 M | $29.57 M |
| Huroc Dam Initial Construction Cost | $2.84 M | $2.87 M | $1.73 M | $1.73 M |
| Long term invasive species control | $1.37 M | $3.40 M | $1.62 M | $3.70 M |
| Total Cost (including initial construction) | $41.30 M | $43.33 M | $32.92 M | $35.00 M |

# 9. Sea Lamprey Barrier Alternatives Analysis

## 9.1 Introduction

Consultation with US Fish and Wildlife Service (USFWS) has indicated that sea lamprey (*Petromyzon marinus*) have been observed in the Huron River downstream of the Flat Rock Dam in relatively low population numbers. Appendix L provides this correspondence along with a Sea Lamprey Control Program (SLCP) Risk Assessment, and Production Potential Report. The USFWS consultation mentions sampling methods that have included eDNA, tagging, and reported captures over the course of 50 years of monitoring with limited positive results. The consultation memo from December 2023 (USFWS, 2023) states that while probability of Sea Lamprey ammocoete presence is statistically low, infestation is still possible as suitable spawning habitat exists upstream of the Flat Rock Dam. As such, USFWS has requested the feasibility-level evaluation of sea lamprey barrier alternatives within the project area. Functional sea lamprey barriers are those that meet SLCP program standards and operate over the spawning seasons from March through June and water temperatures between 8-20°C (Hrodey *et al.*, 2021).

The current Flat Rock Dam is considered an effective sea lamprey barrier when the existing Denil fishway is closed during the lamprey migratory season. USFWS SLCP has not found sea lampreys upstream of the Flat Rock Dam and the raceway and power structure are not considered as viable passages for any aquatic species. As such, the barrier alternatives that are identified and described in Section 9.6 may only be necessary if Dam Alternative 2, 3, or 4 is selected as the path forward for the Flat Rock Dam, and if future assessments indicate increased risk of Sea Lamprey colonization. Dam Alternative 1 which proposed a new fishway at the Flat Rock Dam would need to consider potential closure options within the fishway itself to prevent lamprey from moving upstream.

The lamprey barrier alternatives discussed below include three potential locations within the project reach, at the existing Huroc Dam location, at the existing Flat Rock Dam location, and downstream of the Telegraph Road crossing. Efficacy potential for the alternatives is determined and weighed against impacts. Feasible alternatives are objectively identified and evaluated herein and include no-action alternatives and various barrier technologies. Additional project-specific considerations may be weighed with stakeholders and agencies that influence alternative preference not captured in this analysis. If selected, a barrier initial cost and long-term maintenance would be the financial responsibility of USFWS SLCP.

## 9.2 Barrier Types and Function

Sea lamprey barriers have been generally grouped into 1) physical-barrier systems which exploit the swimming behavior weaknesses of the targeted species; and 2) behavior-barrier systems which rely on light, sound, bubbles, carbon dioxide, chemicals, or electric current to deter volitional passage or stun fishes. Physical barriers can be described as the manipulation of the fluid habitat/environment of a species, while behavioral barriers add constituents to that habitat. Barriers may include both physical and behavioral blockage mechanisms and these combinations can be more robust than a standalone barrier. It is also noted that additional options to barriers may be considered for all types, including trapping and sorting facilities.

Physical barriers can be grouped into jumping and velocity classes. A schematic of a physical barrier is provided in Figure 19. Behavioral barriers for sea lamprey are most commonly electrical with an image of a Great Lakes installation provided in Figure 20.

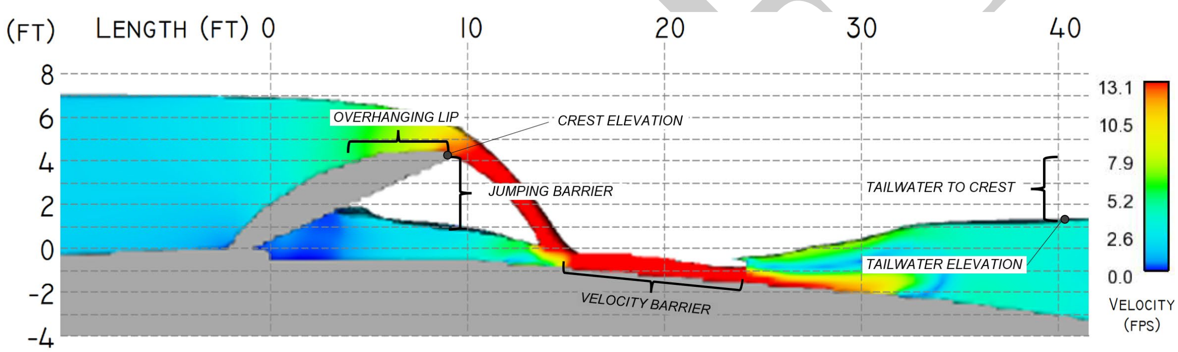


Figure 19: Typical Physical Hydraulic Barrier with Defined Parameters

Figure 20: Electrical Barrier (Johnson et al., 2021)

### *Free-overfall and program standard (physical)*

Jumping barriers, or free-overfall barriers, function by creating a vertical obstacle between the elevation of the tailwater to the crest of a structure. Hunn and Youngs (1980) indicated that a functional barrier generally occurs at a 12-in free-overfall with a 6-in overhanging lip. A free-overfall barrier of 18-in with an overhanging lip is a program standard for GLFC for consideration as completely effective blockage (Hrodey *et al.* 2020; GLFC, 2001). Target flow rates for effective blockage are up to the 25-year return flood. This guideline is adopted herein to evaluate program-standard barrier efficacy. When program-standards are not achieved, additions of complimentary velocity and electric components can be considered as described below.

### *Velocity (physical)*

Velocity barriers rely on creating uniform and concentrated current over a sufficient distance to exhaust an upstream traveling species. Sea lampreys are burst-attach swimmers; any velocity barrier must have a non-attachment surface to prevent resting. Maximum burst speeds of sea lampreys are approximately 13.1 feet/s (McAuley, 1996), although Hoover and Murphy (2018) have noted that values may be closer to 14.8 feet/s or greater. Temperature inversely affects sea lamprey energetics and efficacy of velocity barriers but were not considered in this feasibility analysis.

Velocity barriers are not a program standard for GLFC and are somewhat experimental. GLFT (2016) reports potential for sea lamprey velocity barriers based on local hydraulic head differences. These relationships are used to approximate the possibility for velocity barriers herein, but do not guarantee blockage efficacy if values are met. Additional design would be required for each identified velocity-barrier location.

### *Electrical (behavioral)*

Electrical barriers for sea lamprey control rely on introduced current through the water body that ceases swimming and flushes stunned fishes downstream of the barrier location. Johnson *et al*. (2021) indicated some success with electrical barriers through experimental current technologies and array layouts. Tews *et al.* (2021) noted electrical barriers do function to reduce sea lamprey migrations; although, they are encumbered by multiple maintenance and functionality issues that limit dependable function. Electrical barrier systems may be locally engineered for site-specific constraints to maximize chances of blockage efficacy, but reliability of the systems makes probabilistic efficacy determination difficult. Systems are usually deployed along the channel bottom encased within a concrete pad but can be installed with hanging electrodes as shown in Figure 20.

## 9.3 Hydraulic Conditions and Common Impacts

Physical barriers function through the generation of a local hydraulic drop. Most of the first-barrier systems in Michigan are located at dams, such as the Flat Rock Dam. These structures generate an increase in upstream water-surface elevations Increased upstream water-surface elevations over a baseline condition can have a series of impacts including flooding and harmful interference, sediment and fluvial geomorphology, and fisheries as described below.

### *Harmful Interference*

Raising water-surface elevations to levels above the 100-year recurrence flood level (base-flood elevation, ) or causing inundation of an insurable structure at a higher frequency is denoted harmful interference. Installing a physical barrier crest to generate a sufficient hydraulic drop can result in harmful interference. These effects are mitigated through limiting elevations of the barrier crest or including an adjustable structure.

### *Sedimentation*

Increasing the physical barrier crest height decreases the upstream friction slope of the river and decreases sediment transport capacity. Inflowing sediment from upstream may deposit within the barrier reach and result in conditions similar to the original dam installation. Long-term effects of deposition can include planform and profile fluvial geomorphological shifts and impaired habitat function. Where sedimentation occurs upstream of the barrier, coarse substrates suitable for native and preferred species spawning can become silted-in and embedded over time and lose function. These effects can be mitigated by including an adjustable structure and with the design and planning of periodic flushing operations.

### *Fisheries*

Native and preferred non-jumping fish species will be stopped by a physical barrier system. However, jumping species that can overcome an 18-in free-overfall should not be completely deterred. Mitigating non-jumping fisheries impacts for physical barriers can be accomplished with an adjustable system that is removed or lowered outside of sea lamprey spawning months. Fish ladders should be installed around the barrier systems where a > 18-in free-overfall exists or where locally adverse hydraulics are present, such as at velocity-barrier systems.

Electrical barriers have incidental mortality rates for all fish species encountering the current. Johnson *et al.* (2021) found that a mortality rate of 3% of all fish attempting to pass occurred, which was skewed towards non-jumping species such as sucker, minnows, and chubs.

Trap-and-sort facilities are sometime considered at complete barriers to desired fish passage. These facilities can collect and manually transport jumping and non-jumping species to the headwaters beyond the sea lamprey control system.

## 9.4 Alternatives Identification

Alternatives were developed to analyze the range of possibilities at the site and assess feasibility. While all alternatives could be feasibly constructed, not all alternatives are prudent. Analysis of the identified alternatives considered available existing hydraulic drop, spatial confinement of upstream impacts, overall footprint and construction cost minimization, and probability of success. While attempting to be comprehensive during screening, alternatives did not necessarily consider all other project constraints outside of those affecting the barrier alternatives. These factors may affect alternative selection and overall costs. Alternatives did not consider addition of multiple components (e.g., behavioral to physical). As such, additional refinement would be required at any of the alternatives progressed to design phases.

Three locations were found to cover the reasonable alternatives for the project area. These include Alternative A – Huroc Dam Location; Alternative B – Flat Rock Dam Location; and Alternative C – Downstream Telegraph Road Location. Identified alternative locations attempted to remain within or proximal to the overall project area. Alternative C was located slightly downstream of the project area for public interaction and spatial confinement factors. Moving upstream, the railroad bridge, the Willow Road Bridge, and I-275 Bridge may be the next options for hydraulic containment and feasible barrier locations, which were not evaluated.

Each identified alternative is described below. Conceptual layouts for each alternative are provided in the plan set.

### *Sea Lamprey Alternative A – Huroc Dam Modifications*

The existing Huroc Dam is a low-head grade-control structure, approximately 104-feet wide with crest elevation 582.4 feet. Huroc Dam is not currently considered a sea lamprey barrier. The structure has a pedestrian bridge that spans the Huron River connecting park spaces on the west (river-right) to light mixed-use development to the east (river-left). There is risk of harmful interference to the east with properties within the 100-year regulatory floodplain and lowest-adjacent grades which are below the 100-yr flood level. Overbanking on both sides of the river occurs at the project site at flows below the 2-year recurrence interval. An overbanking constraint was set with 0.25-feet freeboard at 585.8

feet. Uncontrolled overbanking can activate pathways that migrating sea lampreys may utilize to bypass the barrier.

## A-1 – No Action– Modification to Free-Overfall

Alternative A-1 would not modify the Huroc Dam crest elevation or substantially alter the structure itself. The crest may be modified to include a steel overhanging lip to maximize free-overfall conditions. The Huroc Dam was analyzed assuming free-overfall conditions exist. Under this alternative, the crest elevation would be static and submerge with rising tailwater, similar to the existing condition.

## A-2 – Adjustable Structure – No Overbank Modification

Alternative A-2 would remove and replace the Huroc Dam at approximately the same location as the original structure. Under this alternative, an adjustable weir would be installed that tracked an 18-in free-overfall barrier from tailwater levels. At overbanking conditions, the river-right park space would inundate and permit passage around the structure, rendering the barrier unfunctional.

## A-3 – Adjustable Structure - Overbank Berm at River Right

Alternative A-3 would be identical to Alternative A-2 in function other than the inclusion of an overbank berm on river-right (west) to contain flows from overbanking and spilling around the barrier structure. A berm elevation of 592.75 feet was considered in this alternative as an elevation that provides reasonable blockage efficacy without incurring harmful interference at structures. The berm elevation and layout should be optimized if this alternative becomes preferred.

### *Sea Lamprey Alternative B – Flat Rock Dam Modifications*

The existing Flat Rock Dam is a 590-feet wide concrete structure with crest invert elevation of 590.5 feet. The structure is considered a “first barrier” on the Huron River and likely functions primarily as a velocity barrier as flows travel down the concrete, ogee face. No free-overall barrier is present at the main face of the dam under any flow condition. Alternative B would be located at or near the existing structure.

Overbanking occurs upstream of the Alternative B location at the river-left (north) bank which may result in flooding of proximal parcels at approximately the 10-year flood. There are multiple properties and insurable structures below the 100-yr flood level affected by the Flat Rock Dam impoundment. An overbanking elevation constraint was set at 589.8 feet, including 0.25-feet freeboard. A 100-yr flood level constraint was established as 593.1 feet with 0.25-feet freeboard.

## B-1 – No Action – Modification to Free-Overfall

Alternative B-1 would not modify the Flat Rock Dam crest elevation or substantially alter the structure itself. The crest may be modified to include a steel overhanging lip to maximize free-overfall conditions. The Flat Rock Dam was analyzed assuming that free-overfall conditions exists. Under this alternative, the crest would be static and submerged with rising tailwater, similar to the exiting condition.

## B-2 – Adjustable Structure – Tracking Overbanking Constraint

Alternative B-2 would remove and replace the Flat Rock Dam with an adjustable weir structure at approximately the same location as the original structure. The structure would be optimized to prevent overbanking from occurring at or below the discharge it occurs at existing conditions.

## B-3 – Adjustable Structure – Tracking 100-yr flood level Constraint

Alternative B-3 would remove and replace the Flat Rock Dam with an adjustable weir structure at approximately the same location as the original structure. The structure would be optimized to prevent water-surface elevations from meeting or exceeding the existing 100-yr flood level at and below the 100-year flood discharge. Additional fill may be required to fully contain the 100-yr flood level without resulting in harmful interference for this alternative.

### *Sea Lamprey Alternative C – Electrical*

Alternative C would be a new facility located downstream of Telegraph Road. This location was chosen away from the park areas to prevent public interaction and at a confinement in the channel to minimize the structure footprint. Public land is not available at this site and would require acquisitions of private parcels. This location may also be relocated to a more optimized site if selected. Alternative C is envisioned as an electrical-barrier system flush to the channel bottom like those described in Tews *et al.* (2021).

## 9.5 Alternatives Analyses

Alternatives were analyzed for efficacy vs. impacts using a multi-criteria scoring matrix. This section describes the metrics and analysis of these factors. Barrier efficacy for physical-barrier systems is defined by the number of days that the barrier meets threshold criteria. Since these criteria are hydraulically based, it was possible to evaluate efficacy at a feasibility level for Alternative 1 and Alternative 2. Behavioral barriers are not able to have efficacy evaluated at the feasibility stage and would require further site-specific design.

Impacts for the barrier systems can be evaluated at a feasibility level with system-scale effects that would be persistent regardless of future design refinements. These impacts are evaluated as described below.

### *Efficacy of Physical Blockage Hydraulics*

Physical-hydraulic systems were evaluated using efficacy-duration analysis, which combines the structure function with probability of a flow occurring over the spawning period. Flow probability distribution functions were provided for each month at the project location by EGLE (2023) as discussed earlier in this report (Table 4). Flows where each of the alternatives become ineffective were determined through use of the HEC-RAS model developed for this project as described in Section 5.2. Alternative structures were calculated as overflow weirs and represented in the model as rating curves. While hydraulic analyses presented below are based on engineering best practices, reported findings are at a feasibility level and are subject to changes during refinement.

## Free Overfall

Free-overfall was calculated as the difference from the modeled tailwater immediately downstream of the structure to the crest elevation. Adjustable crest elevations varied by tracking tailwater with an 18-in free-overfall barrier. Maximum discharge where the crest maintains an 18-in barrier was limited by upstream water-surface elevation flooding or overbanking constraints which varied by alternative. As an example of a static-crest and adjustable-crest configuration, Figure 21 illustrates Alternative B-1 (no-action) and Figure 22 illustrates Alternative B-3 (overbanking tracking) at the Flat Rock Dam location. The existing, no-action Alternative B-1 loses efficacy at approximately 3,260 cfs, while the adjustable Alternative B-3 loses efficacy near 3,000 cfs.

Table 20 provides the greatest discharge where barriers are effective before increasing tailwater submerges the free overfall. Flows above the identified values would not produce effective barriers for the corresponding alternative based on the performance metrics.

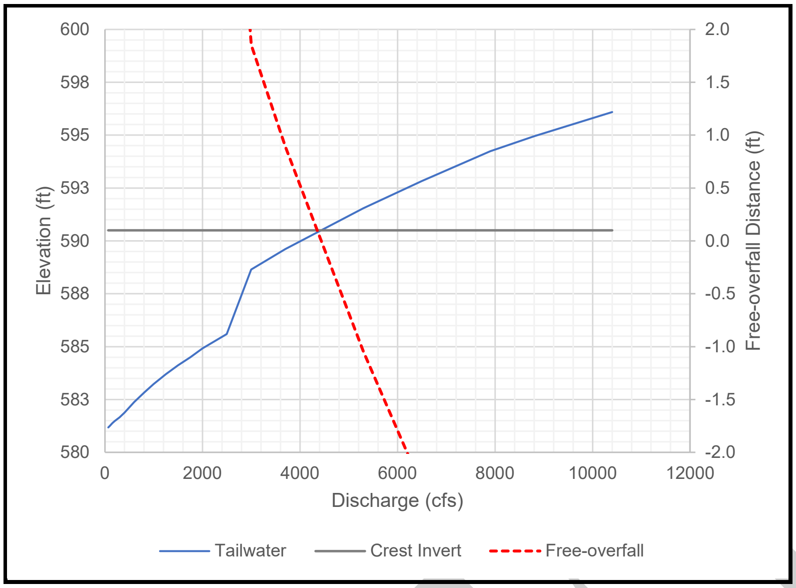


Figure 21: Free-Overfall Hydraulics for Fixed-Crest - Alternative B-1

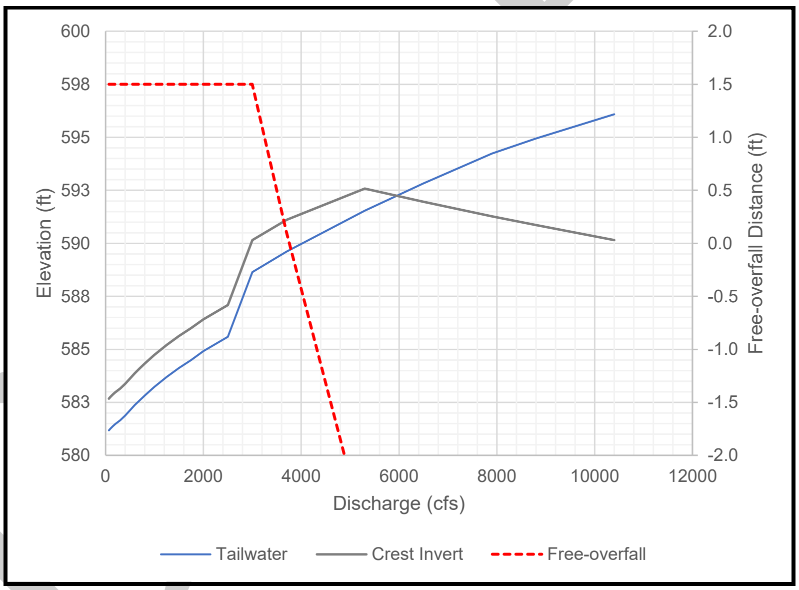


Figure 22: Free-Overfall Hydraulics for Adjustable-Crest - Alternate B-3

Table 20: Free-Overfall Barrier Greatest Discharge Achieving 18-in (Effective Level) or Greater

| Alternative | Adjustable | Max Discharge (cfs) > 18-in |
|---|---|---|
| A-1: Huroc Dam - No Action | | 169 |
| A-2: Huroc Location | x | 700 |
| A-3: Huroc Location with Containment Walls | x | 2500 |

| Alternative | Adjustable | Max Discharge (cfs) > 18-in |
|---|---|---|
| B-1: Flat Rock - No Action | | 3260 |
| B-2: Flat Rock Location - 100-yr flood level | x | 3700 |
| B-3: Flat Rock Location - Overbanking | x | 3000 |

1. 25-year flood discharge = 7,900 cfs

## Velocity

Head loss was calculated as the difference of the upstream water-surface and tailwater elevations for each alternative and then applied within the methodology of average-jet velocity prediction of GLFT (2016). Relationships developed from GLFT (2016) provide feasibility-level estimations of velocity; site-specific modeling and design would be required to refine efficacy predictions.

Table 21 provides a summary of the greatest discharge calculated to indicate a velocity barrier for each alternative for the McAuley (1991) and Hoover and Murphy (2019) thresholds. Flows above the identified values would not produce effective barriers for the corresponding alternative based on the performance metrics.

The no-action alternatives (Alternative A-1 and B-1) were not considered for velocity barriers due to absence of necessary structural modifications for those alternatives. Figure 23 provides an example of average-jet velocity prediction for Alternative B-3, with upstream and downstream water-surface elevations, head difference, and calculated values illustrated.

Table 21: Velocity Barrier Greatest Discharge Achieving Threshold Velocity-Barrier Conditions

| Alternative | Adjustable | Max Discharge (cfs) > 13.1 ft/s | Max Discharge (cfs) > 14.8 ft/s |
|---|---|---|---|
| A-1: Huroc Dam - No Action | | n/a | n/a |
| A-2: Huroc Location | x | 2500 | 1250 |
| A-3: Huroc Location with Containment Walls | x | 5300 | 3700 |

| Alternative | Adjustable | Max Discharge (cfs) > 13.1 ft/s | Max Discharge (cfs) > 14.8 ft/s |
|---|---|---|---|
| B-1: Flat Rock - No Action | | n/a | n/a |
| B-2: Flat Rock Location - 100-yr flood level | x | 10400 | 7900 |
| B-3: Flat Rock Location - Overbanking | x | 5300 | 3700 |

1. 25-year flood discharge = 7,900 cfs

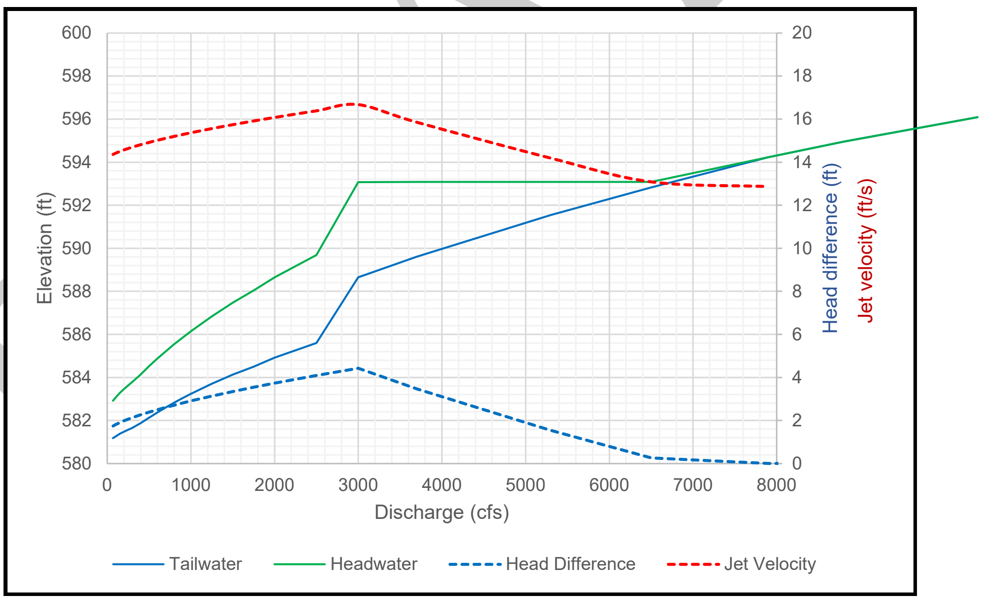


Figure 23: Water-Surface Elevations, Head Difference, and Approximated Jet Velocity – Alternative B-3

## Duration Analysis

Using data from EGLE (2023), the maximum effective discharge for each alternative was aligned with the probability of that flow occurring on any day in a given month. Maximum effective discharge was then translated into total effective days for a month and over the spawning season as a percentage.

Table 22 provides the percentage of time each alternative exceeded free-overfall efficacy thresholds per month based on performed feasibility analyses. Table 23 provides percentages for McAuley (1991) velocity thresholds and Table 24 provides the data for Hoover and Murphy (2019). Values are provided for the preceding months of spawning season (January and February) for reference.

Table 22: 18-Inch Percentage Month Exceeded

| Alternative | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|
| A-1: Huroc Dam - Mod to Overhanging | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.7 |
| A-2: Huroc Location | 76.3 | 68.9 | 35.7 | 36.0 | 60.7 | 79.5 |
| A-3: Huroc Location with Containment Walls | 100.0 | 94.3 | 92.2 | 94.3 | 98.6 | 100.0 |

| Alternative | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|
| B-1: Flat Rock - Mod to Overhanging | 100.0 | 97.9 | 97.8 | 100.0 | 100.0 | 100.0 |
| B-2: Flat Rock Location - 100-yr flood level | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| B-3: Flat Rock Location - Overbanking | 100.0 | 96.7 | 95.9 | 98.2 | 100.0 | 100.0 |

Table 23: 13.1 ft/s Percentage Month Exceeded

| Alternative | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|
| A-1: Huroc Dam - Mod to Overhanging | n/a | | | | | |
| A-2: Huroc Location | 100.0 | 94.3 | 92.2 | 94.3 | 98.6 | 100.0 |
| A-3: Huroc Location with Containment Walls | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

| Alternative | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|
| B-1: Flat Rock - Mod to Overhanging | n/a | | | | | |
| B-2: Flat Rock Location - 100-yr flood level | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| B-3: Flat Rock Location - Overbanking | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Table 24: 14.8 ft/s Percentage Month Exceeded.

| Alternative | Jan | Feb | Mar | Apr | May | Jun |
|---|---|---|---|---|---|---|
| A-1: Huroc Dam - Mod to Overhanging | n/a | | | | | |
| A-2: Huroc Location | 90.3 | 85.5 | 69.2 | 71.4 | 85.0 | 93.4 |
| A-3: Huroc Location with Containment Walls | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | | | | | | |
| **Alternative** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** |
| B-1: Flat Rock - Mod to Overhanging | n/a | | | | | |
| B-2: Flat Rock Location - 100-yr flood level | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| B-3: Flat Rock Location - Overbanking | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

### *Impacts*

Sea lamprey barriers create a discontinuity in the river environment that has incidental impacts which include sediment, fish passage, initial capital cost, maintenance, public safety, and flooding. Methods used for impacts analysis are described below along with relative scoring criteria for alternatives.

## Sediment

Upstream water-surface elevations determined for each alternative were incorporated into a hydraulic analysis of sedimentation. Sedimentation impacts are mostly concerning if the existing Flat Rock Dam is deconstructed, and a restored channel developed. Partial or full deconstruction of Flat Rock Dam could have sediment deposition impacts ranging from unimpeded equilibrium conditions to what is occurring under existing conditions. If the Flat Rock Dam remains in place, or is modified to a partial removal, sediment effects for Alternative A would be limited to the reach between Huroc Dam and Flat Rock Dam.

Figure 24 illustrates a schematic of flow approaching the structure at Alternative B-3 with the barrier in operation at 800 cfs. Also depicted are sediment transport capacities calculated for flows up to the 100-year flood. In this configuration, the approach reach is the restored channel after dam removal. As the flow approaches from the inflow reach, the backwater created by the barrier increases flow depth, slows velocities, and reduces sediment transport capacity. The difference between the inflowing sediment load and outflowing load through the backwater reach was used to approximate quantities of sediment deposited behind the structure.



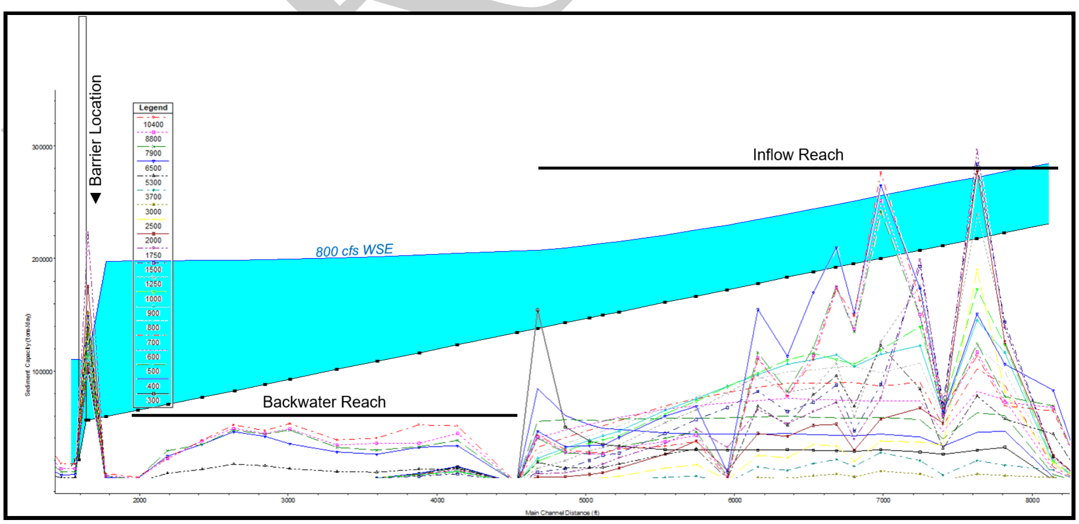


Figure 24: Sediment Transport Capacity with Example Backwater Profile Upstream of Alternative B

Sediment transport was reach-averaged for the inflow and backwater segments for discrete discharges evaluated. Calculated sediment transport per discharge was then weighted by the probability distribution function of discharges over the spawning season (March – Jun) and by the non-operational season (Jul – Feb) to approximate total loads.

Calculations for sediment transport used sediment gradations collected downstream of the Flat Rock Dam outside of the area of fines deposition and used the Laursen-Copeland total load equation with the HEC-RAS model. These methods provided relative quantification of transport; however, were not calibrated. Use of different gradations, methods, and coefficients can return different absolute quantities with orders-of-magnitude variance. Gray *et al.* (2009) provides a sediment yield relationship for watersheds in the Great Lakes region as a function of watershed area which is used by EGLE and USACE for estimation of sediment production in the area. For the 876 $mi^2$ watershed contributing to the project area, the Gray *et al.* (2009) relationship predicted an annual transport of 75,100 tons. Total annual load calculated for alternatives was scaled to these annual estimates.

Table 25 provides sediment capture estimates for the various alternatives with total tons per year. Values indicate deposition of up to 80% of the sediment inflow during operations under normal flow conditions. Deposited sediments during operations were found to be on the order of the sediment supply of the remainder of the year. Capture of sediment at these levels may have a high impact on the river system and will require development of flushing operations to maintain desired channel form.

Table 25:Sediment Transport Feasibility-Level Impacts Results

| Sea Lamprey Alternative | % Capture Mar-Jun | Tons Captured | % Jul-Feb |
|---|---|---|---|
| A-1 | n/a | | |
| A-2 | 59 | 24572 | 74 |
| A-3 | 81 | 33883 | 101 |
| B-1 | n/a | | |
| B-2 | 82 | 34093 | 102 |
| B-3 | 82 | 34094 | 102 |

## Fish

All non-jumping fish will be blocked during functional operations of the sea lamprey barrier alternatives. When the barriers become submerged, or are non-operational, passage through the barrier sites should be possible. Barrier designs should promote passage hydraulics for non-jumping species during non-operational periods by minimizing head differences and backwatering the lowered-structure crests. Other options include trap-and-sort facilities at the barriers.

Each barrier location can feasibly have a bypass incorporated for jumping species. A bypass may be desired if a velocity-barrier system is a component of the design, hydraulic conditions are greater than an 18-in barrier, or for any electrical-barrier system. An 18-in free-overfall would be required at any fishway to prevent escapement. Conceptual locations and layout for fishways are provided in the plan set. Attracting flows, flow distributions, substrate materials, and configuration are necessary design components at any developed fishway alternative.

Medium impacts for fish are expected for the physical-barrier alternatives due to the asynchronous spawning seasons with sea lamprey, ability for fish bypasses during operation, and prescribed lowering of the structure during non-operational times. High impacts are expected for the electrical barrier due to reported mortality rates compared to the physical-barrier alternatives. No-action alternatives were assigned a medium impact due to a channel-spanning persistent barrier.

## Initial Cost

Approximate costs were developed for each alternative based on 2024 estimates at a Class 4 level using the conceptual drawings provided in the plan set. Multiple configurations of the structures exist, along with components and add-ons that would change the overall cost estimates. Parcel and/or easement and right-of-way acquisition was not included in the cost estimates.

Table 26 provides estimates of cost for each alternative where substantial modifications are proposed. A life-cycle maintenance cost is provided for reference on a 50-year expected lifespan. Cost impacts are ranked low, medium, and high based on the three relative values for comparison.

Table 26: Class 4 Cost Estimate for Substantial Modification Alternatives

| Sea Lamprey Alternative | Class 4 Estimate | Annual Maintenance (50-year Life Cycle) |
|---|---|---|
| A-2/3 | $6.55 million | $126,000 |
| B-2/3 | $8.84 million | $168,000 |
| C | $5.21 million | $100,000 |

Costs for a potential sea lamprey barrier would be the responsibility of USFWS SLCP and include initial and long-term operational expenses.

## Maintenance

Facility maintenance needs can vary based on many factors including river debris, sedimentation, ice, and operation frequency. Many adjustable systems require relatively infrequent maintenance and can be reliable for their intended operations for decades; however, adjustable systems do require more attention than static-crest or non-adjustable systems. Electrical barriers have anecdotally required routine maintenance for ensuring complete functionality. Static-crest options are considered low-maintenance impacts, adjustable systems are moderate, and electrical barriers are considered high impact.

## Public Safety

Barrier structures create safety concerns with drowning hazards at physical barriers and electrocution/drowning at electrical barriers. Both barrier systems should be blocked from public interaction during operational periods at a minimum. The hydraulic design of physical barriers should consider flushing hydraulics to prevent recirculation entrapment. Electrical systems should have failsafe shut-offs available in the event of emergencies and be configured to minimize shock hazards to humans in the event of unplanned interaction. All barrier systems create a high public safety impact, though limiting interaction with the structures should mitigate the risk to a medium impact.

## Flooding

The physical-barrier options are constrained by flooding impacts and do not create harmful interference by design. Impacts for the overbanking constrained alternatives are low and the 100-yr flood level tracking alternatives are medium for comparison. For the electrical barrier alternative, no flood impact is anticipated (low impact).

## 9.6 Criteria Matrix

Table 27 provides the developed semi-quantitative scoring matrix of each feasible alternative based on the analyses performed and impacts described above. Scores are relative to other alternatives. For efficacy, high scores indicate that the structure approximately meets the existing condition, with low and medium separated by the 90% blockage-duration limit. For example, an 80% duration where the barrier met or exceeded an 18-inch drop would be ranked as low efficacy, while a 95% would be medium. Color-coding in Table 27 is a qualitative indicator for good (green), medium (yellow), and poor (red), as high- and low-scores can have reversed meanings for different categories. It is noted that the scores for efficacy for the no-action alternative for Huroc Dam (A-1) is low (poor/red), indicating its lack of current barrier status.

Table 27:Criteria Matrix

| | | Relative Score | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sea Lamprey Alternative** | **Adjustable** | **Efficacy** | **Sediment** | **Flood** | **Cost** | **Fish** | **Maintenance** | **Public Safety** |
| A-1: Huroc Dam - Mod to Overhanging | | Low | Med | Low | Low | Med | Low | Med |
| A-2: Huroc Location | x | Low | Med | Low | Med | Med | Med | Med |
| A-3: Huroc Location with Containment Walls | x | Med | High | Low | Med | Med | Med | Med |

| | | Relative Score | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sea Lamprey Alternative** | **Adjustable** | **Efficacy** | **Sediment** | **Flood** | **Cost** | **Fish** | **Maintenance** | **Public Safety** |
| B-1: Flat Rock - Mod to Overhanging | | High | High | Low | Low | Med | Low | Med |
| B-2: Flat Rock Location - 100-yr flood level | x | High | High | Med | High | Med | Med | Med |
| B-3: Flat Rock Location - Overbanking | x | Med | High | Low | High | Med | Med | Med |

| | | Relative Score | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sea Lamprey Alternative** | **Adjustable** | **Efficacy** | **Sediment** | **Flood** | **Cost** | **Fish** | **Maintenance** | **Public Safety** |
| C - Electrical/Behavioral | | High | Low | Low | Low | Hig h | High | Med |

# 10. Combination of Alternatives

The HCMA owns the Flat Rock Dam, and the City of Flat Rock owns the Huroc Dam. Each entity may prefer a different alternative. The table below illustrates the feasibility of combining various alternatives. Since all combinations of alternatives have not been formally evaluated, there may be additional engineering considerations that should be assessed once both dam owners choose a path forward and a more detailed design effort is started.

| | | **Huroc Dam** | | | |
|---|---|---|---|---|---|
| | | **Alternative 1 - No Action – Fish Passage Improvement** | **Alternative 2 – Partial Removal** | **Alternative 3 - Removal with Active Restoration** | **Alternative 4 - Removal with Passive Restoration** |
| **Flat Rock Dam** | **Alternative 1 – No Action - Fish Passage Improvement** | | Feasible | May be Feasible - Studies of the pedestrian bridge piers will likely be required. | |
| | **Alternative 2 – Partial removal** | Feasible | | Adding weirs to the Flat Rock rapids will be necessary to adjust for the head loss from removing the Huroc Dam. This will increase costs and reduce accessible waterfront upstream of the Flat Rock Dam. | |
| | **Alternative 3 – Removal with Active Restoration** | Feasible; modifications to the limits of the stream restoration extents may have to be made due to elevated water levels from the Huroc Dam extending to the Flat Rock Dam location. | | | Feasible |
| | **Alternative 4 – Removal with Passive Restoration** | Feasible; modifications to the limits of the stream restoration extents may have to be made due to elevated water levels from the Huroc Dam extending to the Flat Rock Dam location. | | Feasible | |

# 11. Funding Sources

Various entities, including government agencies, private foundations, and non-profit organizations, offer grants to support dam projects focused on environmental mitigation, safety, maintenance, and rehabilitation. Many of these funding sources operate through competitive selection processes, where projects like dam removal or aquatic restoration are evaluated based on their impact, such as the amount of upstream habitat opened due to removal. In the case of Flat Rock and Huroc Dams, their removal would open approximately 19 miles of the Huron River. Given the significant connectivity enhancement and its position as the lowest impoundment on the river, securing funding from multiple grant opportunities would be highly competitive. Because each alternative prioritizes the restoration of fish passage, each alternative will be eligible for certain grant funding. However, the extent to which the area is restored to its natural ecosystem will likely impact the project's eligibility for funding.

Grant opportunities are available for national, regional, state-specific and water basin specific project types. HCMA would have a higher likelihood of securing grants from Michigan or Great Lakes Basin-specific grant programs compared to more nationally focused grant opportunities.

Upon selecting an alternative, it is anticipated that the Huron River Watershed Council will collaborate with HCMA to identify and pursue specific grant opportunities. A revolving opportunity for supplemental funds also exists through various private foundations, smaller federal-NGO partner programs, and corporate charitable programs. However, these smaller programs often have a shorter lifespan of around three years and are limited, typically under $100,000, with many awards being less than $50,000.

Appendix M contains a spreadsheet listing known potential funding sources that could assist HCMA in financing each alternative.

# 12. Summary and Conclusions

This section will be developed following the second round of stakeholder and public engagement.

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# Appendix A  Feasibility Study Plan Set

# Appendix B  Applicable Historic Drawings

# Appendix C Dam Inspection Safety Reports

# Appendix D Sediment Sample Summary Memo

# Appendix E Wetland Delineation & Protected Species Report

# Appendix F Fish Survey Data and Mussel Mapping Data for the Project Area

# Appendix G Cultural Resources Phase 1 Records Review Report

# Appendix H Attenuation Study Report

# Appendix I Dam Economic Contribution Study

# Appendix J Property Boundary Exhibits

# Appendix K  Alternative Cost Estimates

# Appendix L Sea Lamprey Consultation with US Fish and Wildlife Service

# Appendix M Known Grant Funding Opportunities