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Allegan Dam Feasibility and Conceptual Design Report

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Prepared for: Michigan Department of Natural Resources

Prepared by:

AECOM
10850 Traverse Highway
Traverse City, MI 49684
aecom.com

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1. Introduction and Purpose

This report is intended to consider the feasibility of conceptual design alternatives for addressing fish passage, safety, and maintenance, concerns at the City of Allegan Dam on the Kalamazoo River in Allegan County, Michigan (Figure 1). This study will also investigate opportunities for improving public interaction with the river.

The goals of the dam removal/modification project as determined by Michigan Department of Natural Resources (MDNR) and city staff are to:

- Mitigate safety concerns associated with the deteriorating powerhouse and necessary dam repairs,
- Improve the riverine ecosystem including fish passage and habitat quality,
- Improve recreational opportunities, and
- Manage contaminated sediments and waste within the project site.

The City of Allegan Dam site is part of a USEPA Superfund site for PCB contamination. The Allied Paper Inc./Portage Creek/Kalamazoo River Superfund site includes PCB-contaminated soil and sediment in landfills, paper mill properties, approximately 80 miles of the Kalamazoo River, adjacent riverbanks and contiguous floodplains, and portions of Portage Creek. Allegan Dam is part of the site's operable unit (OU) 5, which includes the bed and floodplain sediment of Portage Creek and Kalamazoo River, and part of subunit Area 5, which includes the Kalamazoo River bed and floodplain from Trowbridge Dam to Allegan City Dam.

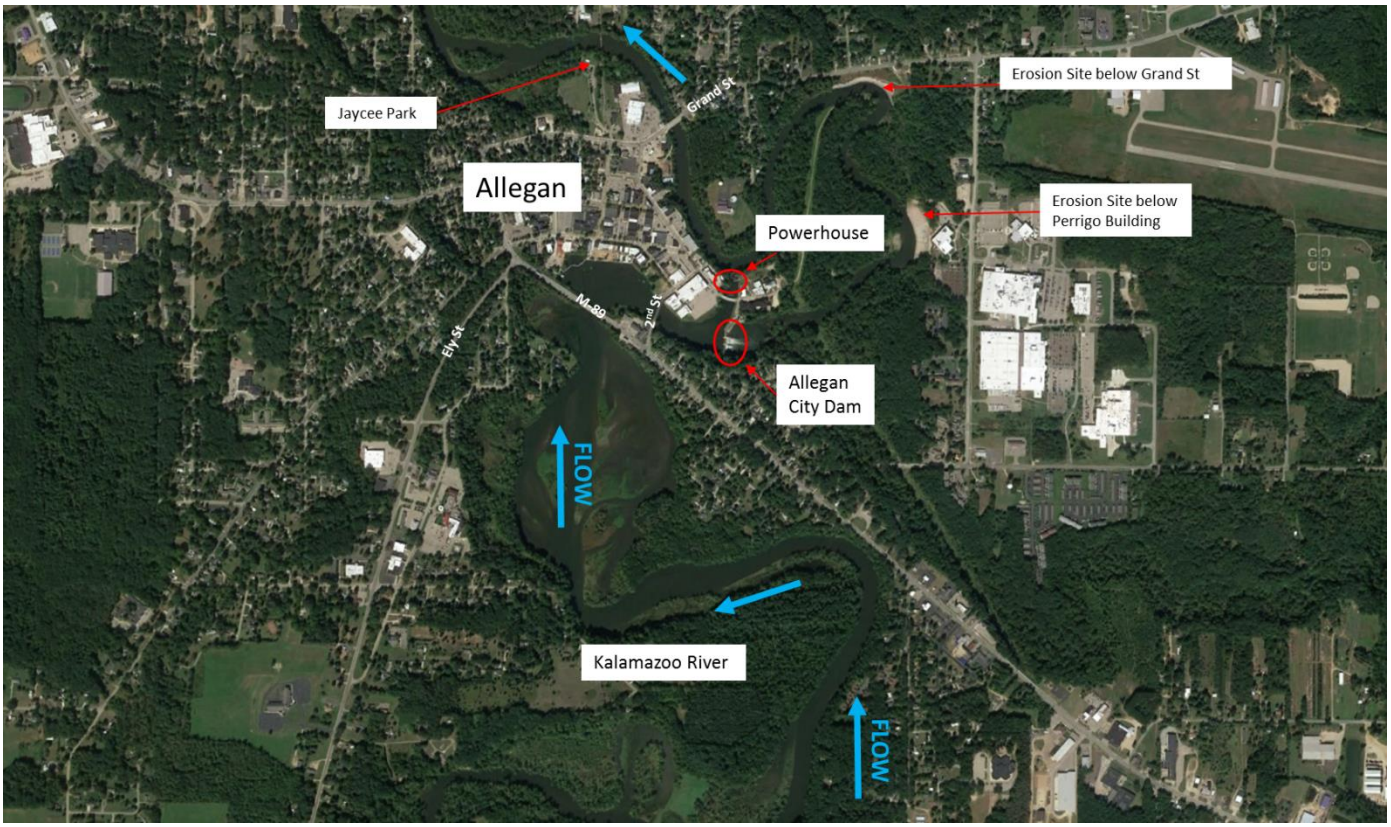

Figure 1. Location of Allegan City Dam.

2. Site Assessment and Data Analysis

The Allegan City Dam NID# MI00489, has a structural height of 14 ft and hydraulic height of 9 ft, a listed storage of 1,100 acre-feet, and is classified as a high hazard dam (USACE, 2019). MDEGLE defines a high hazard dam as - "A dam whose failure may cause loss of life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways or railroads. Dams constructed in existing or proposed residential, commercial or industrial areas will be classified as high hazard dams, unless the applicant presents clear and convincing evidence to the contrary." The dam operates along the mainstem of the Kalamazoo River near downtown City of Allegan and maintains a 135 acre impoundment along downtown Allegan. The dam originally maintained water levels for the adjacent millrace and powerhouse. The millrace extends approximately 500 ft north of the principal spillway to the powerhouse structure, before dropping (~10 ft) back to the river below the oxbow. The powerhouse consists of two sections, the older western section, and newer eastern section, which still contains a turbine and generating equipment. According to maps provided by the City of Allegan, no utility or pipelines pass through the impoundment at, or upstream of the principal spillway.

The dam consists of a 100 ft long right earthen embankment, a 200 ft wide principal spillway section, and a 575 ft long left earthen embankment. The earthen embankments have crest widths of approximately 33 ft. The principal spillway consists of four separate spillway sections: a 51.5-ft wide south stoplog section (spillway bay #1), a 52-ft wide north stoplog section (spillway bay #2), and two 24-ft wide radial gates (spillway bays #3 and #4). The four spillway bays are separated by concrete piers and needle sections (See Figure 2). The dam maintains a head of approximately 9 ft, with 3 ft of freeboard under normal operating conditions (MDEQ 2017).

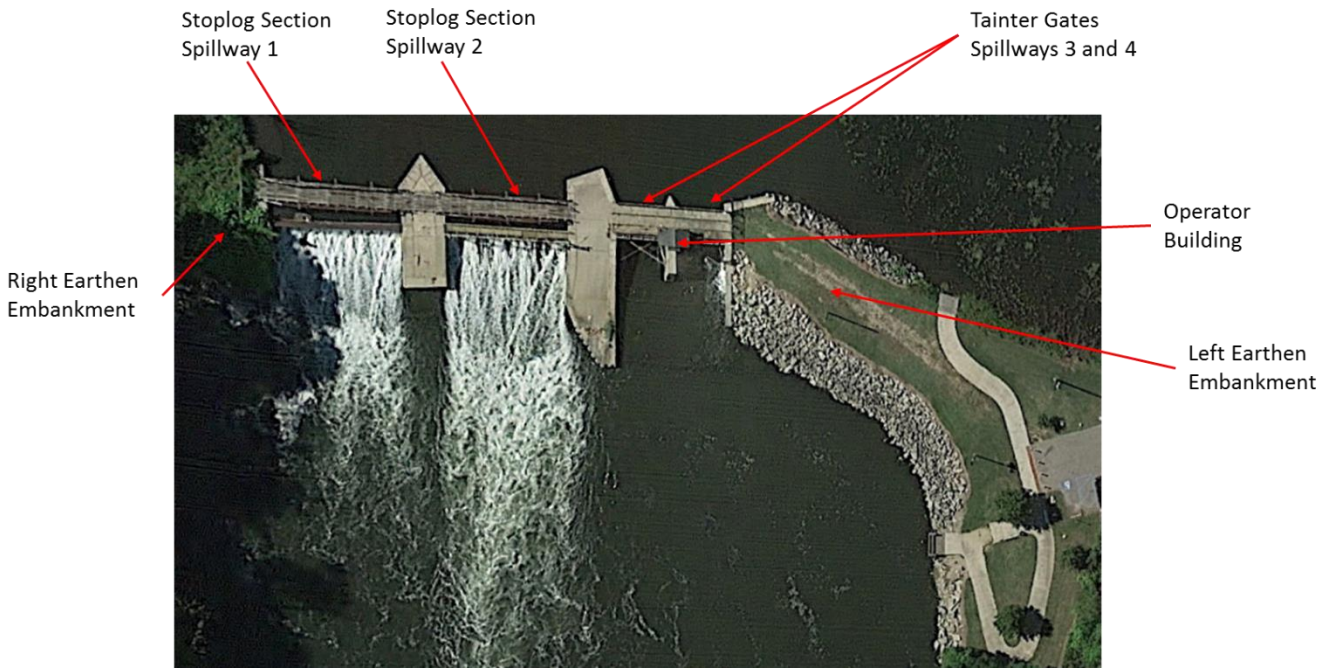

Figure 2. Diagram of Main Spillway Components

As early as 1835 a dam and sawmill may have existed at or near the current site. The current dam, originally named the Imperial Carving Dam, was constructed in 1900 for hydromechanical power (MDEQ 2017). The radial gates were installed in the principal spillway structure around 1910. The dam was used to run machinery for furniture manufacturing. In 1920 the dam was converted to use for hydroelectric power generation, the eastern section of the powerhouse was likely constructed around this time. After electrical generation ended in 1997 the City of Allegan purchased the dam to maintain the downtown waterfront area upstream of the dam. Deteriorating conditions and safety concerns led the City to carry out repairs and upgrades to the dam in 2000 and 2003 (MDEQ 2017). MDNR Fisheries Division recommended removal at this time, however, the City preferred to maintain the impoundment and waterfront in their current condition.

Since that time the powerhouse on the millrace has experienced advanced deterioration and has been condemned. Currently water in the headrace is prevented from flowing into the lower downstream river by walls and gates at the powerhouse. Due to this retention of water at a higher elevation than the downstream river, an inspection report from Lawson-Fisher Associates dated June 2017 noted that any failure at the powerhouse could be sudden and severe (LFA, 2017). However, the concrete bulkhead that was constructed upstream of the intake of the western powerhouse is newer and the intake of the eastern powerhouse is in better overall condition. Both MDEQ and LFA concluded that sudden failure is unlikely in the immediate future (LFA, 2017 and MDEQ, 2017). However, the powerhouse will need to be repaired, replaced, or removed.

The MDEQ 2017 Dam Safety Inspection Report notes that the principal spillway will overtop at the design flow (200-yr flood discharge of 14,000 cfs). At this flow impoundment levels would rise to an elevation of 631.2 ft and overtop portions of the earthen embankment, with maximum overtopping velocity estimated to be 7.3 fps, with a 2.3 ft head differential. Under these conditions the riprap erosion protection on the downstream side of the embankment would be expected to be sufficient such that the embankment would see only minimal damage. As such the dam is considered to safely convey the design flood. The FEMA Flood Insurance Study for this area lists the 100-yr flood water surface elevation at 633.0 ft (FEMA, 1989). The FEAM study used NGVD29 as a datum and the MDEQ report is assumed to reference NAVD88. Converting the datum puts the FEMA 100-yr flood water surface elevation at 632.55 ft. The discrepancy between the FEMA and MDEQ results should be explored during future phases of the project if a non-removal alternative is select to ensure the safety of people and property.

3. Project Goals and Constraints

3.1 Mitigate Safety Concerns at the Dams

As noted above, the Allegan City Dam consists of the main channel concrete dam, the millrace, and two powerhouse sections blocking flow from the millrace to the main channel. The older of the two powerhouse sections has not been operational for some time, and the newer (east) powerhouse section ceased operations in 1997. Significant deterioration to the powerhouse since that time has resulted in the powerhouse being condemned. Also of concern is the deteriorating catwalk over one of the spillways of the mainstem dam. The catwalk is unsafe for use and currently prevents access to the south embankment for maintenance activities. Any alternatives will need to address removal or rehabilitation of the powerhouse structures as well as removal or modification of the mainstem dam.

Any failure of either the powerhouse or principal spillway dam could result not only in damages downstream due to flooding and erosive forces, but also the potential downstream transport of contaminated sediments from within the impoundment.

Other safety concerns include the flooding potential of the low-lying mill district area and Perrigo Plant 1 facility at Water Street and State Street, which lie within the current FEMA delineated 100-yr floodplain, and have experienced repeated inundation events. Information from the city public works director indicated that one of the main operational goals of the dam is to maintain impoundment levels low enough to prevent flooding of these areas.

3.2 Improve Fish Passage and Habitat Quality

The current dam acts as a barrier to aquatic organism passage. Downstream of the dam only one other dam (below Lake Allegan) remains a barrier between Allegan and Lake Michigan. Upstream of Allegan City Dam, a number of dam removals from Trowbridge to Otsego aim to open up over 40 miles of river and stream habitat. All alternatives should take into account the provision of some form of fish passage to allow populations below the dam to reconnect with populations and newly opened habitat upstream of the dam. Providing fish passage would also improve fishing opportunities both upstream and downstream of the dam. The Kalamazoo River Assessment (Wesley 2005), found that “Passing Great Lakes fishes above Lake Allegan into the upper portions of the Kalamazoo River has the potential to re-establish spawning runs of native (lake sturgeon, walleye, whitefish, and suckers) and naturalized (Chinook salmon, coho salmon, steelhead, and brown trout) fishes, and restore self-sustaining fish populations in the river and Lake Michigan. Substantial fishery, recreational, and economic benefits could result from these spawning runs.”

Fish species in the Kalamazoo River which should be considered in fish passage alternatives include: salmonids, sturgeon, smallmouth bass, walleye, and spotted gar. Another important fish species to consider is logperch. This small fish acts as a host for endangered native mussels. Logperch carry the immature mussels up and down the river, transporting them to new habitat and connecting different genetic populations. Habitat fragmentation has been a major cause of decline for native mussels, and designing fish passage that would accommodate logperch and reconnect populations and establish new communities in recently restored habitat is a priority.

Habitat and water quality degradation have occurred due to excessive nutrient issues, unwanted algae growth, low dissolved oxygen, contaminated sediments, and the transition from running water to still-water habitat. The MDNR Kalamazoo River Assessment notes that “this segment of river has excellent gradient that could provide fish habitat in the form of pools and riffles,” and “it should be a high priority to maintain and promote more natural riparian areas in the Kalamazoo River system” (Wesley, 2005). However, the Kalamazoo River currently has fish consumption advisories between the city of Kalamazoo and Lake Allegan for no consumption due to PCB contamination.

3.3 Improve Recreational Opportunities

The Kalamazoo River Water Trail extends from Albion to Lake Michigan. Current portage conditions around Allegan City Dam are considered somewhat dangerous and infrastructure for portaging and recreation are limited upstream and downstream of the dam. Removal of the dam or partial removal with provision of kayak/canoe passage over a fish passage feature would enhance recreational accessibility and opportunities, while increasing boater safety.

Removing the dam or providing fish passage would improve recreational fishing opportunities. The Kalamazoo River Assessment also notes that in this segment “a much better fishery would be expected if the dams were removed and water quality improved,” also noting -“For example, the fish community of the Kalamazoo River between the City of Kalamazoo and Plainwell is diverse and dominated by smallmouth bass and was once over populated with carp. This transition occurred naturally after water quality improvements were made.” (Wesley, 2005)

The removal of upstream dams and removal/management of contaminated sediments in their former impoundments has opened up greater opportunity for paddling and recreation and restored upstream connectivity. Potential area plans also include a desire to consider land trails to connect communities along the river. A goal of both the MDNR and City is to increase boating access, both motorized and non-motorized access. The current portage site around the dam is the next likely opportunity for trailered boat access downstream of Trowbridge dam.

Within the city, one of the goals of the master plan has been to improve and expand recreational opportunities, waterfront access, and non-motorized trails. The alternatives below provide varying amounts of park space and differing opportunities for access and recreation.

3.4 Manage Contaminated Sediments and Waste

As noted above, the Kalamazoo River from Trowbridge Dam to Allegan City Dam makes up Area 5 of the EPA Superfund site for the Kalamazoo River/Portage Creek. Allegan City Dam has trapped contaminated sediments upstream in the impoundment and limits their downstream migration. Any removal of the dam/drawdown of the impoundment would create conditions that could lead to mobilization of contaminated sediment, or exposure of contaminated sediment on reclaimed public lands that could be exposed to public use. Even if the dam were to remain in place, some management of contaminated sediment is expected as part of the Superfund site. Ultimately the EPA-led Superfund program will drive the plans for remediation. However, all dam removal/repair alternatives need to consider the consequences for remediation, removal and disposal, or capping of contaminated sediments within the project area, and must be coordinated with EPA and EGLE. For example, several dam removals upstream have been completed in conjunction with sediment removal.

It is crucial for the City’s decision about dam removal or repair to be made prior to the completion of Superfund remediation plans, in order to coordinate remediation. If the decision is made to keep the dam in place, or to partially remove it, the City would be responsible for maintaining and replacing the dam indefinitely, as it acts as a containment structure preventing downstream movement of contaminated sediments. If the decision is made to alter the impoundment for recreational use (i.e. dredging) or redevelopment (i.e. addition of green space), or to remove the dam in the future, the City would then be responsible for properly remediating contamination associated with those activities. If the decision to remove the dam is made prior to Superfund remediation plans, the intended use of the areas will drive the remediation project extents. In other words, remediation of the restored channel, floodplain, park space, and exposed impoundment soils would become a consideration/inclusion in the Superfund clean-up project, rather than being the responsibility of the City.

4. Alternatives

This conceptual analysis will consider three alternatives – complete dam removal, partial dam removal, and dam rehabilitation/modification. All three alternatives will incorporate measures for isolation or removal of contaminated sediments.

4.1 Complete Dam Removal

The complete dam removal alternative would include removing the entirety of the dam and restoring the river to its pre-dam condition, as closely as is practicable. Under this scenario the powerhouse upper structures would be demolished, but the foundations would be kept and the lower areas filled. Additionally, we would propose construction of a stable earthen slope on the downstream side of the powerhouse to provide a natural aesthetic. The millrace would likewise be filled and used for open space or other uses depending on ownership. This scenario would include the removal and replacement of the Mill District Road bridge with on-grade roadway. Additional park space, landscaping, and a trail or overlook at the former powerhouse site could be incorporated.

The benefits include natural aquatic habitat; fish passage; no dam related operation and maintenance costs; a natural free flowing river; reclaimed bottom lands and floodplains; and abundant recreational opportunities associated with a natural river. The costs include loss of the impoundment/smaller river width; contaminated sediment disposal/exposure; and potential impacts to bridge crossings and other infrastructure. This option would have the greatest aesthetic change from the current conditions.

4.1.1 Hydrologic and Hydraulic Analyses

The Allegan City Dam is operated as a run-of-the-river dam and is not operated to provide flood storage/downstream flood mitigation. This means that inflow equals outflow on a near instantaneous basis, and that downstream flows are not decreased by the dam. Information from the city dam operator indicated that the dam is operated at maximum capacity during storm events to prevent flooding in the area immediately upstream of the dam. A 2001 spillway capacity assessment performed by Lawson-Fisher Associates (LFA 2001) found that the dam has the capacity to pass the 200-yr (14,000 cfs) event, though it would overtop portions of the right embankment. The 200-yr headwater elevation reached 631.2 ft in the spillway capacity model, a rise of 4.5 ft above the normal headwater elevation. Given the impoundment size of 135 acres, this would provide storage of approximately 0.2% of the 200-yr storm event inflow volume, indicating that the dam does not provide any significant flood attenuation. The dam has the spillway capacity (13,550 cfs without overtopping) to pass events smaller than the 200-yr event (100-yr event is 12,000 cfs) without overtopping, and is operated to pass flood flows while preventing upstream flooding.

Assuming no flood attenuation, we can also assume that downstream flood flows and water surface elevations would not change significantly with removal of the dam. Upstream of the dam, flows would remain the same, but water levels could drop as much as 8-9 ft (the normal level of head maintained by the dam) under bankfull conditions. There would also be a significant drop in upstream flood elevations post dam-removal, which would be expected to alleviate some of the flood issues along the low-lying historic district and Perrigo Plant 1 facility. Given the drop in water surface elevation and re-contouring of the channel bottom/impoundment depth, water would no longer flow through the millrace.

4.1.2 Geomorphic Assessment

Upstream of the M-89 bridge the channel likely historically had a braided pattern. The 1837 historic map shows islands and several “bayous” through this area (Figure 3). More current bathymetry (Figure 4) shows the presence of several channels through the impoundment. Final bathymetry would be dependent upon contaminated sediment management and removal as well as more detailed bathymetric and hydraulic analyses. Under all channel restoration scenarios, however, a significant area of new bottomlands would be exposed for recreation, wildlife habitat, or other opportunities. Land ownership

issues would need to be considered here as well as contaminated sediment exposure. The current alternative shows a single channel through the upper impoundment, minimizing the area of flow through contaminated sediments and volume of sediment removal.

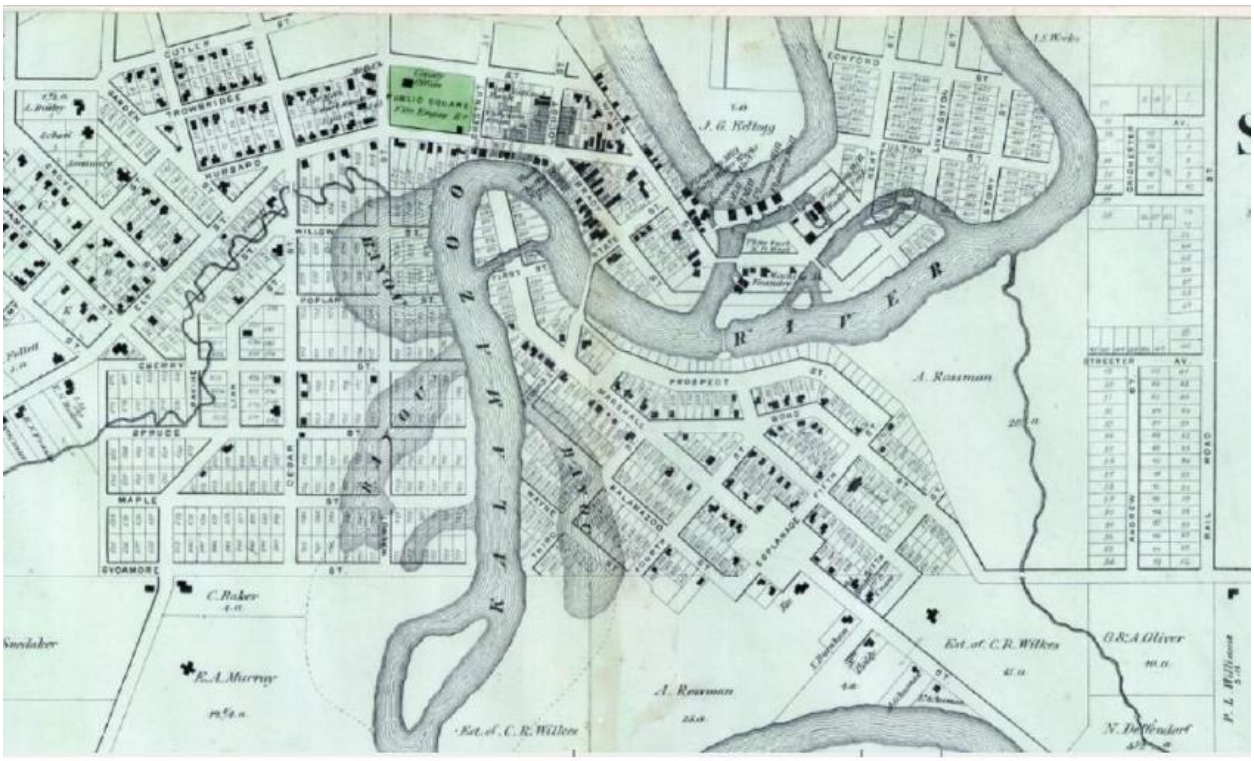

Figure 3. Historic 1873 map of Allegan City and Kalamazoo River.

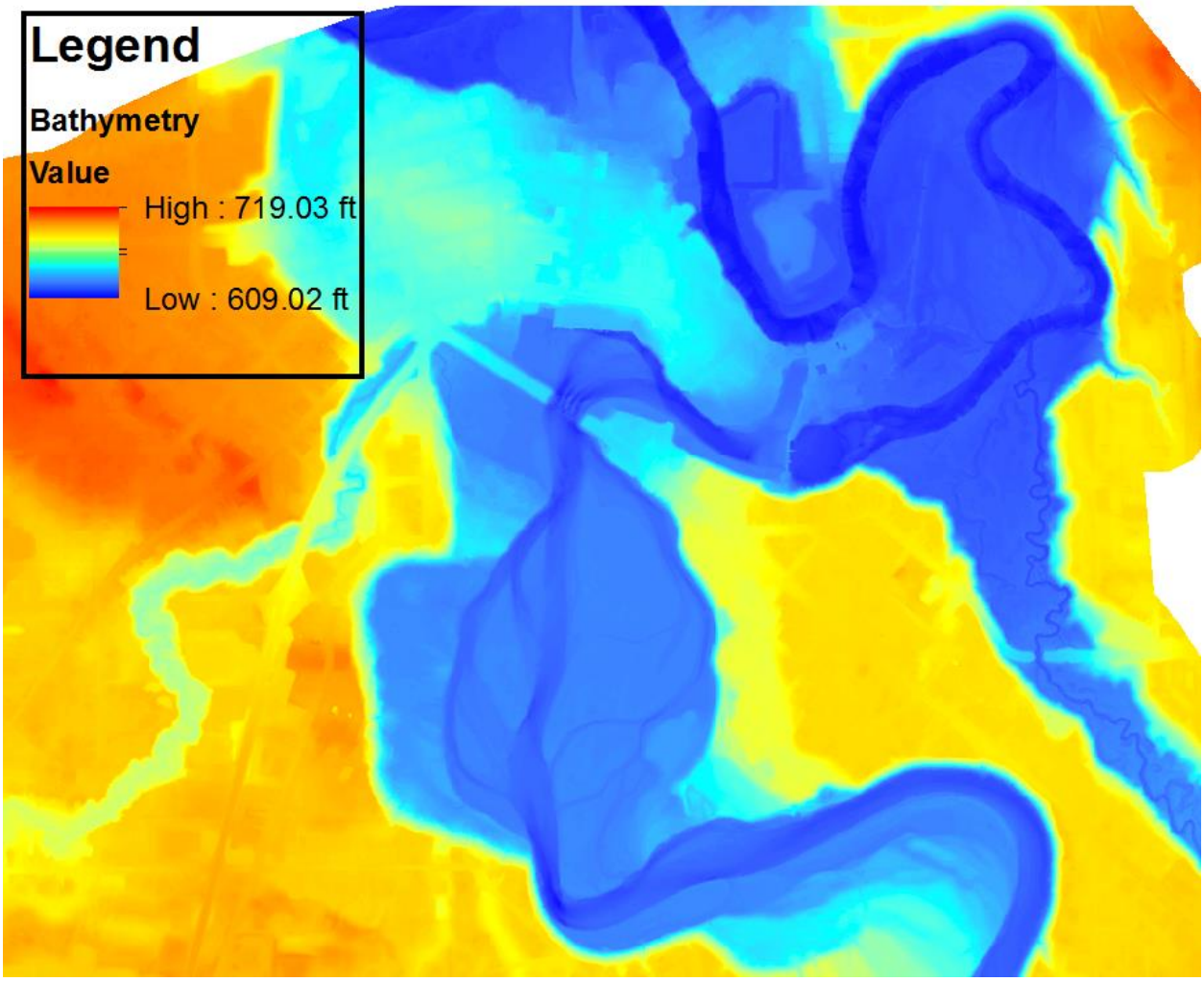

Figure 4. Bathymetry (U.S. ft) of project area. Provided by MDEQ, 2011.

The existing wetland/backwater area just upstream (south-side) of the M-89 bridge would experience a lowering of the water table and water surface elevation. However, this area appears to be fed by a separate tributary/stream source and would remain a wetland area adjacent to the channel, though its wetland type would likely change. The wetland/backwater area just downstream (north side) of the M-89 bridge, adjacent to the west end of the boardwalk and Hanson Park, does not appear to have a separate water source and would be unlikely to remain as a wetland. This area could be converted to parkland between the boardwalk and restored channel, as an extension of Hanson Park. The floating dock and canoe/kayak access at this location would need to be moved. Refer to Figure 5 and below. A full conceptual rendering is located in Appendix A.

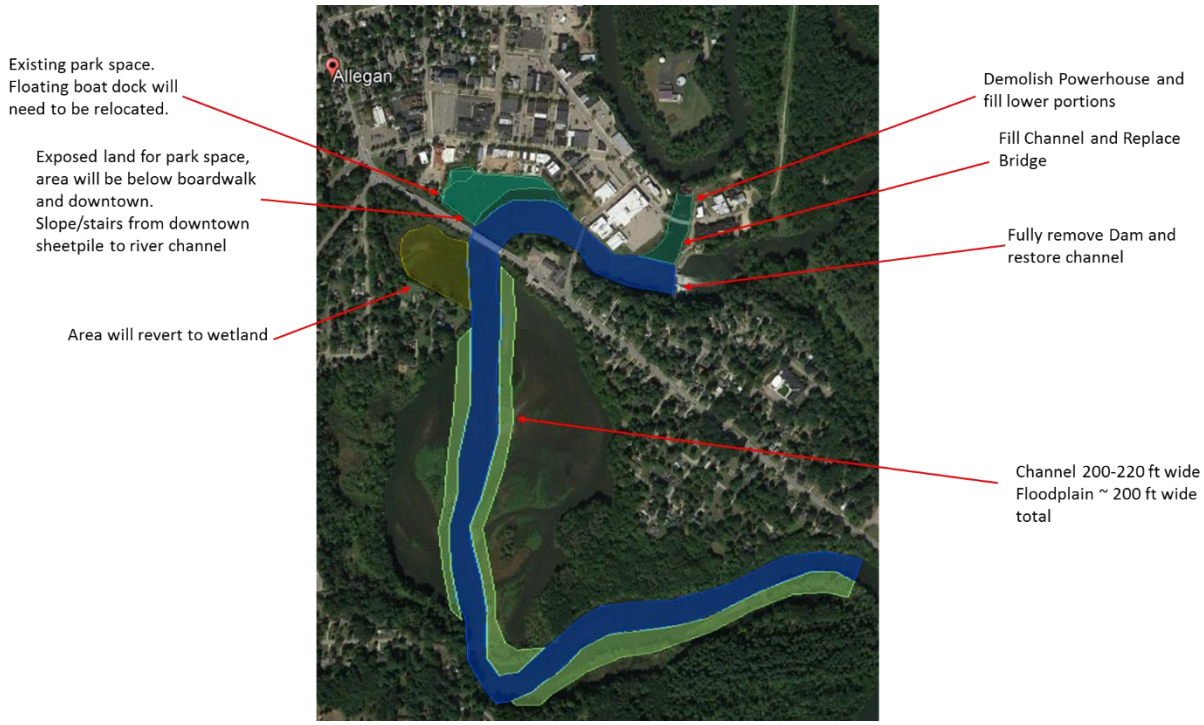

Figure 5. Site Overview for Dam Removal Alternative.

Downstream of the M-89 bridge the channel could be allowed to reestablish itself in the existing preferential flow path along the south bank (Figure 4). This configuration allows for park space along the downtown boardwalk, sloping down to the restored channel, with fill used to stabilize the sheetpile walls along this section. Structural analysis of the sheetpiling would be needed for this alternative. The floodplain and recreational space along the north bank would extend roughly to the Mahan Park area, just upstream of the Second Street bridge. Below Second Street the channel is somewhat constrained and would retain its general path through to the main spillway site, with the exception of no longer connecting to the millrace. Downstream of the dam site, channel geometry would not be expected to change significantly as downstream flows/ water surface elevations would remain largely unchanged. The removal of the dam would allow the natural movement of sediment downstream, which would have the potential to help to alleviate downstream erosion concerns. For instance, the downstream bends below Perrigo headquarters and adjacent to Grand St have seen significant expenditures to mitigate bank erosion, and erosion at these locations may be reduced by the new movement of sediment from upstream. This would depend on the sediment transport processes through the reach, and would require a detailed sediment transport/load analysis to determine downstream effects. The impacts of the selected alternative on downstream bank erosion should be considered during the design phase.

USGS and MDEQ have developed reference curves to predict what channel geometry would be expected for a river based on its region and drainage area. Table 1 shows reference curve data for the drainage area based on reference curve equations from USGS and MDEQ for Southeast Michigan, a local power curve for the Kalamazoo River provided by MDEQ, and the local power curve supplemented with AECOM data gathered for the Trowbridge, and Otsego dam removals. The table shows a range of predicted conditions for channel geometry. The USGS curve seems most consistent with downstream geometry, and is what we have based our estimates on for the conceptual design. Based on regional reference curve data for this area the restored channel would be expected to have a width of approximately 200-220 ft and a depth of approximately 4.5 ft under bankfull conditions (~4400 cfs). A floodplain of one bankfull width is included in all areas where practicable. The full channel and floodplain width would be 400-440 ft. Through the downtown riverfront area channel width could be as wide as 280 ft, with limited space for floodplain in some areas. This geometry would vary throughout the project area based on topography, sediments, gradient, and bedform (riffle, run, pool etc). This channel geometry corresponds well with the channel geometry existing upstream and downstream of the impoundment.

Table 1. Regional Reference Curve Values for Channel Geometry.

Allegan City Dam (Drainage Area = 1554 mi^2)				
Bankfull Characteristic	USGS Report (2009)	MDEQ Local Curve (Present)	Local Power Function	Local Power Function w/ AECOM Data
Width (ft)	208	350	325	243
Depth (ft)	4.87	3.27	3.08	4.26
Area (ft^2)	1007	1060	997	1038
width / depth	43	107	106	57

Proposed channel restoration would incorporate a natural channel design approach, targeting regional reference curve and reference reach geometry. The channel bed would target the pre-dam alluvium as a baseline, to the extent practicable. This would provide a natural channel substrate, uncover pre-dam habitat, remove contaminated sediments, increase channel stability, and mitigate the potential for head-cutting. Once contaminated sediment removal plans are in place, a channel profile and plan can be designed to promote a state of dynamic-equilibrium based on current bed material supply and hydrology.

4.1.3 Fish Passage and Habitat Assessment

Under a full dam removal scenario, the channel profile would be recreated to connect the channel bed upstream of the dam/impoundment with the channel bed downstream of the impoundment; with slope and bedforms similar to those expected under natural, free flowing conditions. Water quality would improve with increased velocity and dissolved oxygen, reduced sedimentation, reduced nutrient levels and a reduction in eutrophication. Habitat would increase for native running-water fishes, with reduced fine sediments, increased bed gradient and increased bedform diversity. Woody debris and riffle/pool patterns would also be restored in the relic channel and could be enhanced with engineered structures for increased habitat value. Removal of contaminated sediment would contribute to improved fish health and recreational opportunities. Improved fish passage would also serve to restore connectivity to native mussel populations and other aquatic species. In addition, mussel beds in the impoundment which have been buried in sediment would be uncovered and returned to running-water habitat. The Kalamazoo River has known occurrences of state threatened and endangered mussels, and the project area would have the potential for propagation and stocking efforts in the future.

Removal of the dam would provide fish passage into the upper reaches of the Kalamazoo River and the newly reconnected reaches from upstream dam removals. As noted, if Allegan City Dam were removed, only one dam would remain between Allegan and Lake Michigan. Providing fish passage or dam removal at Allegan City dam could provide additional influence for adding fish passage at Calkins Dam, which would mean passage would be provided all the way to Lake Michigan. A full dam removal would provide the greatest fish and aquatic species passage opportunity for the widest range of species, and the greatest increase in running-water habitat. Removal of the dam would open up approximately nine river miles upstream to Trowbridge Dam (which is under plans for removal). Coarse estimates of channel velocities show a range of velocities along the length of the channel, as well as across channel cross-sections throughout the project area. Velocities range from 0.25 ft/s to 4.56 ft/s under bankfull flow

conditions. Higher velocities correspond to the narrower/more channelized sections of the river. High velocities can be mitigated by providing boulders, woody debris, and bedforms to create velocity gradients and low velocity areas that allow fish with lesser swimming abilities to pass under a variety of flow conditions. See Table 2 for experimental swimming speeds of a variety of fish species. More detailed hydraulic analysis would be need to be completed once an alternative is selected.

Table 2. Experimental Swimming Speeds for Fish Species.

Scientific Name	Common Name	Swim Category	Min Swim Speed	Max Swim Speed	Swim Speed	Speed Units
Esox lucius	Northern pike	Prolonged	0.62	1.56	Calculated	ft/s
Micropterus dolomieui	Smallmouth bass	Prolonged	1.64	3.87	Calculated	ft/s
Micropterus salmoides	Largemouth bass	Prolonged	NR	NR	1.31	ft/s
Oncorhynchus mykiss	Rainbow trout	Prolonged	1.55	2.73	2.18	ft/s
Oncorhynchus mykiss	Steelhead	Prolonged	2.73	3.21	2.99	ft/s
Oncorhynchus tshawytscha	Chinook salmon	Prolonged	4.10	6.43	5.08	ft/s
Salmo trutta	Brown trout	Prolonged	NR	NR	3.02	ft/s
Sander vitreus	Walleye	Prolonged	0.98	2.20	1.59	ft/s
Target for Logperch and small fish		Prolonged			1.00	ft/s
Oncorhynchus mykiss	Steelhead	Burst	14.01	26.97	20.34	ft/s
Sander vitreus	Walleye	Burst	5.25	8.53	Calculated	ft/s
Oncorhynchus tshawytscha	Chinook salmon	Burst	10.99	22.00	14.00	ft/s
Target for Logperch and small fish					3.00	ft/s

* data from table provided by Matt Diana, MDNR Fisheries

4.1.4 Sediment Assessment

Full dam removal would involve a significant amount of earthwork and sediment management/disposal. More stringent management/containment measures may be required in those areas where sediments would be exposed to potential contact with the public, such as in newly established recreation areas. However, future liability and exposure risk would both be reduced under this alternative. The full dam removal would result in transitioning the "sediment" to "soils" by drawing down the water level and uncovering it. The soils would then be remediated to the appropriate regulatory level, which will result in protecting the aquatic environment, the most likely exposure pathway to humans. Contaminated sediment remediation would be guided, and carried out by EGLE, EPA Superfund planning. The cost of sediment remediation would fall to Superfund, rather than the City.

The 135-acre impoundment has soft sediment deposits varying in thickness from less than one foot to more than 13 feet, according to Superfund sampling and analysis carried out by Wood Environment and Infrastructure Solutions, Inc in April and October 2017. Figure 6 shows sediment sampling points and estimated thickness within the impoundment. Figure 7 shows areas of higher PCB concentrations within the project area. Investigation of sediment quality, depth and contamination levels is ongoing through Superfund. Remedial action levels vary by area and use criteria. The depth of contamination also influences remedial actions. As alternatives are discussed and further developed, more detailed estimates of sediment remediation volumes can be determined.

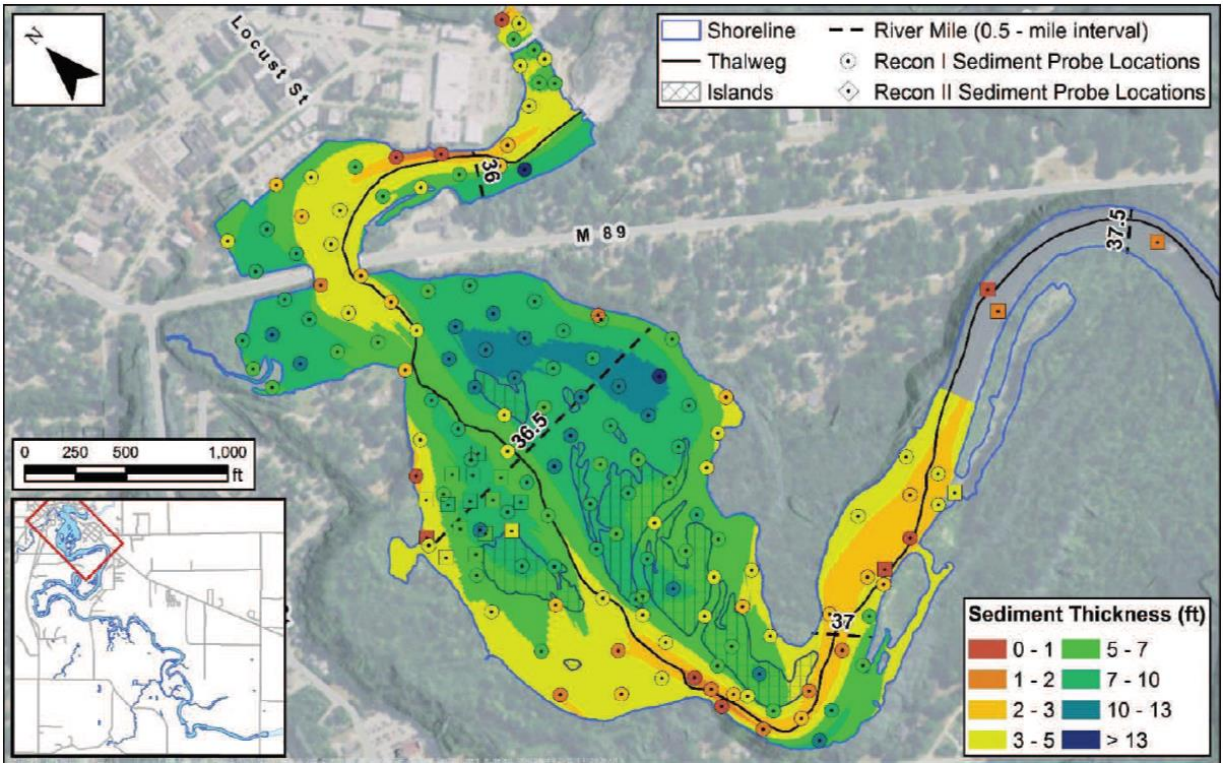

Figure 6. Estimated Sediment Thickness within Allegan City Dam impoundment (Wood, 2018).

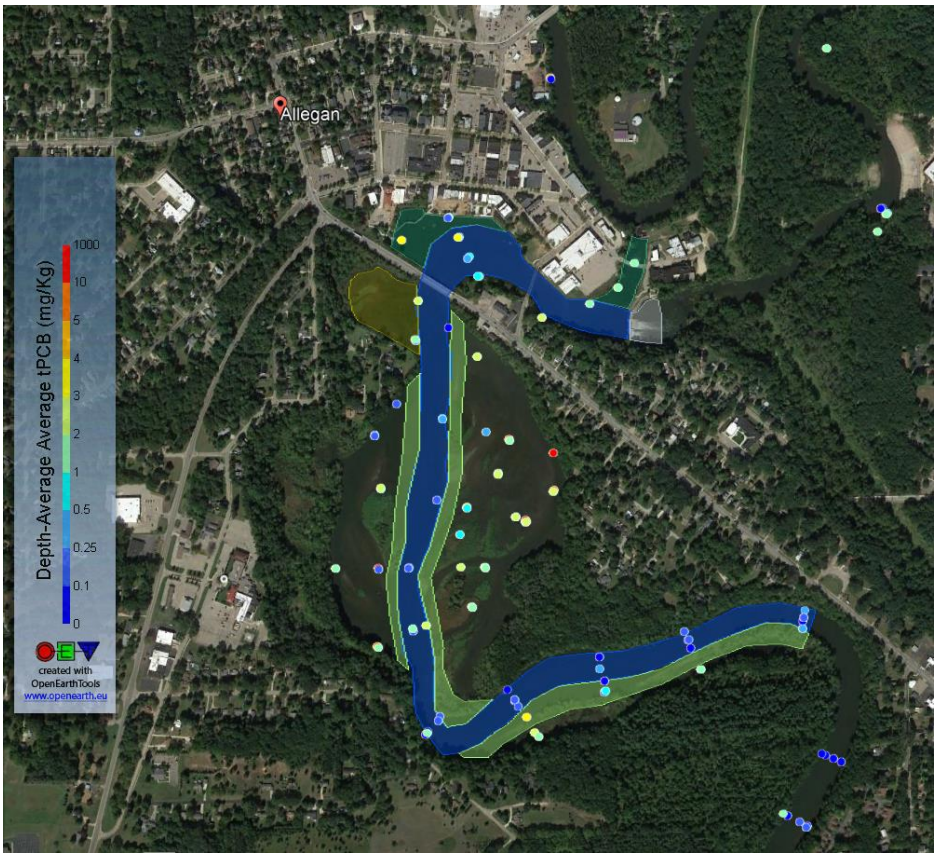

Figure 7. PCB Concentrations at Sediment Sampling Points in the Project Area.

Sediment management volumes would vary depending on channel restoration alternatives. Currently, a single thread, main channel with a floodplain totaling one bankfull channel width is considered. This would require an estimated 300,000 cubic yards of sediment removal/dredging for the channel and floodplain.

4.1.5 Goals Assessment

Dam removal and drawdown of the impoundment could provide for additional park space and non-motorized trails along the river. Such trails could provide connectivity to communities upstream, such as Plainwell, or to other recreational areas nearby. These options would be in line with city and county goals for recreation and development. Increased open space along the downtown area and restored channel could enhance downtown outdoor opportunities and ambience, and be in line with the City's historic and outdoor/nature oriented character. Removal of the dam would also increase boater safety, access, and paddling opportunities which are currently hindered by the presence of the dam and difficult portage. Large areas of reclaimed lands in the upper impoundment would provide the greatest increase in space for recreation and habitat of all the alternatives. Refer to Figure 5 and the full dam removal graphic in Appendix A.

Dam removal would provide the highest level of fish and aquatic organism passage, re-creating conditions naturally found elsewhere along the river and removing all barriers to migration in the project area. Under these conditions, most native and desirable introduced species would be able to pass upstream and downstream. This removal of barriers and restoration of running-water conditions, bedform diversity, and habitat would provide the greatest enhancement to fishery and aquatic organism populations and health. This, in turn, would provide the greatest increase to fisheries recreation and related economic returns. Under dam removal scenarios, the greatest volume of contaminated sediment would be removed or excluded from the channel, further enhancing aquatic ecosystem health.

Full dam removal would involve the greatest amount of earthwork and sediment management/disposal. As such it would have the highest total cost associated with these restoration activities. However, sediment management costs would be borne by the Superfund project. Ongoing exposure and future liability concerns for the City from contaminated sediments would be minimized under this alternative, and at the cost of Superfund/EGLE rather than the City.

The condemned powerhouse and associated risk of failure/liability would be resolved, and dam maintenance and repair costs would be eliminated in the future. Upstream flooding would be mitigated. However, dam removal also represents the greatest change in aesthetics to the downtown area. Detailed hydraulic and scour analyses of the M-89 bridge would be required as well as scour protection measures such as riprap. The 2nd Street bridge is a clear span bridge, with abutments outside of the current channel, but within the floodplain. Investigation of the foundation and more detailed hydraulic and scour analyses would also need to be done to ensure no detrimental effects to the 2nd Street bridge supports. The Mill District Road bridge would be replaced and the millrace filled. This alternative represents both great opportunities and great challenges for significantly reimagining the downtown riverfront area.

The full dam removal alternative would have the greatest availability of grant funding. It would also have the greatest support from MDNR and hence the greatest likelihood to see funding assistance from MDNR. As noted, EPA/Superfund/PRP's would be responsible for sediment remediation planning and costs. The cost of the powerhouse and millrace fill, and the removal of the main spillway dam would be costs to the city, and any grant funding obtained. The overall cost directly to the City could potentially be lowest under this alternative. The long-term maintenance costs to the city would be minimized or eliminated for this alternative.

4.2 Partial Dam Removal

The partial dam removal alternative would reduce the height of the dam, remove above-water appurtenances, and create an area of rapids that would be navigable by small crafts under a range of flow conditions, and accommodate volitional passage of desirable aquatic species. This option would

allow for some of the sediments to stay in place and keep the river wider and deeper, with a lower gradient, than under the complete dam removal alternative.

The possibility was also considered for creating a whitewater feature through the former powerhouse and millrace. While the general channel size and vertical drop might be sufficient for the provision of such a feature, issues concerning fish passage and splitting the river's flow make this option infeasible. During summer months, when such a feature would be used, summer flows are frequently too low to provide flow through both channels, or flow that would be sufficient for a whitewater feature. The high velocities coming from a whitewater millrace would also attract fish to an impassable feature. As such, the partial dam removal alternative would include the demolition and filling of the former powerhouse, as in the full removal alternative, with filling of the millrace and replacement of the Mill District Road bridge. The filling of this area will provide increased protection from flood flows which could cut through the millrace and create a potential breach. A potential alternative, instead of filling the millrace, could be to create a wetland complex within the millrace, or maintain it as a slackwater area/pond, and keep the bridge in place. This alternative would require additional geotechnical and hydraulic analysis to ensure the integrity of the filled powerhouse foundation. Additional park space, landscaping, and a trail or overlook at the former powerhouse site could be incorporated.

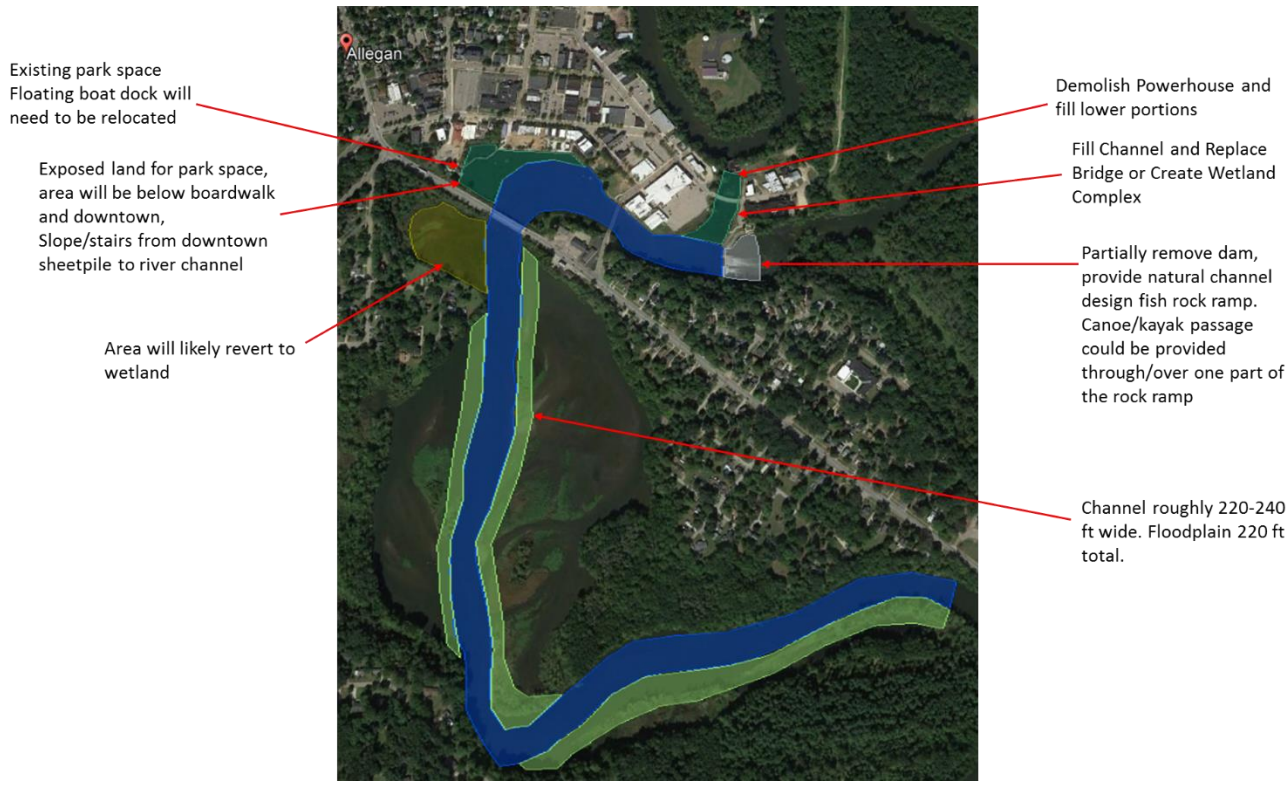

Figure 8. Site Overview for Partial Dam Removal Alternative.

4.2.1 Hydrologic and Hydraulic Analyses

Removal of the above-surface portions of the dam, down to the concrete sill at approximate elevation 620 ft, would drop the water level in the impoundment by 4-5 ft. This drop could be greater given sediment dredging/channel reconfiguration efforts that would deepen the channel.

As with the full dam removal scenario there would also be a significant, though lesser, reduction in upstream flood elevations, which would be expected to alleviate some of the flood issues along the low-lying historic district and Perrigo Plant 1 facility. Given the drop in water surface elevation and re-contouring of the channel bottom/impoundment depth, water would no longer flow through the millrace, unless it were also recontoured/dredged to a lower elevation and maintained as a slackwater area. The

water would be high enough under this scenario to design and maintain the millrace as a wetland complex, if desired.

In order to provide fish passage, a rock ramp feature would be incorporated downstream of the dam sill (Figure 9), stepping down the channel at a 3% or shallower gradient, extending roughly 200 ft downstream to tie-in to the existing streambed. There is some additional space to extend the rock ramp if a shallower gradient were desired, but there are downstream limits from channel bends and islands.

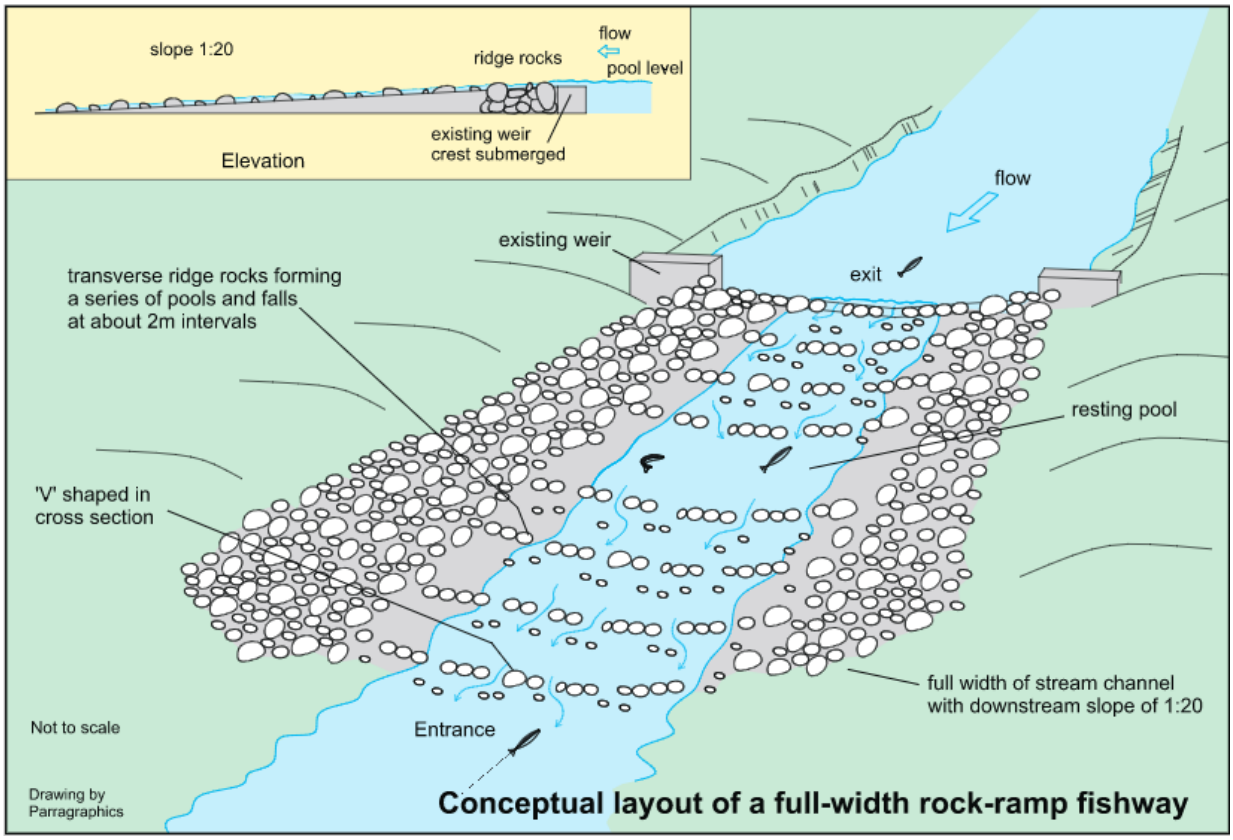

Figure 9. Conceptual depiction of full-width rock ramp for fish passage (Thorncraft and Harris, 2000).

4.2.2 Geomorphic Assessment

Channel/impoundment changes for the partial dam removal would be similar to those for full dam removal. However, the width of the channel through the downtown area of the impoundment would be wider, ~375 ft rather than ~280 ft. The newly exposed park space adjacent to Hanson Park would be smaller. The main channel and floodplain through the upper impoundment would also be wider, 240-280 ft channel width, and deeper, with ~240-260 ft total floodplain width.

A considerable, though lesser, area (approximately 15 fewer acres) in the upper impoundment would be exposed and available for habitat, recreational, or other use. The existing wetland/backwater area just upstream of the north side of the M-89 bridge would remain a wetland area, as in the full dam removal scenario. This configuration would also allow for park space along the downtown boardwalk, sloping down to the restored channel, with fill used to stabilize the sheetpile walls along this section. Structural analysis of the sheetpiling would be needed for this alternative. Below Second Street the channel is somewhat constrained and would retain its general path through to the main spillway site, with the exception of no longer connecting to the millrace. Downstream of the dam site, channel geometry would not be expected to change significantly as downstream flows/ water surface elevations would remain largely unchanged.

As with the full dam removal the proposed channel restoration would incorporate a natural channel design approach. Bedform diversity and woody debris would be incorporated for habitat purposes and bed stability. Some excavation of the channel bed would be needed, but due to the higher elevation at the dam and the shallower gradient, the channel would not reach down to pre-dam alluvium. Once contaminated sediment removal plans are in place, we can then design a channel profile and plan to be in a state of quasi-equilibrium based on current bed material supply and hydrology.

4.2.3 Fish Passage and Habitat Assessment

Habitat changes would be similar to those with the full dam removal alternative. Considerable running-water habitat would be created in the upper impoundment, and opportunities would exist to incorporate natural channel treatments along some portions of the banks in the downtown impoundment area. Fish passage would be provided via a full-channel width rock ramp. By mimicking natural channel design and using boulders to create resting pools and velocity gradients, many targeted species should be able to achieve passage over the remaining dam. How effective a fish passage is depends on the design, flows, site conditions, and species involved. Effectiveness and passage in any given year also depends on flow and site conditions aligning with spawning run times and preferences. More detailed analysis and coordination with the MDNR would be required for this alternative.

Coarse estimates of channel velocities show a range of velocities along the length of the channel, as well as across channel cross-sections throughout the project area. Velocities range from 0.25 ft/s to 3.44 ft/s under bankfull flow conditions. Higher velocities correspond to the narrower/more channelized sections of the river. Over the rock ramp velocities range from 1.0 ft/s – 3.0 ft/s. High velocities can be mitigated by providing boulders, woody debris, and bedforms to create velocity gradients and low velocity areas.

4.2.4 Sediment Assessment

As with full dam removal a significant amount of earthwork and sediment management/disposal would be involved in this alternative. More stringent management/containment measures may be required in those areas where sediments would be exposed to potential contact with the public, such as in newly established recreation areas. However, future liability and exposure risk to the city would both be reduced under this alternative, although not as much as under full removal. Contaminated sediment remediation would be guided by EGLE, EPA Superfund planning

Once remediation plans are made and carried out by EGLE/EPA Superfind, the City would then inherit the remaining sediment condition. If the decision is made to keep a partial dam in place, the City would be responsible for maintaining and replacing that structure indefinitely, as it acts as a containment structure preventing downstream movement of contaminated sediments, or be responsible for remediating the remaining contamination in the future. In addition, the dam would continue to accumulate some sediments behind it, causing the impoundment to become shallower and weedier over time. If the decision is made to alter the impoundment for recreational use (i.e. dredging) or redevelopment (i.e. addition of green space), or to remove the dam in the future, the City would then be responsible for properly remediating contamination associated with those activities.

Considering a single thread main channel and floodplain equivalent to one bankfull width, sediment removal for the channel and floodplain would be approximately 161,000 cubic yards for this alternative.

4.2.5 Goals Assessment

By partially removing the dam, a higher water surface elevation and larger impoundment can be maintained in the downtown waterfront area than with a full dam removal. At the same time, new recreational, trail, and habitat areas can be incorporated along the millrace, Hanson Park and riverfront area, and the upper impoundment. The 2nd Street bridge is a clear span bridge, with abutments outside of the current channel, but within the floodplain. Investigation of the foundation and more detailed hydraulic and scour analyses would also need to be done to ensure no detrimental effects to the 2nd Street bridge supports.

Some shift from slack-water to running-water habitat would be expected in the project area, with accompanying boost in habitat value for running-water game-fish and other aquatic/riverine species. Fish passage would be provided by a full-channel width, natural-type rock ramp, however, fish passage would be less efficient than with a full dam removal – which would be more likely to allow passage for all native species. Boater accessibility and safety through the rock ramp would need to be addressed, however, boater access would be improved by providing passage through the rock ramp, over the dam. As such, partial dam removal would have a middle range value for fish passage and fishery recreation/economic enhancement. A smaller area of land would be exposed for trails, habitat, and recreation than with a full removal. Running-water habitat would also be less. The remaining dam sill would contain/accumulate some amount of sediment and the channel/impoundment would likely become shallower and slower over time.

Safety concerns would be addressed by filling-in and demolishing the powerhouse and removing the above-surface portions of the main spillway, making catwalk replacement and gate maintenance unnecessary. Dam operation/maintenance costs would be reduced or eliminated, though some maintenance and debris removal of the remaining dam sill and rock ramp would be required. The City would need to maintain and possibly replace the remaining dam in time, as it acts as a contaminated sediment containment structure. The millrace could be filled and used for park space, or potentially converted to a wetland complex.

Considerable earthwork and sediment removal/management would be required. The channel and floodplain dimensions would be wider. Sediment would not be removed down to pre-dam alluvium, and a greater extent of slope and channel stability measures would be needed. Water quality would be expected to improve, along with aquatic ecosystem health with the removal of contaminated sediments from the restored channel and floodplain. However, contaminant removal and ecosystem improvement would be less than under a full dam removal. As with the full dam removal, considerable aesthetic changes would occur in the downtown area and upper impoundment.

4.3 Dam Rehabilitation or Modification

The dam rehabilitation or modification alternative would keep the dam in place and modify the existing structure to reduce maintenance costs and reduce risk of failure (See Figure 10). There would be no changes to the river level or physical configuration and the river would look the same from the renovated river front area. Contaminated sediments would be capped or otherwise managed in accordance with Superfund remediation plans. Fish passage would be provided via a fish ladder on the northern bank.

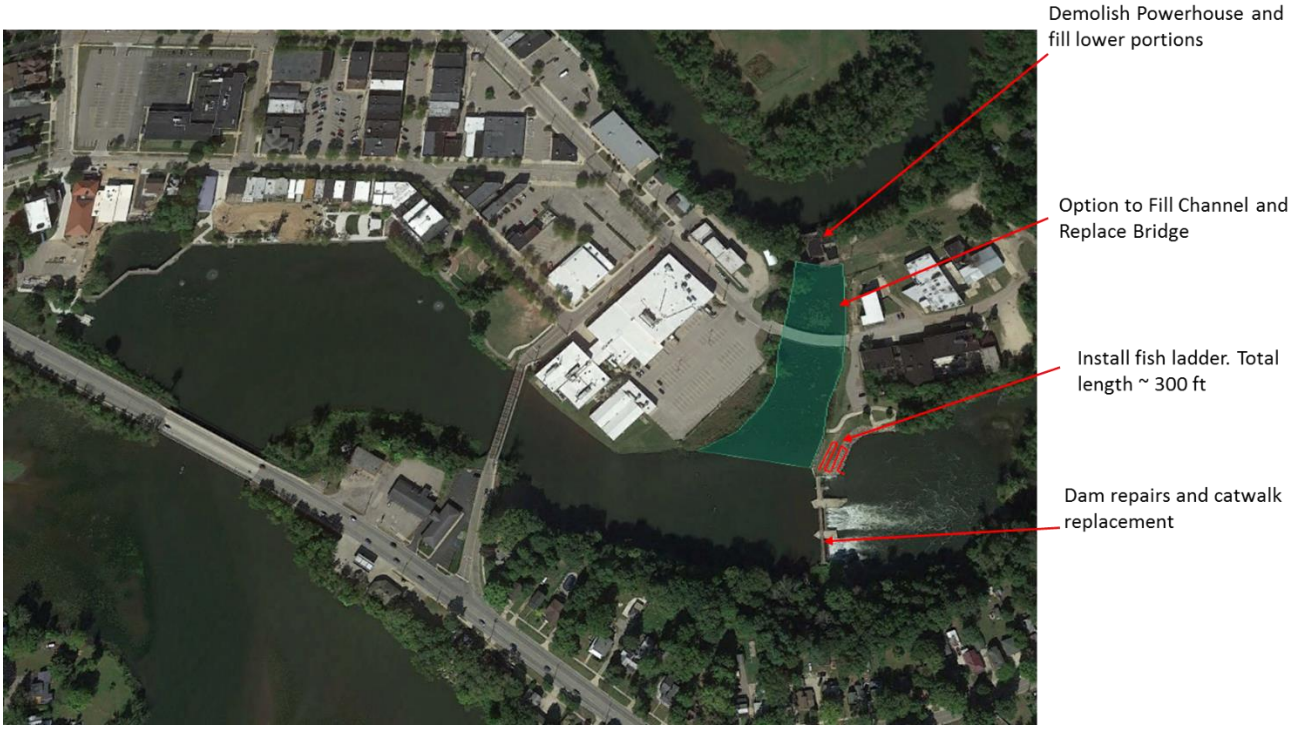

Figure 10. Site Overview for Dam Repair/Maintenance Alternative.

4.3.1 Recommended Repairs/Modifications

The Michigan Department of Environmental Quality (MDEQ), Water Resources Division, Hydrologic Studies and Dam Safety Unit, released a Dam Safety Inspection Report for the Allegan City Dam on December 10, 2017 (MDEQ, 2017). The report summarizes the results of an inspection performed on September 19, 2017.

The report recommends repair or replacement of the existing catwalk which spans across Spillway Bay #1 and Spillway Bay #2. Currently, this catwalk is considered unsafe and access is prevented.

A report by Lawson-Fisher Associates (LFA), dated June 30, 2017, makes the same recommendation (LFA, 2017). In addition, LFA noted minor repairs to concrete abutments are required, and a steel guardrail should be installed on the stop log access catwalk which spans across Spillway #2.

A set of plans developed by LFA, dated July, 2001, shows proposed improvements to Spillway #1 and Spillway #2. These improvements allow for the installation and removal of stop gates at the two spillways. The improvements were completed for Spillway #2 (the aforementioned stop log access catwalk was part of these improvements), but not for Spillway #1.

Instead of replacing the existing catwalk across the two spillways, AECOM recommends implementing the improvements designed by LFA at Spillway #1, with the exception of providing a guardrail on both sides of the catwalk, instead of one as shown on the LFA plans. We further recommend a second guardrail be installed on the stop log access catwalk which spans across Spillway #2. Adding a catwalk across Spillway #1 will allow for the removal of the existing catwalk which is currently inaccessible. We do not recommend replacing this catwalk. Another advantage to installing a catwalk across Spillway #1 in accordance with the LFA plans is that it will allow for the installation and removal of stop gates at that spillway.

We estimate the cost of constructing these improvements will be approximately $50,000. This cost does not include the cost for constructing additional stop gates, nor does it include any engineering fees which may be required.

The 2017 dam inspection report also notes the need to repair, replace, or remove the abandoned powerhouse. A February 3, 2016 Powerhouse Removal Study performed by LFA provided several removal options and cost estimates. Similar to AECOM's recommendation, one option in the report was to keep the existing foundations of both powerhouse sections, remove the upper structure, and fill the entire lower area with cement-based material (LFA, 2016). We concur that this option would be the most cost-effective way to address the safety concerns at the powerhouse and to provide a long-term solution to preventing failure/release of impounded water and sediment through the millrace. Additionally, we would propose construction of a stable earthen slope on the downstream side of the powerhouse to provide a natural aesthetic. Filling the remainder of the millrace and replacing the bridge with on-grade roadway also reduces the risk of a cut-off channel forming through the millrace at high flows. A cut-off channel would breach into the downstream river and potentially release contaminated sediment, while flooding the adjacent low-lying areas of the mill district.

Another alternative could include removing all of the components of the powerhouse and substructure and replacing it with an earthen dam. This would be significantly more expensive and poses significant constructability issues with managing surface and ground water. If this option were pursued, additional geotechnical investigation would be required to determine need for foundation improvements and seepage mitigation. While cost-effectiveness is a concern, other goals and values such as recreational, aesthetic, and ecological concerns could also be incorporated into other alternatives for stabilization and restoration of this area, such as trails, landscaping, and/or an overlook above the river.

4.3.2 Hydrologic and Hydraulic Analyses

No significant changes would be made to the structure or height of the dam. No changes in hydraulics would be expected with the dam repair/maintenance alternative. Water surface elevations throughout the impoundment and downtown area would remain the same, as would downstream flows and tailwater elevations. A portion of the flow would be diverted through the fish passage. Upstream flooding issues would be expected to remain the same.

4.3.3 Geomorphic Assessment

No significant changes to geomorphology would be incorporated in this alternative. The appearance and water levels through the downtown area and upper impoundments would remain as existing. Filling in the powerhouse would provide a permanent barrier to flow through the millrace.

4.3.4 Fish Passage and Habitat Analysis

With the dam remaining in place, provisions would need to be made for fish passage around the dam. A rock ramp up to one of the bays of the dam was considered. However, space is limited below the dam by channel bathymetry, sinuousity, and the presence of downstream islands. In addition, the dam embankment already overtops at the 200-yr design flow, while operating at maximum capacity. Passage would need to be provided without reducing spillway capacity. A fish-ladder on the northern embankment is proposed to allow provisional fish passage around the dam.

Fish ladders in Michigan are observed to pass many species including: coho salmon, chinook salmon, steelhead, suckers, brook trout, brown trout, channel catfish, smallmouth bass, carp, and walleye. Fish with lesser swimming/jumping capabilities such as sturgeon and logperch would be unlikely to pass through the fish ladder. How effective a fish passage is depends on the design, flows, site conditions, and species involved. More detailed analysis and coordination with the MDNR would be required for this alternative.

With the dam and impoundment in place, habitat would remain unchanged as slack-water habitat. While connectivity to restored upper reaches would be provided, habitat value within the project area would not be enhanced, and the impoundment would have limited value for running-water game fish.

4.3.5 Sediment Assessment

No immediate dredging/ channel modification or restoration work would be included for the dam repair/maintenance option. Long-term sediment management would be required, as at all dams, which retain sediment. Contaminated sediment remediation would be guided by EGLE, EPA Superfund planning. Sediment in the impoundment will likely be considered to be capped if it is buried under clean sediment, so very little of the impoundment may be remediated. In addition, the dam would continue to accumulate sediments behind it, causing the impoundment to become shallower and weedier over time. The City would be responsible for maintaining and replacing the dam indefinitely, as it acts as a containment structure preventing downstream movement of contaminated sediments. If the decision is made to alter the impoundment for recreational use (i.e. dredging) or redevelopment (i.e. addition of green space), or to remove the dam in the future, the City would then be responsible for properly remediating contamination associated with those activities.

4.3.6 Goals Assessment

The dam repair/maintenance option would address the safety concerns at the dam by filling the abandoned powerhouse lower portions and removing the upper portions, and addressing the decaying catwalk and limited access to the right embankment. Upstream flood levels would not be mitigated.

A fish ladder/weir on the left embankment would provide passage to some, though not all, species of fish between Lake Allegan and the restored reaches above Allegan where three dams have recently been removed. If fish passage were provided at Calkins Dam, then provisional connectivity would be restored all the way to Lake Michigan. Since the impoundment would remain unchanged, and no channel/running-water habitat would be restored in the project area, this alternative would provide the smallest benefit to fish populations and habitat, and associated economic and recreational opportunities. The fish ladder could act as a local point of interest during spawning runs, however, it’s location on the left bank may further inconvenience portaging for boaters.

This alternative would not enhance boater accessibility or passage around/over the dam. No additional park/recreational areas or trails would be created.

No immediate sediment removal/management would be required, this alternative would have the lowest sediment management cost. Sediment management and remediation would be determined by EPA Superfund, state, and city coordination.

Ongoing maintenance costs and liability concerns with the main spillway of the dam and impounded sediments would remain.

5. Cost Estimates

Conceptual cost estimates were developed for each of the three alternatives based on the available data and proposed channel and floodplain geometry. These early estimates have an expected accuracy range of -30% to +50%. This level of contingency is common at this conceptual evaluation stage. These conceptual costs include estimates for permitting, design engineering, and construction management and oversight. However, these costs are only estimated as a percent of the total construction cost.

The operation and maintenance costs over a 100 year life cycle were also estimated for each alternative. These are provided in the table both in total dollars and converted to net present value for comparison (with 3% interest rate). The dam maintenance and partial dam removal alternatives include the cost of complete replacement of the dam, or remaining dam structure, in the estimates. Often complete

replacement is not necessary, but rather ongoing maintenance and periodic rehabilitation of portions of the structure or appurtenances. However, as the dam would act as a contaminated sediment containment structure indefinitely, complete replacement costs were included as a conservative estimate of what could be needed in the long-term. Table 3 below summarizes the conceptual cost estimates for each alternative discussed in the report above.

Cost estimates are also shown with the sediment management cost removed, as this cost would mainly or entirely fall to Superfund/EGLE and not to the City. Operation and maintenance costs and net present value calculations do not include sediment management, these represent costs expected to fall to the City. Potential grant funding is not taken into account in these estimates.

Detailed conceptual cost estimates are provided in Appendix B. Renderings of conceptual design alternatives, along with detailed cost estimates for park space improvements can be found in Appendix A.

Table 3. Conceptual Cost Estimates.

Estimated Construction Cost	**Dam Repair**	**Partial Removal**	**Full Removal**
Spillway Modifications	$ 1,035,372.35		
Powerhouse Demolition and Head Race Fill	$ 1,028,397.41	$ 1,028,397.41	$ 1,028,397.41
Partial Dam Removal		$ 3,069,852.22	
Full Dam Removal			$ 1,506,103.56
Channel Restoration		$ 3,436,304.40	$ 3,048,090.00
Sediment Management		$ 10,222,000.00	$ 19,107,000.00
Contingencies	$ 1,238,261.85	$ 11,272,412.42	$ 14,813,754.58
Estimated Park Development Cost	$ 256,920.00	$ 1,030,800.00	$ 2,512,200.00
Total Cost with Contingencies	**$ 3,713,103.61**	**$ 30,059,766.45**	**$ 43,522,865.54**
Total Cost without Sediment Mgmt Cost	**$ 3,713,103.61**	**$ 13,704,566.45**	**$ 12,951,665.54**
Total O&M Cost Over 100-yrs	$ 28,925,991.64	$ 5,463,516.37	$ 315,187.50
Net Present Value O&M Cost (100-yr)	$ 6,906,534.31	$ 1,407,235.42	$ 288,693.29
Net Present Value Construction and O&M	**$ 10,310,328.08**	**$ 14,671,652.30**	**$ 12,854,717.31**

	Dam Repair would not be supported by MDNR and associated grants	Partial Removal would not be supported by MDNR and associated grants	Full Removal Costs will be eligible for grant funding from MDNR and other state and federal grant programs, lowering the actual cost to the City
Estimated Cost to the City	**Dam Repair**	**Partial Removal**	**Full Removal**
Spillway Modifications	$ 1,035,372.35		
Powerhouse Demolition and Head Race Fill	$ 1,028,397.41	$ 1,028,397.41	$ 1,028,397.41
Partial Dam Removal		$ 3,069,852.22	
Full Dam Removal			$ 1,506,103.56
Estimated Park Development Cost	$ 256,920.00	$ 1,030,800.00	$ 2,512,200.00
Contingencies, Permitting, Engineering, Admin	$ 1,392,413.85	$ 3,077,429.78	$ 3,028,020.58
Total Cost with Contingencies	**$ 3,713,103.61**	**$ 8,206,479.41**	**$ 8,074,721.54**
Total O&M Cost Over 100-yrs	**$ 28,925,991.64**	**$ 5,463,516.37**	**$ 315,187.50**
Total Construction and O&M Cost over 100-yrs	**$ 32,639,095.25**	**$ 13,669,995.78**	**$ 8,389,909.04**

6. Goals Matrix

A brief summary of the project goals/concerns and how they are met for each of the three alternatives is presented in

Table 4 below. Categories are color-coded as follows: red: no change or negative impact; yellow: some improvement; green: most improvement.

Table 4. Matrix of Project Goals and Alternatives

	Dam Repair and Maintenance	Partial Dam Removal	Full Dam Removal
Dam Safety	Safety addressed, but long-term risks remain	Long-term risk significantly reduced, but sediment containment and dam risks remain	Dam removed, no long term maintenance or liability
Flood Management	Flood issues upstream and erosion issue downstream remain unchanged	Flood levels upstream are lowered	Flood levels upstream are lowered, sediment transport can occur downstream to alleviate some erosion
Maintenance Cost	Dam costs remain, additional cost to implement fish ladder	Some work to maintain rock ramp, boat passage,	No dam or fish passage maintenance costs
Improved Recreation Opportunities	Least change to current condition	Increased boat passage , habitat, open space	Largest increase in boater access, habitat, and open space
Improved Fish Passage	Fish ladder provides passage to some fish	Rock ramp provides passage to numerous fish species	Restored channel approaches natural conditions, provides best conditions for passage for greatest number of species
Improved Fish Habitat	No change from current condition	Some increase in running-water habitat	Significant increase in running-water habitat
Contaminated Sediment Mgmt	Sediment likely to be capped in place, lesser amount removed, becomes responsibility of the City	Medium amount of sediment to manage/dispose of, however, it is removed from project site/ecosystem	Largest amount of sediment to manage/dispose of, however, it is removed from project site/ecosystem
Construction Cost Estimate	$3,302,031.61	$28,410,486.45	$39,503,345.54
Construction Cost without Sediment Remediation Cost	$3,302,031.61	$12,055,286.45	$8,932,145.54
Long Term Operation and Maintance Cost Estimates	$3,492,441.51	$748,633.51	$288,693.29
Potential Funding	MDNR/EGLE/NRD will not assist with cost of repairs/maintenance for existing structure. Fish ladder assistance from MDNR is also uncertain. Sediment capping/remediation would be carried out by EGLE/EPA.	May be able to find grants to support some portions of the partial removal, such as the rock ramp for fish passage. Sediment remediation would be carried out by EGLE/EPA.	Full removal will have the most opportunity for obtaining grants. MDNR would likely assist with full removal and restoration of fish passage and habitat. Sediment remediation would be carried out by EGLE/EPA. The City would potentially bear the lowest cost responsibility under this
Permitting	This alternative would involve addressing known concerns with the dam and powerhouse and continuing to operate/inspect the existing spillway.	The rock ramp would be a new structure and therefore would likely have the greatest permitting effort/challenges.	Considerable permitting effort would be required for erosion control, structure removal, flow management, and changes to the channel. However, the state stakeholder departments would have the greatest support for the dam removal alternative.
Ecological Benefit	No ecological benefit seen from this alternative beyond Superfund basic remediation/capping of sediments.	Some ecological benefit from increased running-water habitat, increased fish passage, sediment capping and soil remediation, which would benefit ecosystem health.	Greatest ecological benefit. Natural flow and sediment transport. Return to pre-dam condition as well as practicable, passage for most native fish and other aquatic organisms, return to running-water habitat throughout project area, potential for restored native mussel habitat, greatest sediment removal and soil remediation, greatest benefit to ecosystem health from contaminant remediation/removal.

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Appendix A

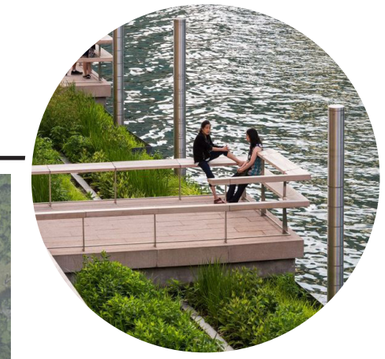
Conceptual Graphics of Alternatives

Wetlands & Potential Stormwater Storage

Hillside Step Down

Hillside Water Feature

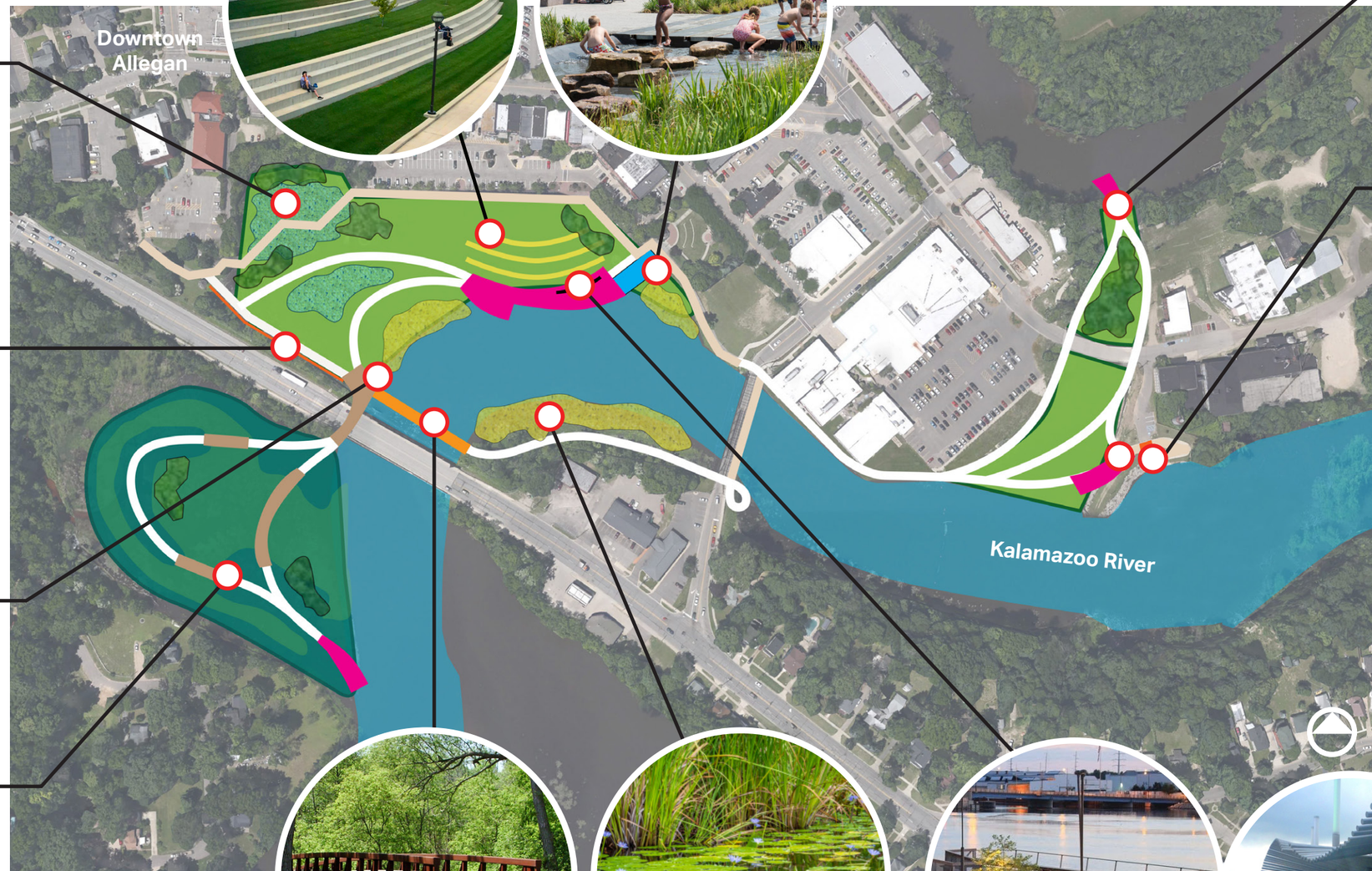
Key Overlooks



Kayak Rail Portage

Relocated Kayak Launch

Wetlands, Trails, & Boardwalks



Boat Launch

- Park Land
- Wetlands
- Trees & Vegetation
- Riparian Vegetation
- Pedestrian Bridges
- Boardwalks
- Overlooks
- Trails
- Existing Walks
- River

Pedestrian Bridge Trail Loop Connection

Fish Habitat / Wetland Fringe

Main Overlook

Bench Swings

ALLEGAN CITY DAM - FULL REMOVAL

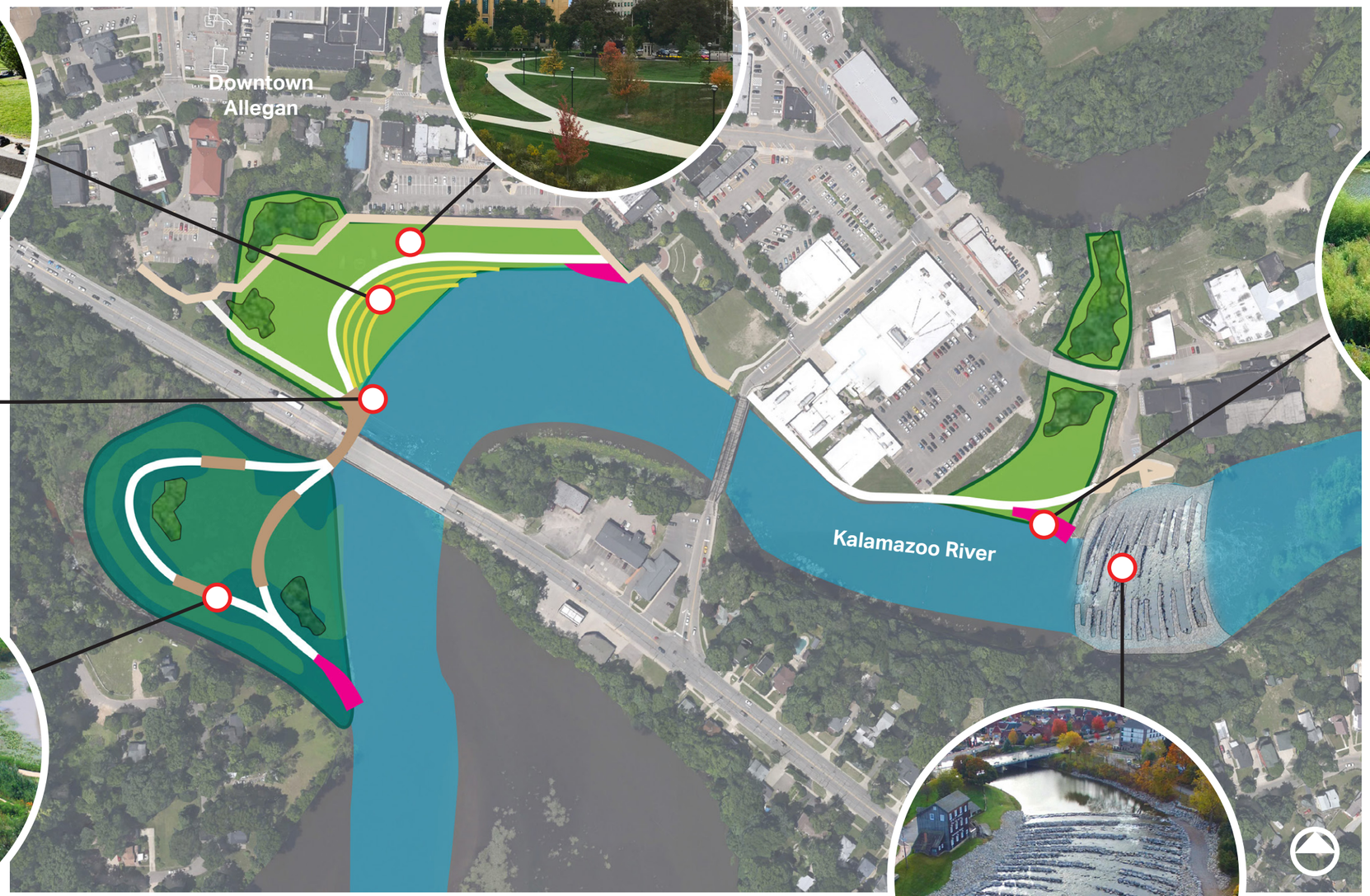
MAY 8, 2019

AECOM

Trails & Lawn Along River

Step Down to River Edge / Water Feature Potential

Relocated Kayak Launch



Key Overlooks

Wetlands, Trails, & Boardwalks

Full Width Rock Ramp Fishway

- Park Land
- Wetlands
- Trees & Vegetation
- Boardwalks
- Overlooks
- Trails
- Existing Walks
- River

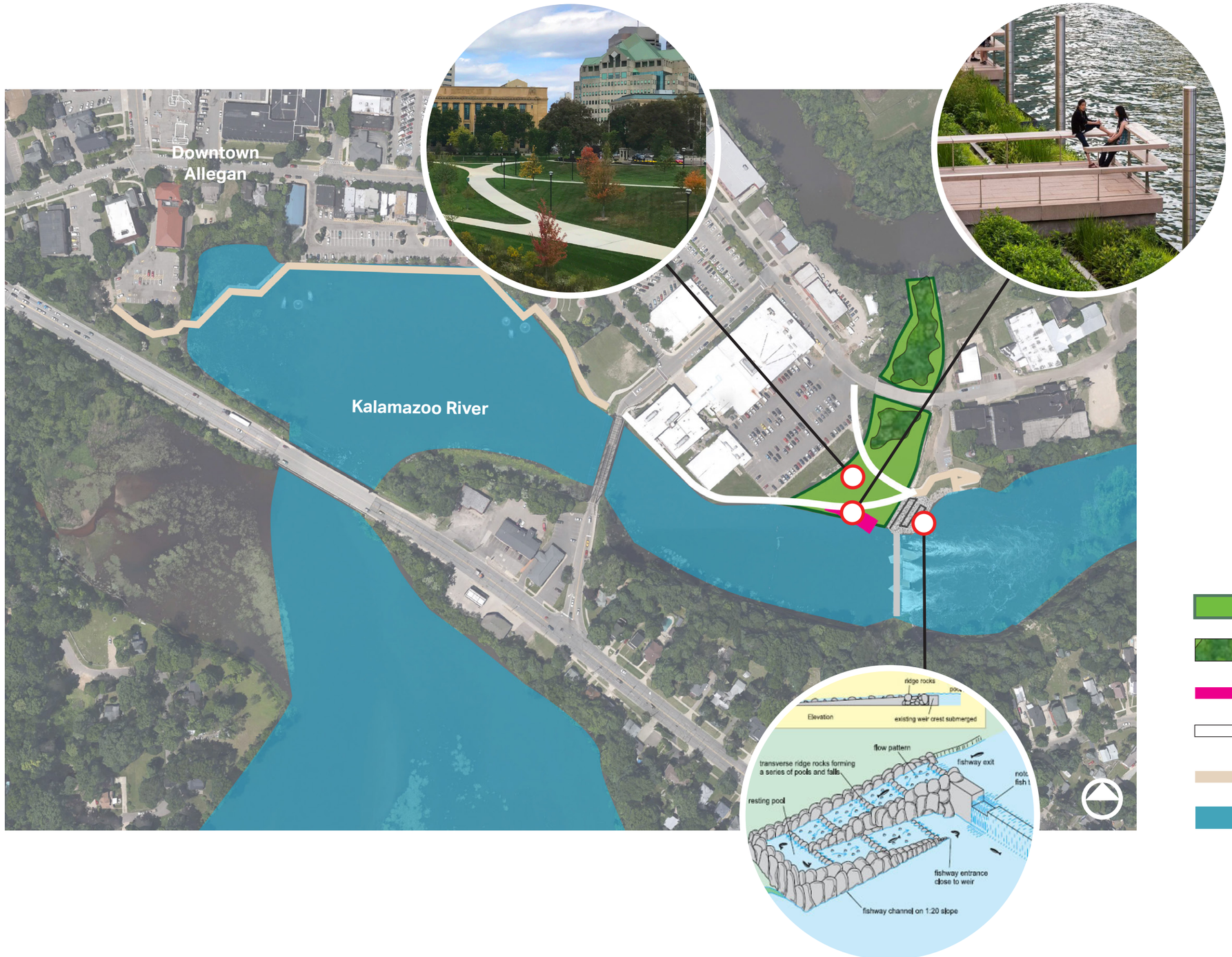
ALLEGAN CITY DAM - PARTIAL REMOVAL

MAY 8, 2019

AECOM

Trails & Lawn Areas

Overlook



Fish Ladder

Park Land

Trees & Vegetation

Overlooks

Trails

Existing Walks

River

ALLEGAN CITY DAM - DAM REPAIR

MAY 8, 2019

AECOM

Appendix B

Conceptual Cost Estimates

Alternative: Full Dam Removal

Allegan City Dam Full Removal	Units	Unit Price	Quantity	Subtotal
Site Services	Lump Sum	$150,000.00	1	$ 150,000.00
Mobilization/Demobilization	Lump Sum	$400,000.00	1	$ 400,000.00
Traffic Control	Lump Sum	$15,000.00	1	$ 15,000.00
Clear Site Vegetation	Acre	$4,000.00	1	$ 4,000.00
Erosion and Pollution Control	Acre	$15,000.00	1	$ 15,000.00
Temporary Access Road	Lump Sum	$60,000.00	1	$ 60,000.00
Vibration Monitoring	Lump Sum	$10,000.00	1	$ 10,000.00
Flow Diversion/Mgmt	Lump Sum	$100,000.00	1	$ 100,000.00
Steel Sheet Piling	Square Foot	$20.00	2550	$ 51,000.00
North Embankment Concrete Wall Removal	CYD	$100.00	167	$ 16,666.67
South Embankment Concrete Wall Removal	CYD	$100.00	119	$ 11,851.85
Transportation and Disposal of Concrete Debris	TN	$15.00	7903	$ 118,548.00
Spillway Pier 1	CYD	$100.00	733	$ 73,333.33
Spillway Pier 2	CYD	$100.00	1304	$ 130,370.37
Spillway Pier 3	CYD	$100.00	122	$ 12,222.22
Dam Sill	CYD	$100.00	1111	$ 111,111.11
RipRap Armoring - North Side	CYD	$100.00	433	$ 43,333.33
RipRap Armoring - South Side	CYD	$100.00	217	$ 21,666.67
Operator Building Removal	LSUM	$25,000.00	1	$ 25,000.00
Catwalk Removal	LSUM	$25,000.00	1	$ 25,000.00
Gate Removal	LSUM	$75,000.00	1	$ 75,000.00
StopLog Removal	LSUM	$25,000.00	1	$ 25,000.00
Concrete Apron Removal	SYD	$30.00	400	$ 12,000.00
Estimated Construction Cost				$ 1,506,103.56

Demolition and Fill of Powerhouse Structures	Units	Unit Price	Quantity	Subtotal
Traffic Control	Lump Sum	$5,000.00	1	$ 5,000.00
Clear Site Vegetation	Acre	$4,000.00	0.5	$ 2,000.00
Erosion and Pollution Control	Lump Sum	$20,000.00	1	$ 20,000.00
Vibration Monitoring	Lump Sum	$10,000.00	1	$ 10,000.00
As-Built Topographic Survey	Lump Sum	$3,500.00	1	$ 3,500.00
Restoration of Original Site Conditions	Lump Sum	$10,000.00	1	$ 10,000.00
Project Close Out	Lump Sum	$10,000.00	1	$ 10,000.00
Hazardous Materials Abatement	Lump Sum	$100,000.00	1	$ 100,000.00
Concrete Fill	CYD	$300.00	347	$ 104,000.00
Flowable Fill	CYD	$161.00	423	$ 68,037.41
Sheet Piling	SFT	$20.00	1288	$ 25,760.00
Pumping Out Powerhouse	Lump Sum	$10,000.00	1	$ 10,000.00
Removal of Abandoned Bridge	SYD	$60.00	200	$ 12,000.00
Demolition of Upper Structures	SFT	$30.00	3500	$ 105,000.00
Removal of Trash Rack	Lump Sum	$2,000.00	1	$ 2,000.00
Bridge Demolition	SFT	$33.00	4800	$ 158,400.00
Fill Mill Race	CYD	$12.00	22600	$ 271,200.00

Topsoil	Acre	$8,000.00	1.85	$ 14,800.00
Seeding	Acre	$6,000.00	1.85	$ 11,100.00
Replace Road	MILE	$2,000,000.00	0.04	$ 80,000.00
Concrete Removal	SYD	$30.00	20	$ 600.00
Miscellaneous Debris Removal	CYD	$25.00	200	$ 5,000.00
Estimated Construction Cost				$ 1,028,397.41

Kalamzoo River Channel Restoration	Units	Unit Price	Quantity	Subtotal
Sediment Management				$19,107,000
Site Mobilization	Lump Sum	$100,000.00	2	$200,000
Water Treatment Costs	per 1,000 gal	$25.00	14,200	$355,000
Capital cost for Treatment	Lump Sum	$1,000,000.00	1	$1,000,000
Annual Operating Costs	per year	$200,000.00	2	$400,000
Flood Plain Sediment Removal	CYD	$6.00	50,000	$300,000
Channel Sediment Removal and Dewatering	CYD wet	$35.00	350,000	$12,250,000
Disposal <50 ppm from channel and floodplain (dry)	CYD dry	$40.00	80,000	$3,200,000
Disposal of Non-Contaminated Materlas (dry)	CYD dry	$6.00	200,000	$1,200,000
Haul Roads	ft	$10.00	14,000	$140,000
River Crossings	each	$3,000.00	4	$12,000
Erosion Control/Sediment Traps	Lump Sum	$50,000.00	1	$50,000
Channel and Bank Stabilization				$1,523,090
Engineered Riffle	SYD	$85.00	5,200	$442,000
Scour Protection	SYD	$85.00	4,634	$393,890
Rootwad/Tree in Low Bank	LF	$300.00	1,500	$450,000
Rock Bank Protection	LF	$100.00	1,200	$120,000
Brush Mattress	LF	$9.00	800	$7,200
Soil Wrap	LF	$50.00	2,200	$110,000
Planting, Stabilization and Erosion Control				$1,525,000
Emergent Seed Mix	Acre	$7,000.00	65	$455,000
Wooded Seed Mix and Tree Plantings	Acre	$7,000.00	30	$210,000
Erosion Blanket and Live Staking	Acre	$6,000.00	20	$120,000
Live Staking	Acre	$5,000.00	4	$20,000
Topsoil	Acre	$8,000.00	90	$720,000
Estimated Construction Cost				$22,155,090
Estimated Park Development Cost				$ 2,512,200.00

Full Dam Removal Cost				$ 27,201,790.96
Contingency Cost (40%)				$ 10,880,716.39
Engineering and Permitting (10%)				$ 2,720,179.10
Construction Admin/RPR (10%)				$ 2,720,179.10
Estimated Total Project Cost				$ 43,522,865.54

Alternative: Partial Dam Removal

Allegan City Dam Partial Removal	Units	Unit Price	Quantity	Subtotal
Site Services	Lump Sum	$150,000.00	1	$ 150,000.00
Mobilization/Demobilization	Lump Sum	$400,000.00	1	$ 400,000.00
Traffic Control	Lump Sum	$15,000.00	1	$ 15,000.00
Clear Site Vegetation	Acre	$4,000.00	1	$ 4,000.00
Erosion and Pollution Control	Acre	$15,000.00	1	$ 15,000.00
Temporary Access Road	Lump Sum	$60,000.00	1	$ 60,000.00
Vibration Monitoring	Lump Sum	$10,000.00	1	$ 10,000.00
Flow Diversion/Mgmt	Lump Sum	$100,000.00	1	$ 100,000.00
Steel Sheet Piling	Square Foot	$20.00	2550	$ 51,000.00
North Embankment Concrete Wall Removal	CYD	$100.00	83	$ 8,333.33
South Embankment Concrete Wall Removal	CYD	$100.00	59	$ 5,925.93
Transportation and Disposal of Concrete Debris	TN	$15.00	2442	$ 36,630.00
Spillway Pier 1	CYD	$100.00	367	$ 36,666.67
Spillway Pier 2	CYD	$100.00	652	$ 65,185.19
Spillway Pier 3	CYD	$100.00	61	$ 6,111.11
Operator Building Removal	LSUM	$25,000.00	1	$ 25,000.00
Catwalk Removal	LSUM	$25,000.00	1	$ 25,000.00
Gate Removal	LSUM	$75,000.00	1	$ 75,000.00
StopLog Removal	LSUM	$25,000.00	1	$ 25,000.00
Rock Ramp			1	$ 1,956,000.00
Weir Boulders	EA	1200	$ 300.00	$ 360,000.00
Additional Rock/Channel Fill Materials	CYD	5200	$ 300.00	$ 1,560,000.00
In Channel Placement (Operator and Excavator)	DAY	12	$3,000.00	$ 36,000.00
Estimated Construction Cost				$ 3,069,852.22

Demolition and Fill of Powerhouse Structures	Units	Unit Price	Quantity	Subtotal
Traffic Control	Lump Sum	$5,000.00	1	$ 5,000.00
Clear Site Vegetation	Acre	$4,000.00	0.5	$ 2,000.00
Erosion and Pollution Control	Lump Sum	$20,000.00	1	$ 20,000.00
Vibration Monitoring	Lump Sum	$10,000.00	1	$ 10,000.00
As-Built Topographic Survey	Lump Sum	$3,500.00	1	$ 3,500.00
Restoration of Original Site Conditions	Lump Sum	$10,000.00	1	$ 10,000.00
Project Close Out	Lump Sum	$10,000.00	1	$ 10,000.00
Hazardous Materials Abatement	Lump Sum	$100,000.00	1	$ 100,000.00
Concrete Fill	CYD	$300.00	347	$ 104,000.00
Flowable Fill	CYD	$161.00	423	$ 68,037.41
Sheet Piling	SFT	$20.00	1288	$ 25,760.00
Pumping Out Powerhouse	Lump Sum	$10,000.00	1	$ 10,000.00
Removal of Abandoned Bridge	SYD	$60.00	200	$ 12,000.00
Demolition of Upper Structures	SFT	$30.00	3500	$ 105,000.00
Removal of Trash Rack	Lump Sum	$2,000.00	1	$ 2,000.00
Bridge Demolition	SFT	$33.00	4800	$ 158,400.00
Fill Mill Race	CYD	$12.00	22600	$ 271,200.00
Topsoil	Acre	$8,000.00	1.85	$ 14,800.00
Seeding	Acre	$6,000.00	1.85	$ 11,100.00

Replace Road	MILE	$2,000,000.00	0.04	$ 80,000.00
Concrete Removal	SYD	$30.00	20	$ 600.00
Miscellaneous Debris Removal	CYD	$25.00	200	$ 5,000.00
Estimated Construction Cost				$ 1,028,397.41

Kalamzoo River Channel Restoration	Units	Unit Price	Quantity	Subtotal
Sediment Management				$10,222,000
Site Mobilization	Lump Sum	$100,000	2	$200,000
Water Treatment Costs	per 1,000 gal	$25	7,000	$175,000
Capital cost for Treatment	Lump Sum	$1,000,000	1	$1,000,000
Annual Operating Costs	per year	$200,000	2	$400,000
Flood Plain Sediment Removal	CYD	$6	25,000	$150,000
Channel Sediment Removal and Dewatering	CYD wet	$35	170,000	$5,950,000
Disposal <50 ppm from channel and floodplain (dry)	CYD dry	$40	39,000	$1,560,000
Disposal of Non-Contaminated Materlas (dry)	CYD dry	$6	97,500	$585,000
Haul Roads	ft	$10	14,000	$140,000
River Crossings	each	$3,000	4	$12,000
Erosion Control/Sediment Traps	Lump Sum	$ 50,000.00	1	$50,000
Channel and Bank Stabilization				$2,338,304
Engineered Riffle	SYD	$85	8,000	$680,000
Scour Protection	SYD	$85	4,634	$393,890
Rootwad/Tree in Low Bank	LF	$300	3,000	$900,000
Rock Bank Protection	LF	$100	2,000	$200,000
Brush Mattress	LF	$9	1,602	$14,414
Soil Wrap	LF	$50	3,000	$150,000
Planting, Stabilization and Erosion Control				$1,098,000
Emergent Seed Mix	Acre	$7,000	45	$315,000
Wooded Seed Mix and Tree Plantings	Acre	$7,000	25	$175,000
Erosion Blanket and Live Staking	Acre	$6,000	18	$108,000
Live Staking	Acre	$5,000	4	$20,000
Topsoil	Acre	$8,000	60	$480,000
Estimated Construction Cost				$13,658,304

Estimated Park Development Cost				$ 1,030,800.00

Estimated Construction Cost				$ 18,787,354.03
Contingency Cost (40%)				$ 7,514,941.61
Engineering and Permitting (10%)				$ 1,878,735.40
Construction Admin/RPR (10%)				$ 1,878,735.40
Estimated Total Project Cost				$ 30,059,766.45

Alternative: Maintain Dam

Demolition and Fill of Powerhouse Structures	Units	Unit Price	Quantity	Subtotal
Traffic Control	Lump Sum	$5,000.00	1	$ 5,000.00
Clear Site Vegetation	Acre	$4,000.00	0.5	$ 2,000.00
Erosion and Pollution Control	Lump Sum	$20,000.00	1	$ 20,000.00
Vibration Monitoring	Lump Sum	$10,000.00	1	$ 10,000.00
As-Built Topographic Survey	Lump Sum	$3,500.00	1	$ 3,500.00
Restoration of Original Site Conditions	Lump Sum	$10,000.00	1	$ 10,000.00
Project Close Out	Lump Sum	$10,000.00	1	$ 10,000.00
Hazardous Materials Abatement	Lump Sum	$100,000.00	1	$ 100,000.00
Concrete Fill	CYD	$300.00	347	$ 104,000.00
Flowable Fill	CYD	$161.00	423	$ 68,037.41
Sheet Piling	SFT	$20.00	1288	$ 25,760.00
Pumping Out Powerhouse	Lump Sum	$10,000.00	1	$ 10,000.00
Removal of Abandoned Bridge	SYD	$60.00	200	$ 12,000.00
Demolition of Upper Structures	SFT	$30.00	3500	$ 105,000.00
Removal of Trash Rack	Lump Sum	$2,000.00	1	$ 2,000.00
Bridge Demolition	SFT	$33.00	4800	$ 158,400.00
Fill Mill Race	CYD	$12.00	22600	$ 271,200.00
Topsoil	Acre	$8,000.00	1.85	$ 14,800.00
Seeding	Acre	$6,000.00	1.85	$ 11,100.00
Replace Road	MILE	$2,000,000.00	0.04	$ 80,000.00
Concrete Removal	SYD	$30.00	20	$ 600.00
Miscellaneous Debris Removal	CYD	$25.00	200	$ 5,000.00
Estimated Construction Cost				$ 1,028,397.41

Main Spillway Modifications and Fish Passage	Units	Unit Price	Quantity	Subtotal
Site Services	Lump Sum	$150,000.00	1	$ 150,000.00
Mobilization/Demobilization	Lump Sum	$50,000.00	1	$ 50,000.00
Concrete Cylinders	EA	$166.00	3	$ 498.00
Weld Inspector	DAY	$580.00	1	$ 580.00
Job Trailer	MO	$873.00	1	$ 873.00
Crane Crew	DAY	$1,475.00	1	$ 1,475.00
Concrete Patching	SF	$43.00	2	$ 86.00
Remove Steel Trusses at Walkways	EA	$125.00	4	$ 500.00
Field Welding	LF	$11.75	83	$ 975.25
L 2 X 2 X 1/4	LF	$28.00	106	$ 2,968.00
L 3 X 3 X 3/8	LF	$46.00	41	$ 1,886.00
C6 X 8.2	LF	$48.50	53	$ 2,570.50
3/8" Plate	SF	$22.00	14	$ 308.00
S6X12.5 Vertical Extensions	LF	$35.50	119	$ 4,224.50
S8 X 18.4 Trolley Rail	LF	$45.00	53	$ 2,385.00
Steel Guardrails	LF	$65.40	159	$ 10,398.60
2" FRP Grating	SF	$35.50	159	$ 5,644.50
Fishladder	VF	$80,000.00	10	$ 800,000.00
Estimated Construction Cost				$ 1,035,372.35

Estimated Park Development Cost				$ 256,920.00

Estimated Construction Cost				$ 2,320,689.76
Contingency Cost (40%)				$ 928,275.90
Engineering and Permitting (10%)				$ 232,068.98
Construction Admin/RPR (10%)				$ 232,068.98
Estimated Total Project Cost				$ 3,713,103.61

					Date	16-May-19
Conceptual Cost of Construction						
PROJECT: Allegan Dam Full Removal						
Park Development						
		Allegan, Michigan				
		ESTIMATOR		TE		
Construction Costs						
	QUANTITY		LABOR & MATERIAL			
	NO.	UNIT	PER			TOTAL
	UNITS	MEAS.	UNIT	TOTAL		COST
Mobilization, 5% Const Cost	1	LS	$100,000	100,000		$100,000
Construction Sign	2	LS	$1,000	2,000		$2,000
Erosion and Sediment Control	1	LS	$15,000	15,000		$15,000
Excavation/Grading	11000	CY	$25	275,000		$275,000
Stepped Edge Stone Blocks	120	EA	$1,200	144,000		$144,000
Relocated Kayak Launch	1	LS	$5,000	5,000		$5,000
Fountain Relocation	3	EA	$5,000	15,000		$15,000
Conc Walks	2400	SY	$25	60,000		$60,000
Boardwalk Overlook	600	LF	$800	480,000		$480,000
Ped Bridge	300	LF	$1,200	360,000		$360,000
Spriral Ramp to 2nd St Bridge	1	LS	$400,000	400,000		$400,000
Topsoil Import	1200	CY	$25	30,000		$30,000
Seeding and Mulching	30000	SY	$3	90,000		$90,000
Trees, 2" cal.	90	EA	$600	54,000		$54,000
Ornamental Trees	35	EA	$400	14,000		$14,000
Perennials	600	EA	$45	27,000		$27,000
Aqutic Plantings	300	EA	$75	22,500		$22,500
Subtotal						**$2,093,500**
Contingency, 20%						**$418,700**
Construction TOTAL						**$2,512,200**

					Date	16-May-19
Conceptual Cost of Construction						
PROJECT: Allegan Dam Partial Removal						
Park Development						
		Allegan, Michigan				
		ESTIMATOR		TE		
Construction Costs						
	QUANTITY		LABOR & MATERIAL			
	NO.	UNIT	PER			TOTAL
	UNITS	MEAS.	UNIT	TOTAL		COST
Mobilization, 5% Const Cost	1	LS	$100,000	100,000		$100,000
Construction Sign	2	LS	$1,000	2,000		$2,000
Erosion and Sediment Control	1	LS	$15,000	15,000		$15,000
Excavation/Grading	7000	CY	$25	175,000		$175,000
Stepped Edge Stone Blocks	120	EA	$1,200	144,000		$144,000
Relocated Kayak Launch	1	LS	$5,000	5,000		$5,000
Fountain Relocation	3	EA	$5,000	15,000		$15,000
Conc Walks	1720	SY	$25	43,000		$43,000
Boardwalk Overlook	200	LF	$800	160,000		$160,000
Topsoil Import	1200	CY	$25	30,000		$30,000
Seeding and Mulching	30000	SY	$3	90,000		$90,000
Trees, 2" cal.	65	EA	$600	39,000		$39,000
Ornamental Trees	35	EA	$400	14,000		$14,000
Perennials	600	EA	$45	27,000		$27,000
Subtotal						**$859,000**
Contingency, 20%						**$171,800**
Construction TOTAL						**$1,030,800**

					Date	16-May-19
Conceptual Cost of Construction						
PROJECT: Allegan Dam Repair						
Park Development						
		Detroit, Michigan				
		ESTIMATOR		TE		
Construction Costs						
	QUANTITY		LABOR & MATERIAL			
	NO. UNITS	UNIT MEAS.	PER UNIT	TOTAL		TOTAL COST
Mobilization, 5% Const Cost	1	LS	$15,000	15,000		$15,000
Construction Sign	2	LS	$1,000	2,000		$2,000
Traffic Control, 5% Const Cost	1	LS	$15,000	15,000		$15,000
Demo, Misc	300	CY	$50	15,000		$15,000
Excavation,	1000	CY	$25	25,000		$25,000
Bioretention Soil	250	CY	$75	18,750		$18,750
Bioretention Rock	250	CY	$75	18,750		$18,750
Curb Inlet	3	EA	$2,000	6,000		$6,000
Runnel/trench Drain	3	EA	$4,000	12,000		$12,000
Headwalls	3	EA	$2,000	6,000		$6,000
Conc Walks	200	SY	$25	5,000		$5,000
Topsoil Import	900	CY	$25	22,500		$22,500
Turfgrass establishment	6000	SY	$3	18,000		$18,000
Trees, 2" cal.	24	EA	$600	14,400		$14,400
Ornamental Trees	8	EA	$400	3,200		$3,200
Perennials	300	EA	$45	13,500		$13,500
Interpretive Signs	2	EA	$2,000	4,000		$4,000
Subtotal						**$214,100**
Contingency, 20%						**$42,820**
Construction TOTAL						**$256,920**

Net Present Value Life Cycle Cost Estimates

	Alternatives		
Year	Dam Repair	Partial Removal	Full Removal
0	$ 3,713,103.61	$ 13,704,566.45	$ 12,951,665.54
1	$31,387.50	$62,662.50	$63,037.50
2	$31,387.50	$62,662.50	$63,037.50
3	$31,387.50	$62,662.50	$63,037.50
4	$30,000.00	$3,000.00	$63,037.50
5	$60,000.00	$7,800.00	$63,037.50
6	$30,000.00	$3,000.00	$0.00
7	$30,000.00	$3,000.00	$0.00
8	$30,000.00	$3,000.00	$0.00
9	$30,000.00	$3,000.00	$0.00
10	$60,000.00	$7,800.00	$0.00
11	$30,000.00	$3,000.00	$0.00
12	$30,000.00	$3,000.00	$0.00
13	$30,000.00	$3,000.00	$0.00
14	$30,000.00	$3,000.00	$0.00
15	$60,000.00	$7,800.00	$0.00
16	$30,000.00	$3,000.00	$0.00
17	$30,000.00	$3,000.00	$0.00
18	$30,000.00	$3,000.00	$0.00
19	$30,000.00	$3,000.00	$0.00
20	$60,000.00	$7,800.00	$0.00
21	$30,000.00	$3,000.00	$0.00
22	$30,000.00	$3,000.00	$0.00
23	$30,000.00	$3,000.00	$0.00
24	$30,000.00	$3,000.00	$0.00
25	$60,000.00	$7,800.00	$0.00
26	$30,000.00	$3,000.00	$0.00
27	$30,000.00	$3,000.00	$0.00
28	$30,000.00	$3,000.00	$0.00
29	$30,000.00	$3,000.00	$0.00
30	$60,000.00	$7,800.00	$0.00
31	$30,000.00	$3,000.00	$0.00
32	$30,000.00	$3,000.00	$0.00
33	$30,000.00	$3,000.00	$0.00
34	$30,000.00	$3,000.00	$0.00
35	$60,000.00	$7,800.00	$0.00
36	$30,000.00	$3,000.00	$0.00
37	$30,000.00	$3,000.00	$0.00
38	$30,000.00	$3,000.00	$0.00
39	$30,000.00	$3,000.00	$0.00
40	$60,000.00	$7,800.00	$0.00
41	$30,000.00	$3,000.00	$0.00
42	$30,000.00	$3,000.00	$0.00
43	$30,000.00	$3,000.00	$0.00
44	$30,000.00	$3,000.00	$0.00
45	$60,000.00	$7,800.00	$0.00
46	$30,000.00	$3,000.00	$0.00
47	$30,000.00	$3,000.00	$0.00
48	$30,000.00	$3,000.00	$0.00
49	$30,000.00	$3,000.00	$0.00
50	$25,381,829	$4,896,328.87	$0.00
51	$30,000.00	$3,000.00	$0.00

	Alternatives		
Year	Dam Repair	Partial Removal	Full Removal
52	$30,000.00	$3,000.00	$0.00
53	$30,000.00	$3,000.00	$0.00
54	$30,000.00	$3,000.00	$0.00
55	$60,000.00	$7,800.00	$0.00
56	$30,000.00	$3,000.00	$0.00
57	$30,000.00	$3,000.00	$0.00
58	$30,000.00	$3,000.00	$0.00
59	$30,000.00	$3,000.00	$0.00
60	$60,000.00	$7,800.00	$0.00
61	$30,000.00	$3,000.00	$0.00
62	$30,000.00	$3,000.00	$0.00
63	$30,000.00	$3,000.00	$0.00
64	$30,000.00	$3,000.00	$0.00
65	$60,000.00	$7,800.00	$0.00
66	$30,000.00	$3,000.00	$0.00
67	$30,000.00	$3,000.00	$0.00
68	$30,000.00	$3,000.00	$0.00
69	$30,000.00	$3,000.00	$0.00
70	$60,000.00	$7,800.00	$0.00
71	$30,000.00	$3,000.00	$0.00
72	$30,000.00	$3,000.00	$0.00
73	$30,000.00	$3,000.00	$0.00
74	$30,000.00	$3,000.00	$0.00
75	$60,000.00	$7,800.00	$0.00
76	$30,000.00	$3,000.00	$0.00
77	$30,000.00	$3,000.00	$0.00
78	$30,000.00	$3,000.00	$0.00
79	$30,000.00	$3,000.00	$0.00
80	$60,000.00	$7,800.00	$0.00
81	$30,000.00	$3,000.00	$0.00
82	$30,000.00	$3,000.00	$0.00
83	$30,000.00	$3,000.00	$0.00
84	$30,000.00	$3,000.00	$0.00
85	$60,000.00	$7,800.00	$0.00
86	$30,000.00	$3,000.00	$0.00
87	$30,000.00	$3,000.00	$0.00
88	$30,000.00	$3,000.00	$0.00
89	$30,000.00	$3,000.00	$0.00
90	$60,000.00	$7,800.00	$0.00
91	$30,000.00	$3,000.00	$0.00
92	$30,000.00	$3,000.00	$0.00
93	$30,000.00	$3,000.00	$0.00
94	$30,000.00	$3,000.00	$0.00
95	$60,000.00	$7,800.00	$0.00
96	$30,000.00	$3,000.00	$0.00
97	$30,000.00	$3,000.00	$0.00
98	$30,000.00	$3,000.00	$0.00
99	$30,000.00	$3,000.00	$0.00
100	$60,000.00	$7,800.00	$0.00
NPV Maintenance only	$6,906,534.31	$1,407,235.42	$288,693.29
NPV Life-Cycle Total	$10,310,328.08	$14,671,652.30	$12,854,717.31

Total Cost Over 100 years	$28,925,991.64	$5,463,516.37	$315,187.50

5.13.2019

Inputs:

Lifecycle Cost Item	Unit Price	Unit	Maintain Dam	Partial Removal	Full Removal
Invasive Species Control	$ 750.00	$/acre	$1,387.50	$59,662.50	$63,037.50
Rock Ramp Debris Cleaning	$ 500.00	LSUM	$0.00	$500.00	$0.00
Rock Ramp Boulder Mgmt	$ 2,500.00	LSUM	$0.00	$2,500.00	$0.00
Dam Operation and Maintenance	$ 5,000.00	LSUM	$5,000.00	$0.00	$0.00
Dam and Fishladder Inspection and Repairs, Every 5 years	$ 30,000.00	LSUM	$30,000.00	$4,800.00	$0.00
Dam Replacement		LSUM	$25,381,829.14	$4,896,328.87	$0.00
Fish Ladder Operation and Maintenance	$ 25,000.00	LSUM	$25,000.00	$0.00	$0.00
Total cost every 5 years -			$186,937.50	$318,112.50	$315,187.50
Total cost every 5 years without Invasive Species Control			$180,000.00	$19,800.00	$0.00