US Army Corps
of Engineers
Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

GRAND TRAVERSE COUNTY, MICHIGAN

APPENDIX A - ENGINEERING

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

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Acronyms and Abbreviations

ANS	aquatic nuisance species
BRDC	Boardman River Dams Committee
CAP	Continuing Authorities Program
cfs	cubic feet per second
CMP	corrugated metal pipe
GIS	geographic information system
GLFER	Great Lakes Fishery and Ecosystem Restoration
HDPE	high density polyethylene
HEC-RAS	Hydrologic Engineering Center's River Analysis System
IT	Implementation Team
LOMR	Letter of Map Revision
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
PCB	polychlorinated biphenyl
PEM	palustrine emergent
PFO	palustrine forested
PSS	palustrine scrub-shrub
SIAM	Sediment Impact Analysis Methods
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VE	Value Engineering
WRDA	Water Resources Development Act

1 Introduction

This study evaluates the feasibility of an ecosystem restoration project on the Boardman River. The Boardman River system, with approximately 130 miles of river and 186,000-acre watershed (MDNR 2002), is the largest river that flows to Grand Traverse Bay in Lake Michigan. This tributary to the Great Lakes provides, or historically provided significant spawning grounds for several species of fish, including lake sturgeon (*Acipenser fulvescens*), brook trout (*Salvelinus fontinalis*), dace, and other coldwater species. Four dams and a fish weir are located along the Boardman River: James P. Price Trap and Transfer / Harvest Facility, Union Street Dam, Sabin Dam, Boardman Dam, and Brown Bridge. The Brown Bridge Dam is being removed by the Implementation Team (IT) and is not discussed in this report.

The fish weir is approximately three quarters of a mile upstream from Grand Traverse Bay. The James P. Price Trap and Transfer Facility / Harvest Facility is owned by the City of Traverse City and operated by the Michigan Department of Natural Resources (MDNR). It is currently used to harvest salmon eggs. The Union Street Dam is at river mile 1.1. It is a low-head, high hazard potential dam located within the municipal boundary of Traverse City. It maintains a typical hydraulic head of six to seven feet, with up to four feet of freeboard (STS 2008). The Sabin Dam is classified as a high hazard potential dam[1] at river mile 5.3. It consists of 442 feet of earthen embankment, a powerhouse, and a spillway with tainter gates and stop log structures (Prein and Newhof 2009). It was typically operated with a hydraulic head of 24 feet and a structural height of 30 feet. As of 2011, Sabin Pond had been drawn down approximately four feet leaving 20 feet of head. The Boardman Dam is classified as a high hazard potential dam at river mile 6.1. Discharge from the Boardman Dam flows directly into the impoundment created by the Sabin Dam. The Boardman Dam consists of a 650-foot detached embankment to the left of the dam, an emergency spillway in the left bank, a concrete spillway structure and the penstock intake, and a short right embankment. A short middle embankment is located between the spillway chute and the powerhouse. An excavated power canal feeds the reservoir to the intake structure. To meet Michigan Department of Environmental Quality (MDEQ) dam safety requirements, the impoundment level was lowered approximately 17 feet. This reduction in normal pool elevation was required to stabilize the dam due to deficient spillway capacity. The reduction in pool

> The **Implementation Team** was formed to provide coordination of the settlement agreement (Schram 2005) negotiated between Traverse City Light and Power, The City of Traverse City, Grand Traverse County, Grand Traverse Band, Michigan Hydro Relicensing Commission and the resource agencies as part of Federal Energy Regulatory Commission license surrender.

[1] "A "high hazard potential classification" is defined by the Natural Resources and Environmental Protection Act 451 of 1994 as "any dam located in an area where failure may cause serious damage to inhabited homes, agricultural buildings, campgrounds, public utilities, main highways, or Class I carrier railroads; where environmental degradation would be significant; or where danger to individuals exists with the potential loss of life". A dam's classification is not a reflection of the dam's structural condition. No laws or regulations exist that would require removal or repair of Union Street, Sabin or Boardman Dams in the future without project condition.

elevation would be maintained until the deficiency is corrected or the dam is removed. This creates a hydraulic head of approximately 38 feet. The structural height of the dam is 62 feet.

The James P. Price Trap and Transfer Facility / Harvest Facility includes instream structures that support moveable grates that can be used to block larger aquatic species while allowing passage of water and smaller wildlife. The MDNR uses the grates to block passage of fish during the fall salmon run. At other times of the year, when grates are not in place, free passage upstream is possible.

The Union Street dam is generally operated as a run-of-the-river. The moveable grates are left in an open position and maximum flows are allowed through the structure. The Sabin and Boardman Dams were operated as run-of-the-river dams, with the operational goal being no changes to the impoundment water surface elevation when they were hydroelectric projects. The non-Federal sponsor is removing the Brown Bridge Dam and has determined that the Union Street Dam must maintain the existing water level of Boardman Lake. The Union Street Dam adds approximately six to seven feet to the level of Boardman Lake (a natural lake). Thus, the Sabin and Boardman Dams are being evaluated for modification and removal, and the Union Street Dam is being considered for only modifications to improve the ecosystem.

The Boardman River is a predominantly groundwater-fed coldwater river. Sections of the river are designated as a Blue Ribbon Trout Stream. This designation is given to streams that provide a premium trout fishing experience and have excellent water quality. The dams and their resulting impoundments disrupt the natural thermal regime of the river and create warmwater habitat. The project objectives include restoring coldwater habitat and restoring connectivity. Implicit in these objectives is the removal of warmwater habitat.

The ecological restoration of the Boardman River, through the removal of Boardman and Sabin Dams and the modification of Union Street Dam, is focused on restoring the historic form, function and natural characteristics of the river system. Based on available information this can be accomplished using limited hard engineering, such as grade control structures, rock armoring, and cross vane and j-hook weirs. Instead, the final design approach should focus on identifying the location of the historic channel through additional data collection and identifying engineering approaches designed to place the river in this location with the incorporation of appropriately sized locally obtained bed substrate particles also incorporating the use of Large Woody debris wherever possible. The exception to this approach would be in areas proximate to critical infrastructure that must be protected such as the Cass Road Bridge and in areas where the topography, soils or geology has been modified through activities such as dam and road construction. The result of this approach would be a natural river in form, function and character that requires little to no long term maintenance.

This Appendix summarizes the preliminary engineering efforts of the Feasibility Study. These efforts include topographic survey, geotechnical investigation, structural evaluations, groundwater analysis, wetland impact analysis, hydrologic and hydraulic modeling, preliminary engineering and design analysis of measures, and cost estimating. This report is part of the Detailed Project Report.

1.1 Study Purpose and Scope

This Feasibility Study explores the potential to restore Great Lakes tributary habitat for fish by restoring the connectivity and coldwater characteristics of the Boardman River and potentially increasing the diversity of species moving between the Great Lakes and the river. This is accomplished by evaluating the potential modification or removal of three of the dams on the river (Union Street, Sabin Dam and Boardman Dam). Restoration of habitat has been identified as a high priority for the entire Great Lakes Basin via the support plan for the Great Lakes Fishery and Ecosystem Restoration (GLFER) program.

The project objectives include reconnecting and restoring Great Lakes tributary habitat (i.e., the Boardman River), allowing unimpeded movement of woody debris and sediment materials through the river system, negating thermal disruption, and restoring the natural balance between coldwater and coolwater species. These objectives shall be accomplished without transporting pollutants into Grand Traverse Bay of Lake Michigan, losing flood protection, negatively impacting existing infrastructure, or allowing upstream migration of aquatic invasive species. Inherent in these objectives, is the loss of warmwater habitat that exists in the impoundments. Compared to coldwater habitat, warmwater lentic habitat is abundant in northern Michigan. There are over 100 warmwater lakes in Grand Traverse County and Kalkaska County and more than 11,000 inland lakes in the State (MDNR 2012b) of which the vast majority are warmwater lakes. Conversely less than 20 percent of rivers in Michigan's lower peninsula have coldwater characteristics (Seelbach et. al 1997). Expected results of the project include enhanced populations, diversity, and movement of coldwater and coolwater fish species between the Boardman River system and Grand Traverse Bay of Lake Michigan and loss of warmwater habitat. In contributing to the restoration of Great Lakes tributary habitat, these project objectives and expected outcomes constitute a high basin-wide priority, as indicated in the GLFER support plan.

1.2 Study Authority

This Feasibility Study was conducted under the authority of Section 506 (GLFER) of the Water Resources Development Act (WRDA) of 2000 (Public Law 106-541), directing the Secretary of the Army to "plan, design, and construct projects to support the restoration of the fishery, ecosystem, and beneficial uses of the Great Lakes."

The Boardman River Feasibility Study was conducted by the Detroit District, U.S. Army Corps of Engineers (USACE) in coordination with Grand Traverse County as the local sponsor. This project was first initiated as a Section 206, Ecosystem Restoration Project under the USACE Continuing Authorities Program (CAP). Because of funding constraints within the CAP, as well as the project's strong emphasis on fisheries, USACE and project sponsor determined that the project could be conducted under Section 506 authority (GLFER) of the WRDA of 2000. A Preliminary Restoration Plan was subsequently prepared under that authority in Fiscal Year 2005–06, resulting in a determination that sufficient Federal interest exists to recommend that the study continue into the Feasibility Phase.

1.3 Description of the Selected Alternative

The alternative selected is to modify the Union Street Dam, remove the Sabin Dam, and remove the Boardman Dam. This alternative provides the greatest benefits. It allows for a high percentage of sturgeon passage from Lake Michigan to the Boardman River via a trap-and-transfer operation requiring small changes to the existing fish weir located along the lower Boardman River. The Sabin and Boardman Dams removal maximizes available habitat for all species considered. The Proposed Action at each dam is described below.

1.3.1 Union Street Dam Modifications

Historically, lake sturgeon have been found in the Boardman River below the Union Street Dam (MDNR Boardman River Fish Distribution Maps; USFWS 2008). The dam blocks movement upstream for foraging or spawning purposes. Because the Boardman River provides suitable habitat for lake sturgeon (MDNR 2007), a measure that meets project objectives by providing lake sturgeon access to the Boardman River that is within project constraints is desirable. In accordance with the U.S. Fish and Wildlife Service's desire to retain the Union Street Dam as a lamprey barrier, removal of the dam is not under consideration. However, the Union Street Dam is proposed for modification to pass lake sturgeon in a downstream direction and block aquatic nuisance species (ANS) from the Great Lakes from moving up the Boardman River. Upstream passage of lake sturgeon would be achieved by trapping and transferring via truck to a location above the Union Street Dam.

The trap-and-transfer operation would be conducted at the James P. Price Trap-and-Transfer facility and modifications would be made to the Union Street Dam to allow downstream passage of lake sturgeon. Upstream passage of lake sturgeon would be accomplished by fishery technicians trapping and transferring sturgeon at the existing trap-and-transfer facility to upstream locations, such as Medalie Park, Hull Park, or the Boardman River Nature Center (site of the Sabin Dam). Operational constraints in the form of a sturgeon specific "standard operating procedure" would be developed to limit mortality to adult sturgeon and other fish species present during the trap-and-transfer activities. Minimizing mortality must be a primary concern of the trap-and-transfer operation because the numbers of spawning sturgeon are small.

Downstream passage would be accomplished by modifying the existing Union Street Dam to be more conducive to passing adult sturgeon while maintaining the existing level of ANS (e.g., sea lamprey) protection. This measure is expected to require the following:

- Two fishery technicians to perform the upstream trapping and transfer operation, for 20 hours per week while sturgeon are moving upstream (approximately mid-April to early May).
- A truck suitable for transporting sufficient water to support sturgeon to the discharge location. The truck would need to be modified to hold and discharge fish and water as the discharge location may not have a launch.
- Elevator system at weir facility to bring sturgeon and water to truck level.

- Stairs to safely allow fishery technicians to move from the water level to the weir level.
- Modification to the Union Street fish ladder to facilitate downstream passage of adult sturgeon. The modification would include the modification/replacement of the existing auxiliary spillway (200 cubic yards of concrete, two 48-inch diameter culverts 150 lineal feet long) and developing inlet characteristics that would attract sturgeon and accommodate downstream passage. (Amaral et al. 2002; Kynard and Horgan 2001) The existing fish ladder would be maintained to continue facilitating the upstream passage of salmonids and other species. The existing hydraulic conditions at the modified auxiliary spillway would not be changed in order to maintain the existing level of ANS protection.

This measure meets the objective of reconnecting the Great Lakes with the Boardman River. The existing Union Street Dam and the existing fish ladder would remain and the auxiliary spillway would be rebuilt to improve its ability to pass sturgeon downstream. These modifications would also increase the efficiency of downstream passage for other species

This measure also addresses most of the project constraints; it would:

- Maintain existing flood protection
- Maintain the level of Boardman Lake
- Maintain the current level of ANS protection
- Avoid impacts to existing infrastructure
- Avoid impacts to contaminated sediments
- Avoid excessive sediment release during construction

1.3.2 Sabin Dam Removal

Currently, the Sabin Dam blocks fish movement, fragments coldwater habitat, traps sediment and organic material, and warms the water within the impoundment and downstream of the dam. Removing the Sabin Dam mitigates these problems within project constraints.

Complete dam removal has the potential to achieve all of the objectives within all of the project constraints. Dam removal would include removal of the concrete spillway (but not the existing powerhouse) and provide for a 60-foot-wide bankfull channel and up to 60 feet of total floodplain bench through the earthen dam. An engineered rifle is proposed at the site of the existing auxiliary spillway to provide grade control, proper substrate and tie the pre-dam river elevation through the impoundment into the existing channel alignment below the dam.

The exposed bottomlands would be restored using permanent seeding on 10 acres, live staking and plantings on 1 acre of steep slopes and the remaining (approximately 29 acres) area would be allowed to passively re-vegetate using the native seed bank. Erosion from the exposed bottomlands would be controlled by restoration activities in areas of steep slopes. Restoration includes seeding (10 acres), planting (1 acre) and 10,000 square yards of erosion control blankets. Approximately 4,600 feet of free-flowing channel would form through the former

impoundment. The river would be allowed to choose its own path. In doing so, it would move sediment and self-armor with existing gravel, cobble, and boulders. It is expected, based on bathymetry and depth of refusal data, that the restored river would follow the pre-dam river channel. Approximately 600 feet of stream bank protection (toe revetments, root wad revetments, brush mattresses, etc.) are expected in areas of tight meanders. Sediment management would occur via sediment traps immediately upstream and downstream of the existing dam, sediment traps as needed within the impoundment, slow drawdown and active sediment removal along the exposed banks by land-based excavators (to provide appropriately dimensioned floodplain). Approximately 94,800 cubic yards of sediment is expected to be moved and disposed of onsite during removal of the Sabin Dam and restoration of this segment of the Boardman River. The proposed drawdown and construction methods are designed to limit the quantity of sediment that would be transported downstream.

The breaching operation would consist of notching the concrete spillway down to lower the impoundment at a maximum rate of 1 foot per day. The structural stability and integrity of the existing concrete spillway would allow for controlled removal of concrete. The incremental height is subject to modification based on field observations of sediment migration. The spillway structure would continue to be lowered to 2 feet below the proposed river profile to accommodate the construction of the engineered riffle.

This measure meets all of the objectives of the project. It would eliminate thermal impacts of the dam; eliminate fragmentation of coldwater habitat; allow for natural movement of suspended sediment, sediment bedload, and organic material; and allow for fish passage.

This measure addresses most of the project constraints; it would:

- Maintain existing flood protection. However, the restored channel would have to be analyzed carefully and new Letters of Map Revision (LOMRs) may be needed.
- Maintain the level of Boardman Lake. (Note that this constraint is not applicable because the Sabin Dam is upstream of Boardman Lake.)
- Prohibit invasive species. (Note that sea lamprey is the primary invasive species of concern and needs to be blocked as close to Lake Michigan as possible. This currently occurs at Union Street.)
- Avoid impacts to existing infrastructure (such as utilities, roads, etc.).

Sabin impoundment has elevated concentrations of some contaminants. These contaminants may need to be managed to protect human and aquatic health. Soil and sediment data collected to date (see **Environmental Assessment** for detailed analysis) indicates that Arsenic levels are above background levels, but below the nonresidential criteria that the MDEQ has developed. Thus, no capping is expected; however, post removal testing would be required to verify that contaminant levels are below MDEQ specified limits.

Further, the drawdown and construction phase is designed to limit the quantity of sediment that would be transported downstream. This would be accomplished by the controlled breaching method, sediment trapping and removal methods and proper soil and erosion control methods.

Integration with MDNR facilities and coordination with MDNR fishery staff is not required for this measure.

1.3.3 Boardman Dam Removal

The Boardman Dam is being considered for removal or modification to eliminate the environmental impacts caused by the dam. Currently, the Boardman Dam blocks fish movement, fragments coldwater habitat, traps sediment and organic material, and warms the water within the impoundment and downstream of the dam.

Complete dam removal has the potential to achieve all of the objectives within all of the project constraints. Dam removal would remove a 60-foot-wide channel and a total of 60 feet of floodplain bench (30 feet each side) at the earthen dam. The exposed bottomlands would be restored using permanent seeding on 25 acres, live staking and plantings on 2 acres of steep slopes and the remaining 76 acres would be allowed to passively re-vegetate using the native seed bank. Erosion from the exposed bottomlands would be controlled by restoration activities in areas of steep slopes. Restoration includes seeding (25 acres), planting (2 acres) and 20,000 square yards of erosion control blankets. Approximately 8,000 feet of free-flowing channel would form through the former impoundment. The river would be allowed to choose its own path. In doing so, it would move sediment and self-armor with existing gravel, cobble, and boulders. It is expected, based on bathymetry data, that the restored river would follow the pre-dam river channel. Approximately 1,000 feet of stream bank protection (toe revetments, root wad revetments, brush mattresses, etc.) are expected in areas of tight meanders. Sediment management would occur via sediment traps immediately upstream and downstream of the existing dam, sediment traps as needed throughout the impoundment, slow drawdown and active sediment removal along the exposed banks by land-based excavators (to provide appropriately dimensioned floodplain). Approximately 207,400 cubic yards of sediment, earthen embankment and road fill is expected to be moved and disposed of onsite during removal of the Boardman Dam and restoration of this segment of the Boardman River. The proposed drawdown and construction methods are designed to limit the quantity of sediment that would be transported downstream.

The breaching operation would consist of initially pumping down the impoundment at a rate of one foot per day. The bypass pumping would require operating ten 24-inch axial flow pumps with a combined capacity of 400 CFS (which exceeds the typical mean flow of June through September). During the drawdown, the contractor would begin removing the earthen berm, always maintaining a minimum of five feet of freeboard until the impoundment level is within three feet of the proposed river profile. At such time, the contractor would complete removal of the earthen dam. As a redundant safety measure, the contractor shall have onsite flexible hard armor mats (ArmorFlex) to place in a constructed channel across the earthen berms, should the

pumps fail. This would prevent excessive scour, provide structural support for the earthen berm and greatly reduce the potential for an uncontrolled release of water and sediment.

This measure would eliminate thermal impacts of the dam; eliminate fragmentation of coldwater habitat; allow for natural movement of suspended sediment, sediment bedload, and organic material; and allow for fish passage.

This measure also addresses most of the project constraints; it would:

- Maintain existing flood protection. However, the restored channel would have to be analyzed carefully and new LOMRs may be needed.
- Maintain the level of Boardman Lake. (Note that this constraint is not applicable because the Boardman Dam is upstream of Boardman Lake.)
- Prohibit invasive species. (Note that sea lamprey is the primary invasive species of concern and needs to be blocked as close to Lake Michigan as possible. This currently occurs at Union Street.)
- Avoids impacts to existing infrastructure. (Cass Road crossing would be maintained by the local authorities. Impacts to utilities would be minimized during construction.)

However, Boardman impoundment has high levels of some contaminants. These contaminants may need to be managed to protect human and aquatic health. Soil and sediment data collected to date (see **Environmental Assessment** for detailed analysis) indicates that arsenic levels are above background levels, but below the nonresidential criteria developed by the MDEQ. Further, the drawdown and construction phase is designed to limit the quantity of sediment that would be transported downstream. This would be accomplished by the breaching method, sediment trapping methods and proper soil and erosion control methods.

Integration with MDNR facilities and coordination with MDNR fishery staff is not required for this measure.

1.4 Cost Estimate For Selected Alternative

The costs estimates for each of the measures were developed from unit costs obtained from local contractors, approximated based on previously bid projects, or from published unit costs (MDOT 2012). Overall project costs were then compared to similar projects in the region to verify the validity of the estimates. The following section discusses major cost components of the selected alternative and describes the assumptions associated with those costs. Cost estimates are provided in Tables 1-1 and 1-2 for modification of the Union Street Dam, Table 1-3 for removal of the Sabin Dam, and Table 1-4 for the Boardman Dam.

1.4.1 Union Street Dam

The fish lift for the trap-and-transfer facility is conceptualized as a hoist system capable of lifting four tons 10 feet vertically. This system would be incorporated into the existing fish weir. The four-foot by eight-foot loading platform would be flat to facilitate the loading of temporary bins for placement of fish and water. The bins would be attached to the lifting platform via straps.

Fishery technicians would collect sturgeon and manually place them in the bins. The lift would raise the bins to the loading dock area where they would be transferred to trucks for transfer to an upstream location. Downstream passage of sturgeon at the Union Street Dam would be facilitated by modifying the existing auxiliary spillway. The modifications would include constructing a permanent concrete sill in place of the current gate. The top of the sill would be even with the elevation of the fish ladder entrance. The approach to the sill, from upstream, would gradually slope up to direct the bottom swimming sturgeon up and over the sill. Once over the sill, the sturgeon would drop into a plunge pool, before exiting through one of the two 48-inch diameter culverts. The plunge pool and culverts are being reconstructed and lowered to accommodate the sea lamprey barrier requirements. These modifications would ensure that the dam maintains its current level of lamprey protection, while better facilitating downstream passage of adult sturgeon. Table 1-1 provides a summary of the costs associated with these modifications.

Table 1-1: Fish Passage Cost Details for the Union Street Dam

Conceptual River Restoration Boardman River - Union Street Dam							
Dam Modification For Fish Passage Measures							
Date:	**10/9/2012**						
Item No.	Description	Estimated Quantity	Units		Unit Cost		Total Cost
DOWNSTREAM FISH PASSAGE							
1.	Demolition of Existing Auxillary Spillway	200	CY	$	60	$	12,000
2.	Structural Concrete / cast in place	200	CY	$	500	$	100,000
3.	48" Culvert	300	LF	$	200	$	60,000
4.	Gate	1	EA	$	50,000	$	50,000
5.	Earthworks	1500	CY	$	10	$	15,000
6.	Site Clearing	0.5	AC	$	7,500	$	3,750
7.	Fencing / Railings	60	LF	$	15	$	900
UPSTREAM FISH PASSAGE							
8.	Steel Framing	0.32	Tons	$	5,000	$	1,600
9.	Metal Deck	32	SF	$	25	$	800
10.	Mechanical Lift	1	LS	$	170,000	$	170,000
INCIDENTAL CONSTRUCTION AND REVEGETATION							
11.	Construction Office	4	Month	$	750	$	3,000
12.	Temporary Construction Entrance	2	EA	$	2,000	$	4,000
13.	Temporary Sheet Piling	720	SF	$	25	$	18,000
14.	Sheet Pile Mobilization	1	LS	$	10,000	$	10,000
15.	Erosion Control	0.5	AC	$	2,000	$	1,000
16.	6" Topsoil (furnished)	0.5	AC	$	7,000	$	3,500
17.	Seeding and Restoration	0.5	AC	$	1,500	$	750
18.	Signage	1	Lump Sum	$	5,500	$	5,500
	Total Construction Cost					**$**	**459,800**
	Estimated Engineering Costs (20%)					$	91,960
	Estimated Administration Costs (5%)					$	22,990
	Subtotal Project Cost					**$**	**574,750**
	Contingency (20%)					$	114,950
	Easements and Acquisitions					$	5,208
	Total Estimated Project Cost					**$**	**694,908**

CY = Cubic Yards
LS = Lump Sum
EA = Each
LF = Lineal Foot
SF = Square Foot
AC = Acres

1.4.2 Sabin Dam

The majority of the costs associated with the dam removal option are in earthworks. The earthworks comprise three different earth moving operations: floodplain and dry channel excavation, earthen embankment removal, and sediment removal and disposal from trap

cleaning. The floodplain and dry channel excavation work is anticipated to be completed after drawdown has progressed to a point where these areas are no longer inundated and have undergone some in-situ dewatering (i.e., "in the dry"). However, because bearing capacities of the soils in the impoundment are unknown, the excavation method anticipated is the use of small dozers, excavators, and dump trucks on haul roads. Removal of embankment earth would likely be conducted with dump trucks and excavators. The sediment trap cleaning would likely be conducted with a stationary excavator and dump truck.

Sediments within Sabin impoundment have been shown to have elevated levels of some contaminants. Available data suggests the levels are above background and below direct contact values for nonresidential areas. Thus, no mitigation is expected. This expectation assumes that soil samples taken after dam removal would be less than the nonresidential criteria. (Note: All sediment and soil samples collected in Sabin Impoundment have been below this limit.)

Another significant cost associated with the project is the actual breaching of the dam. The breaching plan entails notching down the concrete spillway to lower the impoundment water surface elevation at a maximum rate of one foot per day. This would minimize velocities and sediment transport outside of channel areas, and therefore minimize the need for active sediment management. During the drawdown process, sediment traps would be maintained immediately above and below the breach, as well as throughout the impoundment. Table 1-2 provides a summary of the costs associated with the removal of the Sabin Dam. These costs were derived from local contractors and verified by comparison to previous projects.

Table 1-2: Preliminary Costs for the Sabin Dam Removal

Conceptual River Restoration Boardman River - Sabin Dam

Alternative 1: Dam Removal / Breach Plan

Item No.	Description	Estimated Quantity	Units	Unit Cost	Total Cost
EARTHWORKS AND SITE PREPARATION					
1.	Site Clearing	5	AC	$7,500.00	$37,500.00
2.	Channel Bottom Dredging	200	CY	$15.00	$3,000.00
3.	Floodplain and Dry Channel Excavation	26800	CY	$10.00	$268,000.00
4.	Dam Excavation	20000	CY	$8.00	$160,000.00
5.	Embankment Earth (Engineered Fill)	0	CY	$5.00	$0.00
6.	2" Topsoil (salvaged)	20	AC	$7,000.00	$140,000.00
7.	6" Topsoil (furnished)	0	AC	$14,000.00	$0.00
8.	Sediment Trap Cleaning	47800	CY	$10.00	$478,000.00
STREAM RESTORATION					
9.	Bank Stabilization (As Needed)	600	LF	$50.00	$30,000.00
10.	Rock Cross Vanes		CY	$90.00	$0.00
11.	Rock W Weirs		CY	$90.00	$0.00
12.	J Hook Vanes		CY	$90.00	$0.00
13.	Engineered Riffle	1340	SY	$50.00	$67,000.00
DAM REMOVAL					
13.	Breach Dam	1	Lump Sum	$100,000.00	$100,000.00
14.	Remove Spillway	1	Lump Sum	$150,000.00	$150,000.00
INCIDENTAL CONSTRUCTION AND REVEGETATION					
15.	Construction Office	4	Month	$750.00	$3,000.00
16.	Temporary Construction Entrance	1	EA	$2,000.00	$2,000.00
17.	Temporary Stream Crossing / Ford	2	EA	$3,000.00	$6,000.00
18.	Temporary Haul Road	8000	LF	$20.00	$160,000.00
17.	Erosion Control	10000	SY	$5.00	$50,000.00
18.	Temporary Seeding	5	AC	$125.00	$625.00
19.	Permanent Seeding	10	AC	$1,500.00	$15,000.00
20.	Live Staking and Plantings	1	AC	$12,000.00	$12,000.00
21.	Signage	1	Lump Sum	$5,500.00	$5,500.00
	Total Construction Cost				**$1,687,625.00**
	Estimated Engineering Costs (20%)				$337,525.00
	Estimated Administration Costs (5%)				$84,381.25
	Subtotal Project Cost				**$2,109,531.25**
	Contingency (20%)				$421,906.25
	Total Estimated Project Cost				**$2,531,437.50**

AC = Acres
CY = Cubic Yards
EA = Each
SY = Square Yards
LF = Linear Feet
LS = Lump Sum

1.4.3 Boardman Dam

The majority of the costs in the dam removal option are in earthworks and dam breaching. The earthworks comprise three different earth moving operations: floodplain and dry channel excavation, earthen embankment removal, and sediment removal and disposal from trap cleaning. The floodplain and dry channel excavation is anticipated to be completed in the dry. However, because bearing capacities of the soils in the impoundment are unknown, the excavation method anticipated is the use of small dozers, excavators, and dump trucks on haul roads. Embankment earth would likely be conducted with dump trucks and excavators. The sediment trap cleaning would likely be conducted with a stationary excavator and dump truck.

Sediments within Boardman impoundment have been shown to have elevated levels of some contaminants. Available data suggests the levels are above background and direct contact values for residential areas, but below nonresidential criteria. Thus, no mitigation would be required. This expectation assumes that soil samples taken after dam removal would be less than the MDEQ nonresidential criteria. (Note: All sediment and soil samples collected in Boardman Impoundment have been below this limit.)

Another significant cost associated with the project is the actual breaching of the dam. The breaching plan entails pumping water out of the impoundment, over the earthen berm, and into the newly constructed channel downstream. The bypass pumping would require pumping at a variable rate that would drawdown the impoundment approximately one foot per day. Additional pumps would be maintained onsite in the event of larger flows. During the drawdown, the contractor would begin removing the earthen berm, always maintaining a minimum of five feet of freeboard until the impoundment level is within three feet of the proposed river profile. At such time, the contractor would complete removal of the earthen dam. As a redundant safety measure, the contractor shall have onsite flexible hard armor mats (ArmorFlex) to place in a constructed channel across the earthen berms, should the pumps fail. This would prevent excessive scour, provide structural support for the earthen berm and greatly reduce the potential for an uncontrolled release of water and sediment.

Table 1-3 provides a summary of the costs associated with the removal of the Boardman Dam. These costs were derived from local contractors and verified by comparison to previous projects. Table 1-5 provides a summary of the recommended alternative anticipated and high costs.

Table 1-3: Preliminary Costs for the Boardman Dam Removal

Conceptual River Restoration Boardman River - Boardman Dam

Alternative 1: Dam Removal / Breach Plan

Item No.	Description	Estimated Quantity	Units	Unit Cost	Total Cost
EARTHWORKS AND SITE PREPARATION					
1.	Site Clearing	5	AC	$7,500	$37,500
2.	Channel Bottom Dredging	1000	CY	$15	$15,000
3.	Floodplain and Dry Channel Excavation	42400	CY	$10	$424,000
4.	Road & Dam Excavation	58400	CY	$8	$467,200
5.	Embankment Earth (Fill for Cass Rd and Bridge)	20000	CY	$5	$100,000
6.	2" Topsoil (salvaged)	100	AC	$7,000	$700,000
8.	Sediment Trap Cleaning	85600	CY	$10	$856,000
STREAM RESTORATION					
9.	Bank Stabilization (As Needed)	1000	LF	$50	$50,000
14.	Engineered Riffle	1340	SY	$50	$67,000
DAM REMOVAL					
15.	Breach Embankment	1	Lump Sum	$790,000	$790,000
	Breaching Operation	$30,000			
	Core Wall Demo	$60,000			
	ArmorFlex Matting	$100,000			
	Bypass Pumping	$600,000			
INCIDENTAL CONSTRUCTION AND REVEGETATION					
20.	Construction Office	4	Month	$750	$3,000
21.	Temporary Construction Entrance	1	EA	$2,000	$2,000
22.	Temporary Stream Crossing / Ford	2	EA	$3,000	$6,000
23.	Temporary Haul Road	10000	LF	$20	$200,000
22.	Erosion Control	20000	SY	$5	$100,000
23.	Temporary Seeding	10	AC	$125	$1,250
24.	Permanent Seeding	25	AC	$1,500	$37,500
25.	Live Staking and Plantings	2	AC	$12,000	$24,000
26.	Signage	1	Lump Sum	$5,500	$5,500
	Total Construction Cost				$3,885,950
	Estimated Engineering Costs (20%)				$777,190
	Estimated Administration Costs (5%)				$194,298
	Subtotal Project Cost				$4,857,438
	Contingency (20%)				$971,488
	Total Estimated Project Cost				$5,828,925

AC = Acre
CY = Cubic Yard
EA = Each
SY = Square Yard
LF = Linear Feet
LS = Lump Sum

Table 1-4: Cost Summary for Each Dam

Dam	Expected Costs
Union Street Dam	$689,700
Sabin Dam	$2,531,438
Boardman Dam	$5,828,925
Total	$9,050,063

1.4.4 Construction Sequencing and Schedule

The construction sequencing and schedule for this project would be primarily driven by two factors; sediment management during the drawdown process, and minimizing traffic interruption on Cass Road. The drawdown and breaching operation for the Sabin and Boardman Dams would consist of breaching the dams at approximately one-foot increments and allowing the water level within the impoundment to equalize prior to lowering the subsequent one-foot increment. During this time, sediment would need to be removed from the sediment traps as it is mobilized by the river. A detailed discussion on the drawdown operation and sediment management can be found in Section 6.

A conservative estimate for the duration of the breaching operation is necessary to accommodate impacts from weather and variable sediment transport rates. Additionally, to minimize risk of sediment migration the Boardman Dam would be breached prior to the Sabin Dam. This would allow for any sediment that could potentially be released during the Boardman drawdown to be captured in the Sabin impoundment.

The river restoration efforts in both impoundments would begin concurrently with the breaching operations. A theoretical schedule has been provided in Table 1-6. Actual dates would be determined during the design phase of the project. Work would begin with excavating floodplain benches in the upper reaches of the impoundments and progress downstream as the water level is drawn down. Channel and bank stabilization measures would be installed once the river reaches its expected final elevation. Restoration would be completed with seeding and planting.

Improvements at the Union Street Dam and MDNR trap-and-transfer facility would have minimal impacts on infrastructure and public use. Work at the Union Street Dam would disrupt use of the park and the water main that runs across the dam would have to be protected. In addition, work on these structures has the potential to impact spawning patterns and harvesting operations. Spawning times for species of concern are typically in the spring and fall months.

Table 1-5: Approximate Construction Schedule for Selected Alternative

Task Name	Duration	Start Date *	Finish Date *
Define Channel DS of Boardman and into Sabin	30 days	06/06/2016	07/05/2016
Boardman Breach	60 days	07/05/2016	08/31/2016
Sabin Breach	40 days	08/25/2016	10/05/2016
Boardman Restoration	120 days	07/05/2016	10/30/2016
Sabin Restoration	120 days	08/25/2016	12/21/2016
Union Street Dam and MDNR Trap-and-Transfer Facility Modifications	85 days	06/06/2016	08/26/2016

* The dates provided are representative and would need to be finalized during the design phase.

1.4.5 Operation and Maintenance for Selected Alternative

Operation and maintenance needs are a key factor in determining the feasibility of a measure. Removal of the Boardman and Sabin Dams would result in no need for operation or maintenance, since these reaches would be restored to natural riverine conditions. The Union Street Dam modifications would require regular operation and maintenance. The trap-and-transfer operation at the MDNR facility would require staffing of two technicians during sturgeon spawning season. Additionally, the lift equipment necessary to transfer the fish would require maintenance. Operational activities would be required when adult sturgeons are moving downstream after spawning in the spring. The downstream passage of sturgeon at the Union Street Dam would require stop logs to be inserted into the upstream slot of the existing fish ladder. This is to stop downstream swimming fish from entering existing fish ladder. The existing step-pool fish ladder is not conducive to downstream passage of large fish, which could become stuck and harmed. The stop logs would insure that downstream passage of sturgeon would occur via the new structure. The stop logs could be removed during other times of the year. The passage and stop logs would require periodic inspection and maintenance to maintain the desired level of operation. Potential concerns could be condition of concrete and seals on stop logs.

2 Survey and Mapping

Survey efforts have taken place along approximately 24 miles of stream, beginning at Medalie Park just upstream of Boardman Lake, and ending approximately 2 miles upstream of the Brown Bridge Dam impoundment. This survey data has been compiled in numerous reports and studies completed by the USACE and the Boardman River Dams Committee (BRDC).

River survey, geomorphic, and bathymetric data collection and reconnaissance were conducted by personnel or contractors of USACE-Detroit District between 2005 and 2007. Stream survey cross-sections were taken at a minimum spacing of 1,000 feet, except for a 2,000-foot stretch upstream of Keystone Pond where survey cross-sections were taken at a minimum spacing of 500 feet. Survey data were also collected at all bridge overpasses, culverts, piers, and other stream crossings. Survey cross-sections extend 200 feet into both the left and right overbanks.

Data were collected for stratified bed material and sediment along the Boardman River and within the ponds. Numerous photographs were taken to document the river condition and establish reference reaches along the Boardman River. The reference reaches represent stable sections of river and include full riffle/pool sequences. Survey-to-monument benchmarks tie all elevation data to a common datum. The information collected thus far is suitable for developing a hydrologic and hydraulic model of existing conditions.

Flow measurements and sediment transport data were collected by the U.S. Geological Survey (USGS) at its gaging station on the Boardman River above Brown Bridge Road near Mayfield, Michigan. Sediment samples were analyzed and sediment transport rating curves were developed by USGS. Sediment samples were analyzed for size class and weight by discharge interval. The results of these efforts were transmitted to the USACE. The sediment sampling and data analyses conducted thus far are suitable to provide a screening level understanding of sediment sources and sinks within the project area.

A field survey was conducted by Baird in April of 2011 to assess any changes since 2007 to the conditions of the reservoirs and dam operations as a result of drawdown efforts to update the hydraulic models. Movement of the accumulated sediment wedge on the upstream extent of Boardman Pond as a result of drawdown efforts was noted in aerial imagery and confirmed through field observation. Additionally, Baird observed the operations of the dams, including spillways, intakes, and outfalls to update the structures in the hydraulic model to reflect baseline conditions.

The data collected are critical to establishing the existing conditions scenario and project alternatives for the Boardman River and the Union Street, Sabin, and Boardman Dams. These data characterize the hydraulic, sediment, and geomorphic regime of the current system. They have been used to update the hydraulic models of the system and to develop the Sediment Impact Analysis Methods (SIAM) study and the sediment transport model.

3 Hydraulic and Hydrologic Studies

A hydraulic model, using the USACE's Hydrologic Engineering Center's River Analysis System (HEC-RAS), was developed for the Boardman River (USACE 2008). The model was used to characterize existing water levels and river profiles during the 100-year event, as well as those that would occur under future conditions with removal of the Sabin and Boardman Dams. The hydraulic model includes about 24 miles of stream beginning at the USGS Flow Gage at Ranch Rudolph (approximately 2 miles upstream of the Brown Bridge Dam) and ending at Grand Traverse Bay. The existing model was developed using a variety of data sources, including the Federal Emergency Management Agency Flood Insurance Study HEC-2[2] data for Traverse City, survey data collected by Gordie Fraser and Gosling Czubak under contract to the USACE, geographic information system (GIS) contour data supplied by Grand Traverse County, USACE bathymetry data for the impoundments, design drawings of bridges and structures, and dam structure data used in the MDEQ Boardman River hydraulic model. The hydrology data (boundary conditions, discharge values for flood events, and flow change locations) used in the model were developed by the MDEQ Hydrologic Studies Unit. The model was modified and updated in May 2009 as part of the SIAM Modeling Baseline Conditions Study by USACE-Detroit. The existing model of the Boardman River covers the entire project area to encompass the base case and future conditions scenario.

The model underwent numerous modifications to better assess existing conditions and simulate future alternatives including:

- Improvements to the representation of the spillway configuration of the dams were made to the model. The previous model was based on design drawings, which included power generation equipment. Much of this equipment has been removed and gate positions have been changed to drawdown Boardman and Sabin Ponds. The model was updated to reflect these changes and these changes have been applied to the existing conditions and future scenarios models.
- New river channel and impoundment water levels were incorporated. Boardman Pond and Sabin Pond have been lowered, creating a new river channel and modifying the impoundment water level. These changes have been incorporated into the existing conditions model where possible. Bathymetric survey data of the ponds was completed pre-drawdown, so hydraulic cross-sections representing drawn down conditions could not be modified without further survey data.
- Union Street was initially modeled as if all stoplogs were out. Because the configuration of the Union Street Dam consists of multiple culvert-type spillways, the Union Street Dam was built as a bridge with multiple culvert openings instead of as an inline structure. An inline structure was added directly upstream of the Union Street Dam in the model to represent the stoplogs.

[2] HEC-2 is the predecessor to the USACE's HEC-RAS computer program.

- A new model was created to represent the recommended alternative. The existing conditions model was modified by removing the dams and replacing the impoundments with the feasibility level design proposed river channel. This computer model was utilized as a design tool for the removal/modification of the dams to test configurations for potential impacts on water levels and also as the basis for the sediment transport model.

The previously described HEC-RAS model was used to conduct low flow, spawning conditions flow, and flooding conditions analyses for the existing baseline conditions of the Boardman River and three project dams. Results of the low flow and spawning conditions flow were used to support development of the Habitat Suitability Index models and are described in the Engineering Appendix. Results of the flood conditions are described below.

Flood analyses included hydraulic modeling of the 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent-annual-exceedence-probability events (2-, 5-, 10-, 25-, 50-, 100-, and 500-year events). Flow data for these events were developed and provided by MDEQ. A summary of water levels from representative cross-sections along the river for the 1-percent flood are presented in Table 3-1. The baseline conditions model represented the dams as per their configuration and operation through the 2007 baseline conditions study. The dams were operated in “run of river” mode, for hydropower generation. This means discharge release was equal to incoming flows, to maintain stable pond elevations (no change in storage) in the reservoirs. In addition, the dams were not designed or constructed for flood control therefore, had no flood pool capacity. For this reason, model simulations of flood flow under baseline conditions showed no rise in pool level. Consequently, removal of the dams resulted in no loss of flood storage, and downstream water levels were estimated to not increase. Within the existing impoundments, the water levels decrease significantly as a result of the draining of the reservoirs.

Table 3-1: Changes in Water Levels from Baseline Conditions to the Proposed Alternative Upstream, Downstream, and within the Sabin and Boardman Impoundments

Location	Description	Discharge	Water Surface Elevation (feet) (100-year event)		
		100-year (cfs)	Original	Alternative	Difference (feet)
Upstream of Airport Road	Approximately 600 feet upstream of bridge centerline	1,700	593.67	593.67	0
Downstream of Sabin Dam	Approximately 1500 feet downstream of existing spillway	1,700	596.26	596.26	0
Lower Sabin Dam	Just upstream of existing dam structure	1,700	612.96	604.54	-8.42
Upper Sabin Dam	Upstream of school bus garage area	1,700	613.06	611.6	-1.46
Lower Boardman Pond	Just upstream of island	1,500	645.45	624.55	-20.9
Mid Boardman Pond	Narrows	1,500	645.45	629.5	-15.95
Upper Boardman Pond	Peninsula point	1,500	645.45	637.43	-8.02
Upstream of Boardman Pond	Meander bend	1,500	657.06	655.31	-1.75
Upstream of Boardman Pond	Upstream of meander bend	1,500	662.06	658.66	-3.4
Downstream of Beitner Rd	First XS* downstream of bridge	1,500	669.77	669.77	0

*XS – cross section

The results from Table 3-1, along with cross-section locations, are illustrated in Figures 3-1 and 3-2. In these figures, the locations of cross-sections in Table 3-1 are illustrated by vertical arrows. The most prominent results in the figures are the removal of the Boardman and Sabin Dams, along with removal of the large sediment deltas currently stored in the existing impoundments. Removal of the vast majority of these sediments and construction of the proposed flood plain areas are critical to providing adequate flood conveyance and floodplain storage for larger events. During larger flood events, the vegetated flood plains (with trees, shrubs, etc.) provide important attenuation (reduction in peak discharge rates, and extension of flood duration) and offset and loss to flood routing through reservoirs that occurs with the existing impoundments.

Corresponding with the results in Table 3-1 and Figures 3-1 and 3-2, preliminary flood inundation areas are illustrated in Figure 3-3. These illustrate the flood inundation for the Boardman and Sabin impoundments, following dam removal. The water level impact of the

removal of the Sabin and Boardman Dams with the anticipated channel alignment through the existing impoundments as compared to the existing conditions is illustrated in Figure 3-1 and 3-2. Flood extents under the proposed conditions decreased dramatically with the removal of the dams within the impoundment areas. These preliminary flood extents were created using available 2-foot contours for the river valley; a TIN was developed for the alternative condition with the anticipated channel alignment and flood channel built in. Only minor differences between the flood extents occur:

- Near the Sabin Dam, the new channel is planned to flow just to the right of the existing intake structures;
- The new channel is planned to go through the earthen impoundment for the Boardman Dam and flow into the existing Sabin impoundment from the west instead of the existing powerhouse structure;
- The TIN for the upstream extent of Boardman Pond under the alternative includes the anticipated channel, while the existing conditions TIN only includes the water surface. Therefore differences in this location do not reflect increased flooding in this area, rather differences in available datasets.

Note that these results are uncalibrated. Anticipated channel alignment is preliminary for feasibility level planning purposes and should be optimized during final design.

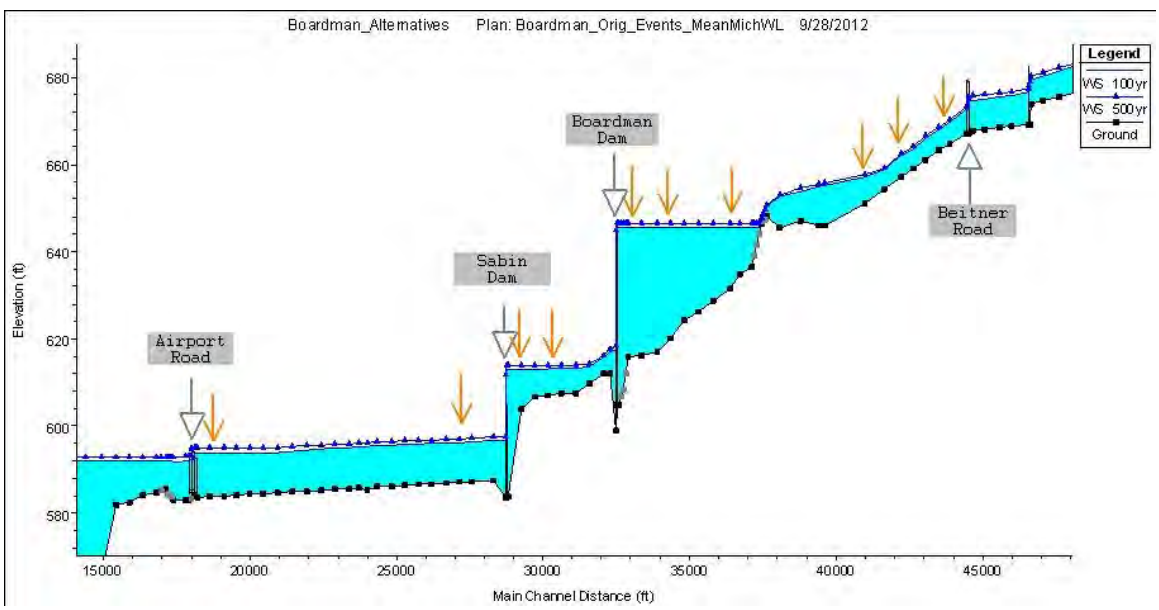

Figure 3-1: Longitudinal profile of the existing conditions of the Boardman River from Beitner Road to the upstream extent of Boardman Lake under the 100-year event. Orange arrows relate to the locations listed in the above table.

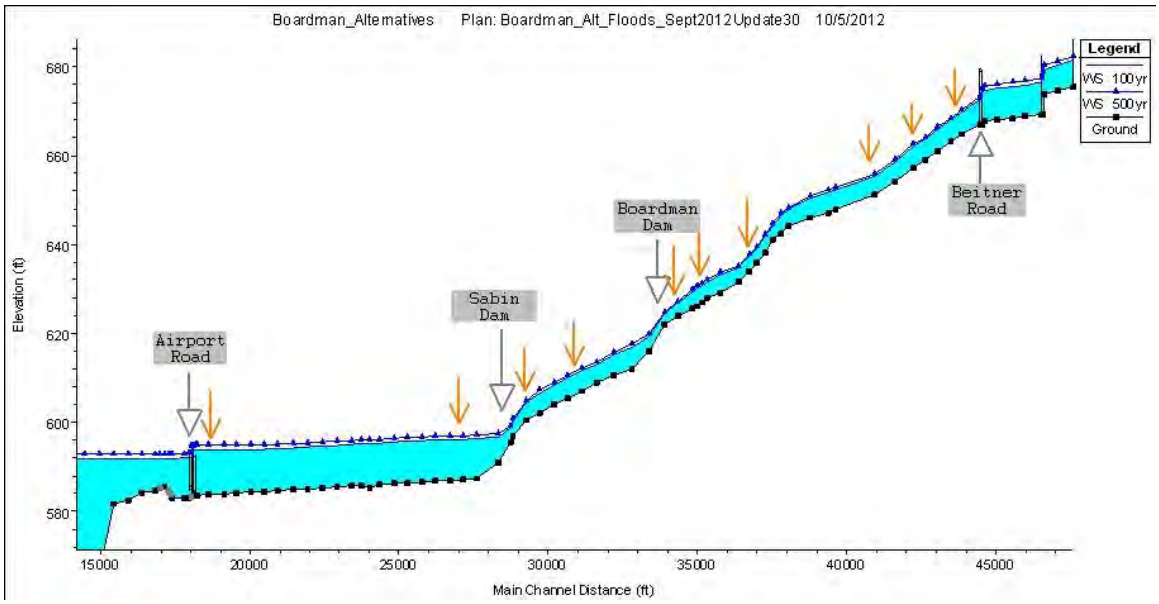

Figure 3-2: Longitudinal profile of the dam removal alternative removing the Sabin and Boardman Dams from Beitner Road to the upstream extent of Boardman Lake under the 100-year event. Orange arrows relate to the locations listed in the above table.

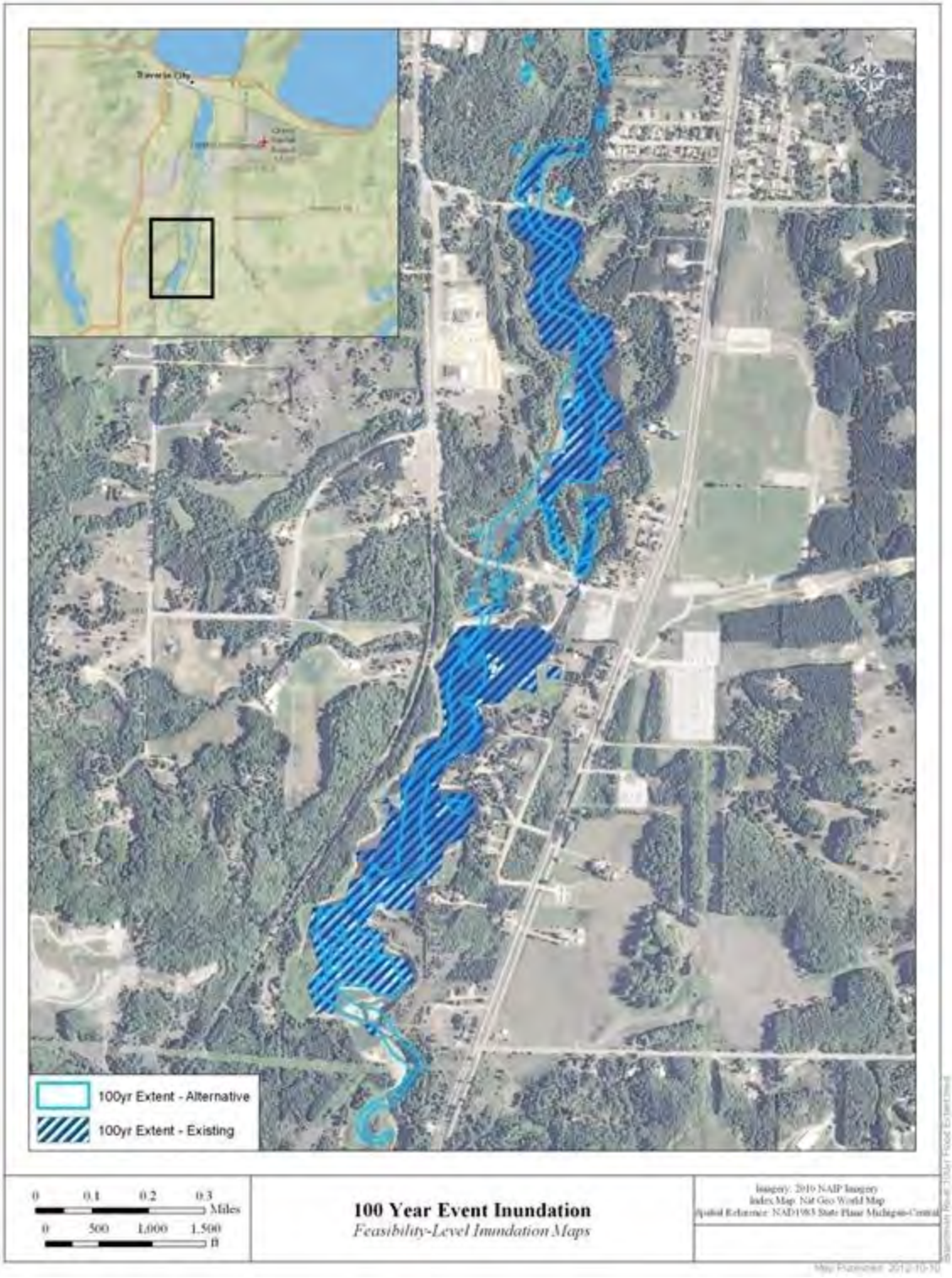

Figure 3-3: Estimated 100-year flood extents under existing conditions from Beitner Road (top right) to Airport Road (bottom left)

4 Sediment Fate and Transport Studies

Sediment fate and transport modeling and analysis were conducted to support feasibility design and construction purposes. Attachment 1 includes a detailed description of the modeling and analysis conducted to support the feasibility-level design. The Boardman River impoundments hold large volumes of sediment that could potentially be mobilized during dam removal or modification, and released downstream if not controlled. To protect the fishery habitat from excessive sedimentation during and after dam removal or modification, understanding the quantity, fate, and transport of the sediment within the Boardman River system is essential. The May 2009 SIAM Modeling Existing Conditions Study examined areas of sediment excess and limitation within the study area. Current modeling efforts rely on data from the 2009 study, additional survey data representing existing conditions, and channel and removal alternatives design specifications to adequately represent sediment transport and deposition patterns related to the alternatives; these sediment transport modeling efforts are intended to assess the impact that sediment would have on riverine habitat. The sediment fate and transport studies included the following activities, and results are described in detail in the Sediment Management Framework section:

- Assess the contamination level of sediment in each impoundment, based on available 2010 dredged samples within Boardman Pond and Sabin Pond, and how it would affect disposal options based on MDEQ regulations for contact and disposal.
  - While several metals tested exceed MDEQ background levels, only arsenic exceeds residential direct contact criteria.
  - No MDEQ regulations exist for recreational direct contact criteria; therefore, criteria are developed on a project-by-project basis. Based on the direct contact criteria developed previously for a nearby project and the minimal increase in arsenic above background levels, onsite disposal with topsoil cover is considered likely.
  - No organochlorine pesticides, polychlorinated biphenyls (PCBs), or semivolatile organic compounds were detected in any of the Boardman River ponds.
- Quantify how much sediment would be input into the system and transported for each alternative.
  - Sediment volume estimates were developed for the future river system, including floodplain and channel volumes. These were based on an analog approach, using existing surveys of the river provided by USACE, as well as additional field survey data.
  - Volumes of material to be disposed of, as well as disposal options, were identified.
- Evaluate sediment transport, deposition, and scour for existing conditions and each alternative.
  - The Baseline Conditions SIAM modeling report (USACE 2009) was used to provide estimates of sediment budgets and baseline sediment status for the system. The results

represented various sections of the Boardman River as either being in sediment balance, surplus, or deficit.

- Sediment transport modeling was conducted for the recommended alternative (remove the Boardman and Sabin Dams) and is used to provide comparison with the baseline conditions modeling to assess the potential for downstream sediment impacts, following dam removal.

Sediment transport modeling comparing transport under existing and the recommended alternative was completed using the HEC-RAS sediment transport simulation tool. A comparison of the channel inverts and invert changes at the end of a 15-year simulation is shown in Figure 4-1. These results illustrate the differences in sediment transport within the study area for the existing conditions and the proposed alternative. Removal of the dams restores natural sediment transport in the Boardman River as compared to the existing ponds that allow for buildup of alluvial sediments and block natural passage of sediments to downstream reaches. Removal of the dams would restore the natural sediment transport of the river. The model predicts that the relatively flat section of river approximately one mile downstream of Sabin Dam would accumulate sediment. The uncalibrated sediment transport model predicts a maximum of 8 ft of accumulation immediately downstream of Sabin Dam. This section of the river was previously dredged and is incised. Thus, significant accumulation in this section of the river is possible and would restore more appropriate channel dimensions. The sediment transport modeling shows minimal accumulation in the vicinity of the South Airport Road culverts; thus, maintenance issues associated with the road crossing are not expected. These areas of the river should be monitored to assess potential impacts of sediment accumulation.

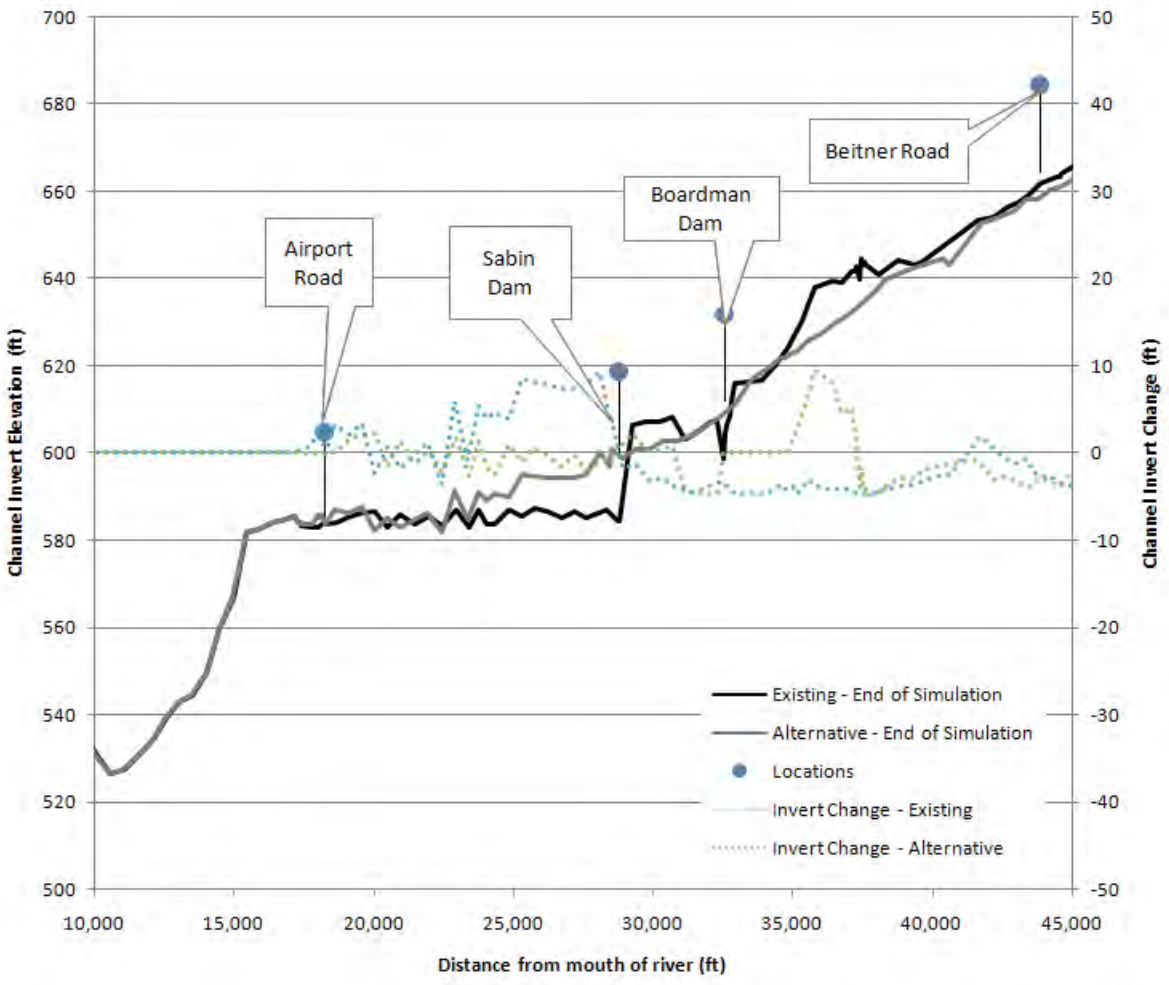

Figure 4-1: Comparison of channel inverts and invert changes for existing and alternative conditions

4.1 Sediment Management Framework

This section discusses a preliminary sediment management framework for Sabin and Boardman Ponds. This framework assumes that all sediment exists at a contamination level below thresholds requiring special handling and disposal techniques. Areas for sediment disposal/placement have been identified within the existing impoundment boundaries that account for all of expected sediment removed during restoration. Additional offsite disposal locations for management of sediment are being examined. Contaminants are not expected to have an impact on disposal locations and no mitigating measures, such as, clean cover, are expected.

For Sabin and Boardman Ponds, a total sediment volume to be mobilized through the establishment of the proposed cross-section and likely profile has been estimated. These feasibility-level designs are only estimates of where the new river channel and floodplain may occur. Refined field data collected during the design phase would be used to establish the pre-

dam channel alignment, profile and floodplain width. This information would be used to finalize the channel design. The proposed channel cross-section is based on observations of natural channel and floodplain width outside of the currently impounded areas.

Mechanical methods and natural processes would be used to establish the proposed channel (bankfull) and floodplain alignment. Mechanical removal of instream and floodplain sediment would occur in the wet and/ or dry, as needed to establish the desired floodplain width and channel alignment. For example, off line (in the dry) mechanical excavation may be needed through the former delta if depth of refusal data shows the historic channel was in a location different from where it formed during the drawdown. Sediment traps would be constructed during the removal process near the Sabin and Boardman Dams to aide in the capture of rapid-settling bedload sediments (sands and coarser sediments) that have built up behind the dams over time. These trapped sediments would then be removed by mechanical means to upland storage locations outside the existing channel and above the 100 year (1 percent) flood elevation. The frequency of sediment removal from the traps would depend on how rapidly they fill. Rate of infill would be dependent on upstream restoration activities, depth of impoundment (i.e. at the beginning of dewatering or near the end of dewatering), precipitation and level of vegetative cover. Given these unknowns sediment traps would be observed hourly and scheduled for clean-out on an as needed basis. A sediment trap would be cleaned out when the available capacity is 1 foot.

The sediment traps at the dam would need to be of sufficient size to capture fine grain sand material as it is mobilized upstream in the impoundment. The sizing of the basin is based on the travel time through the sediment trap and the rate of settling of the sediment. The settling velocity of the sediment is based on Stokes Law which was further developed by Rubey for specific particle sizes (Sturm, 2001). To further insure that sediment that is deposited in the trap is not re-suspended, the critical velocity for incipient motion was calculated using Einstein's equation (Sturm, 2001). After evaluating the geometry of the sediment traps upstream and downstream of the dams, it was determined that traps would capture sediments larger than 0.125 mm (fine sand) upstream of the breach and 0.27 mm (fine to medium sand) downstream of the breach. The majority of the sediments (75 percent) deposited in the impoundments has been found to be greater than 0.125 mm according to soil sampling data in Attachment 1.

Settling Velocity is expressed by the Rubey equation as:

$$w_f = F_* \sqrt{\left(\frac{\gamma_s}{\gamma} - 1\right) g d_s}$$

Where:

$$F_* = \sqrt{\frac{2}{3} + \frac{36}{d_*^3}} - \sqrt{\frac{36}{d_*^3}}$$

$$d_* = \left[\frac{\left(\frac{\gamma_s}{\gamma} - 1\right) g d^3}{\nu^2}\right]^{1/3}$$

$\gamma = the\ unit\ weight\ of\ water\ (9.81\ kN/m^3)$

$\gamma_s = the\ unit\ weight\ of\ sediment\ (12.5\ \ kN/m^3)$

$g = gravity\ (9.81\ \ m/sec^2)$

$d_s = sediment\ particle\ diameter (0.125\ mm)$

$\nu = kinematic\ viscosity\ of\ water\ (1.3x10^{-6}\ m^2/s)$

Critical Velocity as expressed by Einstein's equation:

$$V_c = 5.75 u_{*c} log\left[\frac{12.2R'x}{k_s}\right]$$

Where:

$u_{*c} = critical\ value\ of\ shear\ velocity\ (which\ is\ a\ function\ of\ particle\ size)$

$R' = hydraulic\ radius$

$x = a\ correction\ factor\ for\ smooth\ and\ transitional\ turbulent\ flow$

$k_s = equivalent\ sand\ grain\ roughness$

The resultant settling velocity was found to be 0.0015 feet per second for sediment greater than 0.125 mm. This would require a settling time of 3,234 seconds (54 minutes) for a five feet deep trap. The critical velocity for incipient motion was found to be 0.79 feet per second. Based on these calculations, the minimum trap geometry should roughly be 270 feet wide, by 1000 feet long and five feet deep. These characteristics are not likely achievable downstream of the breach locations. However, based on the bathymetry data, the impoundments would suffice to capture these sediments until the drawdown is within five feet of the proposed river elevation. Prior to completing the drawdown, deposited sediments would be removed from the upstream trap area as part of the sediment management. As the drawdown is completed the downstream sediment trap would be relied upon to capture sediments mobilized from the construction activity. Based on the available space (approximately 200 feet wide by 300 feet long), these traps would be capable of capturing fine to medium sand (0.27 mm).

The construction activities described above would result in fine silts and clays to be transported downstream to Boardman Lake. This material would be managed via the slow drawdown of the impoundment which would limit, but not eliminate movement of fine grained material. The magnitude and duration of fine sediment that is released downstream during construction should be monitored. During PED water quality based expectations related to turbidity and fine material levels should be developed with the regulatory agencies. This approach to managing the short and long term impacts of mobilized material would reflect a level of control commensurate with the environmental risk they pose during transport and settlement in Boardman Lake. Sediment quality sampling reported that all contaminants sampled were below the PEC and only arsenic

and cadmium were above the TEC which indicates there should be limited to no toxicity from the mobilized sediments. This conclusion is further supported by the lack of sediment quality related water quality or aquatic toxicity issues in either Boardman or Sabin ponds.

Mechanical excavation would likely be required within the existing impoundments to establish a floodplain bench to provide a naturally functioning restored river channel. Excavating the floodplain bench would decrease stresses within the channel during larger storm events and prevent head-cutting and bank erosion. Excavation of the floodplain bench can be done in a coordinated approach during the impoundment drawdown, in the dry. Figure 4-2 illustrates the proposed channel section and floodplain bench.

A sediment volume required to excavate the floodplain bench has been estimated for Sabin and Boardman Ponds. Potential fill areas (following drawdown) have been identified within both Sabin and Boardman Ponds to accommodate this sediment. These estimates are preliminary and for feasibility purposes only. Bathymetric data in the reservoirs was taken before recent drawdowns and therefore does not reflect any sediment movement that may have happened since the drawdowns.

While natural processes would mobilize sediment within the two Ponds, mechanical excavation would be required to breach existing dams and establish proposed channel alignments in these areas. As the earthen dam material is likely well drained, it would be placed in existing channel areas near powerhouse structures that would no longer be used after proposed channel restoration.

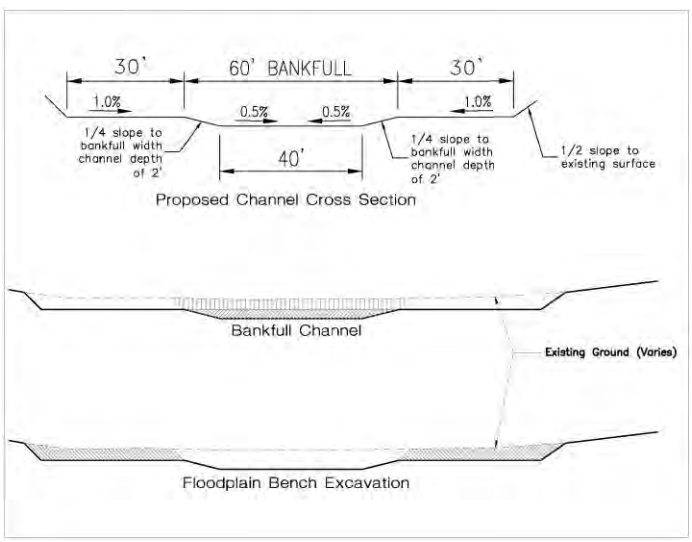

Figure 4-2: Proposed channel cross-section

The likely alignment would include engineered riffles/grade control structures at the locations of the existing Boardman and Sabin Dams (Figure 4-2). These riffles would add stability to the restored channel in areas of relatively steep natural grade. These riffle areas were compared to a geomorphic study of the Boardman River upstream of the impounded areas conducted by USACE (2007) to assure that channel slope was comparable to natural riffles in this river. In addition, engineered rock riffles would provide habitat and fish passage in the restored channel.

Velocities simulated at the riffles were less than fish burst speeds to insure that they can navigate the engineered riffles. In addition to the riffles natural ability to minimize headcutting, these engineered riffles would provide additional stability when they are keyed into and around the existing core wall that would remain below the bottom of the channel. As an added benefit, these riffles can create white water conditions that tend to attract kayakers and canoe enthusiasts.

Figures 4-4 and 4-5 illustrate the implementation of engineered riffles and bank stabilization measures. Figure 4-5 also shows an example of engineered rock riffles during low flow that exhibits natural materials resisting erosion, dissipating energy.

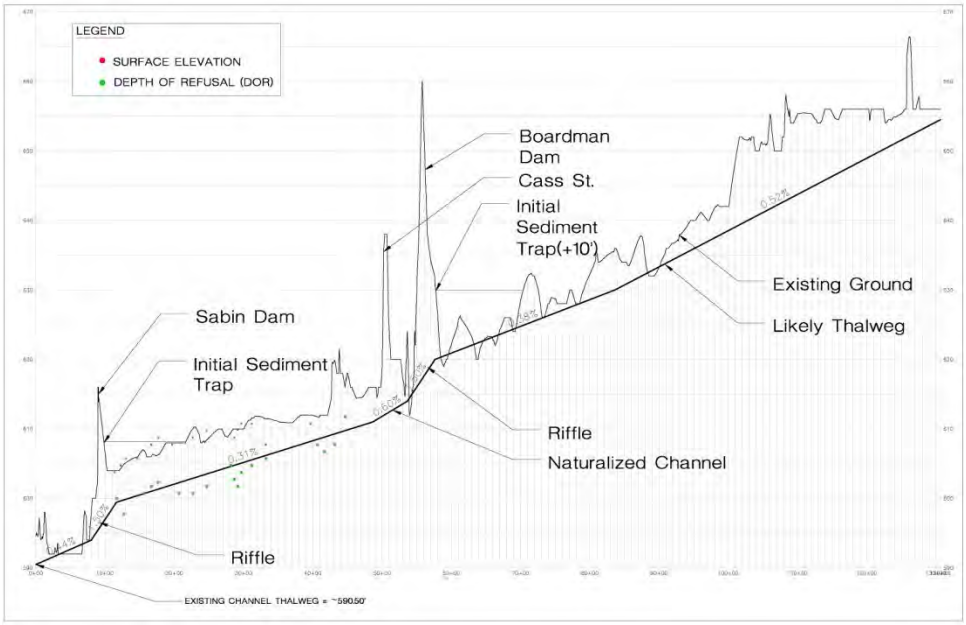

Figure 4-3: Likely profile of restored Boardman River

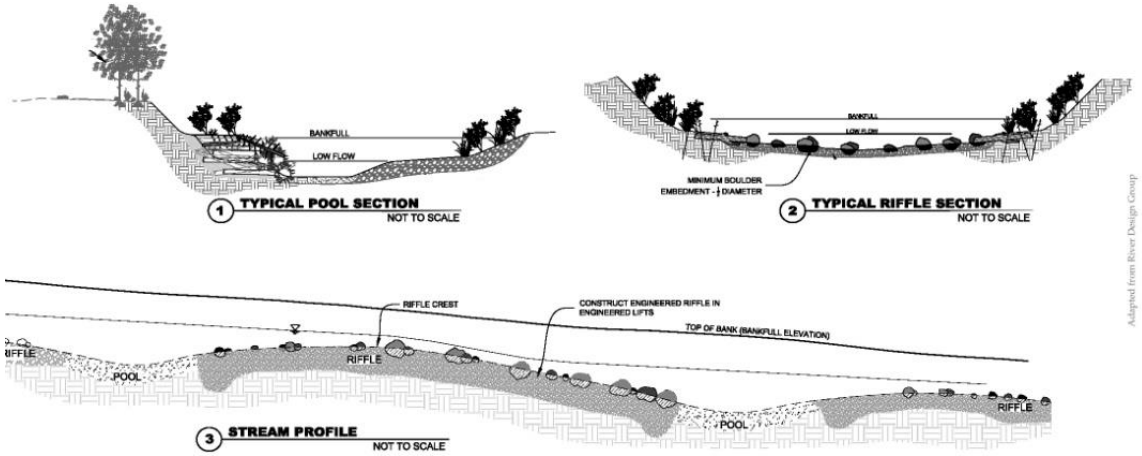

Figure 4-4: Profile of riffle/pool configuration with typical sections

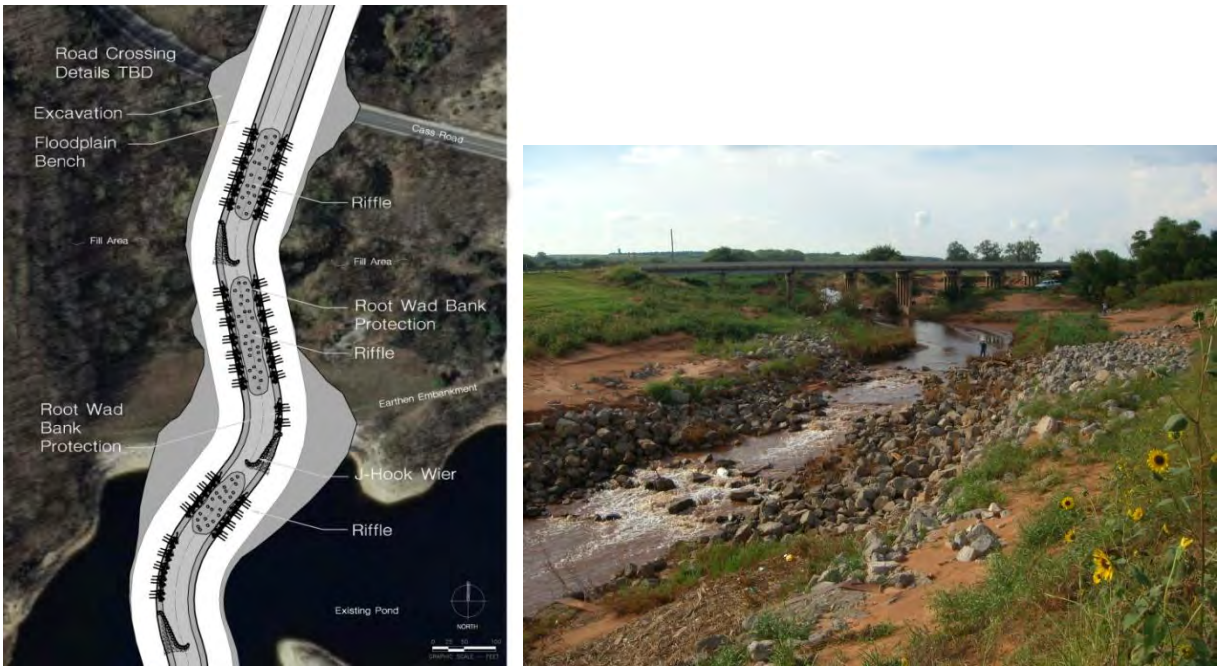

Figure 4-5: Application of engineered riffles and bank stabilization measures

In addition to engineered rock riffles, other bank stabilization measures may be used to redirect the channel and protect stream banks. These measures may include soil wraps, brush matting, rock and log toe protection, and root wad bank protection. These features provide varied habitat with structure, shade, and controlled scour holes. Soil wraps and brush matting would provide bank protection and a stable base for vegetative growth. Rock and log toe protection would provide armoring at the toe of the bank where failure may occur. Root wad structures would provide dual benefits. First, they would provide habitat for fish. Secondly, they would provide bank stabilization in high-stress areas. In addition, engineered riffles would provide spawning habitat for some species and reduce the possibility of head cutting within the former impoundment.

4.1.1 Sediment Management within Boardman Pond

It is anticipated that the establishment of a stable river channel through the historic Boardman Pond would require management by mechanical and passive measures approximately 281,000 cubic yards of sediment. Ten areas have been identified for the disposal of sediment. Areas A-E shown in Figure 4-6 would accommodate sediment from Sabin Pond, and Areas F–J would accommodate sediment from Boardman pond. All proposed sediment areas avoid wetlands as identified in Section 9.3.

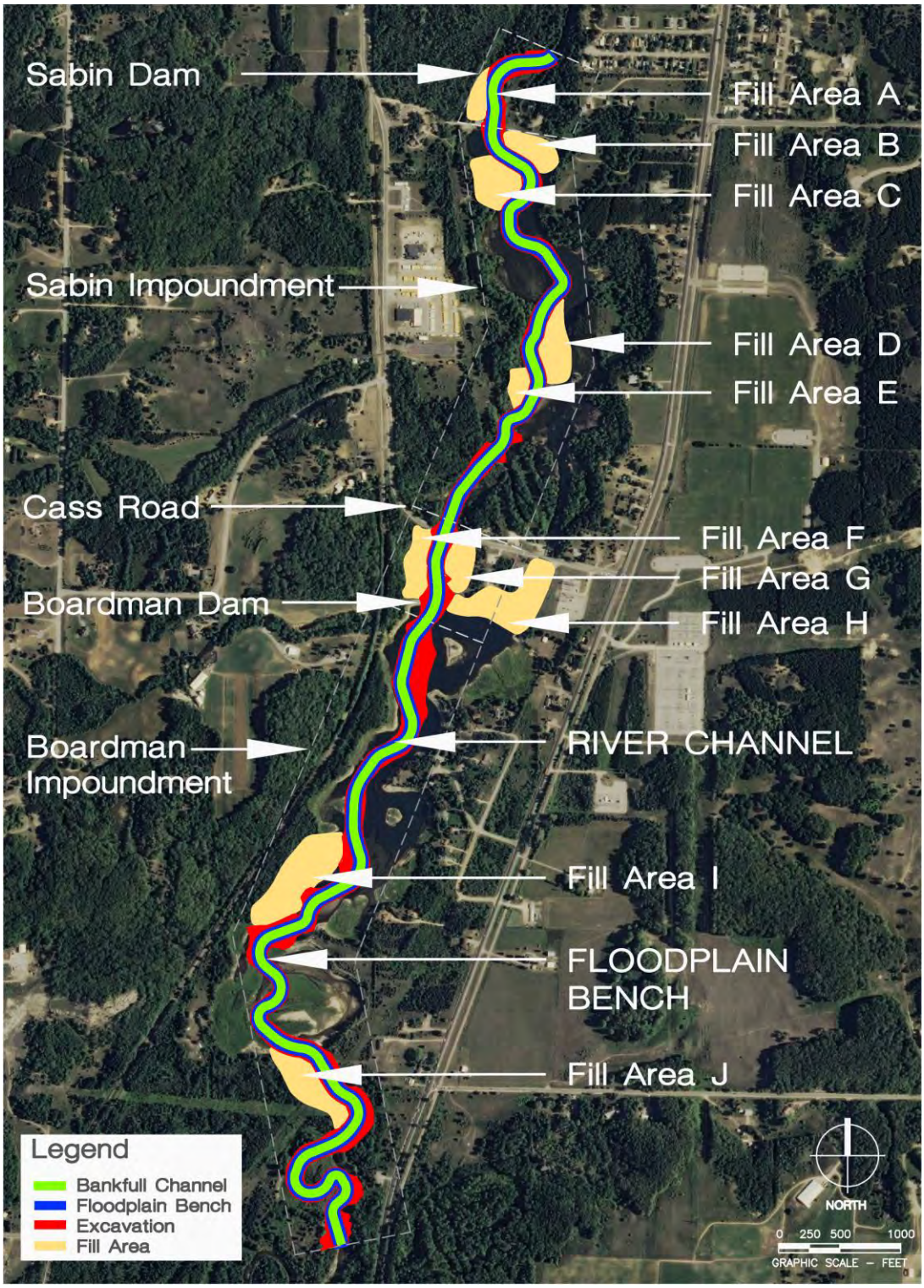

Figure 4-6: Sediment fill areas in Sabin and Boardman Ponds

Total sediment volume and volume storage areas have been calculated using three-dimensional surface comparisons in Autocad Civil3d software. The proposed cross-section has been applied

to the likely profile and alignment. The resulting TIN has been compared to the existing conditions TIN to determine a sediment volume likely to be mobilized.

An excess sediment storage volume of approximately 25 percent has been identified to provide a contingency for variation in the establishment of the likely channel alignment and uncertainty in the sediment volume estimates of the impoundments.
Table 4-1 provides a breakdown anticipated sediment volumes by source and management method, Table 4-2 provides a breakdown of the sediment disposal locations, and Table 4-3 provides the disposal capacity of each fill area.

Table 4-1: Anticipated Sediment Volumes

Restoration Area	Total Anticipated Sediment Volume (Cubic Yards)	Anticipated Channel Volume to be Managed via Sediment Traps (Cubic Yards)	Anticipated Floodplain Bench Excavation Volume (Cubic Yards)
Sabin Dam	20,000	(7,500) (included in excavation volume)	20,000
Sabin Impoundment	74,600	47,800	26,800
Boardman Dam	58,400	(37,800) (included in excavation volume)	58,400
Boardman Impoundment	128,000	85,600	42,400
Total:	281,000	133,400	147,600

Table 4-2: Anticipated Disposal Locations

Restoration Area	Anticipated Sediment Volume (Cubic Yards)	Adjacent Disposal Volume (Cubic Yards)	Adjacent Disposal Areas
Sabin Dam	20,000	13,500	A
Sabin Impoundment	74,600	82,800	B,C,D,E
Boardman Dam	58,400	76,300	F,G
Boardman Impoundment	128,000	174,400	H,I,J
Total:	281,000	(347,000)	

Table 4-3: Capacity of Primary Sediment Disposal Areas near the Boardman Dam

Disposal Area	Square Feet	Acres	Cubic Yards
A	55,000	1.26	13,500
B	92,700	2.13	15,400
C	135,600	3.11	21,000
D	125,400	2.88	23,700
E	48,800	1.12	22,700
F	93,200	2.14	36,000
G	82,600	1.90	40,300
H	234,700	5.39	86,000
I	204,000	4.68	56,000
J	140,800	3.23	32,400
Total:	1,212,800	27.84	347,000

4.1.2 Sediment Management Within Sabin Pond

Initial construction activities would include breaching the dam at the concrete spillway and drawing down the impoundment at one-foot increments. The actual drawdown rate would be dependent on the rate of sediment transport into the sediment traps. The concrete spillway would continue to be removed to an elevation of two feet below the proposed engineered riffle. The floodplain bench would be excavated through the earthen berm. Earthen material excavated from the channel and embankment (approximately 20,000 cubic yards) is expected to be free of contamination, and would be disposed of in Fill Area A. This area is located downstream from the existing powerhouse covering an area of approximately 1.26 acres, and would accommodate 13,500 cubic yards of fill.

A sediment trap would be provided by breaching the Sabin Dam to an elevation of +608 feet (three feet above the existing impoundment bottom). Sediment accumulating in the sediment trap would periodically be removed mechanically as construction commences and placed in Fill Area B. Additional temporary sediment traps would be installed throughout the impoundment to minimize the distance sediment is hauled to disposal sites.

Additional material excavated from Sabin Pond (a total of approximately 74,600 cubic yards) can be placed in Fill Areas B, C, D, and E as construction continues. Figure 4-6 provides plan view locations of the sediment disposal areas.

Fill Areas B and C can be utilized as the impoundment becomes dewatered and would be fine graded from the boundary of the proposed floodplain bench above the 100 year flood elevation to the existing earthen dam and impoundment walls. Fill Area B covers 2.13 acres existing

impoundment bed and accommodates 15,400 cubic yards, while Fill Area C covers 3.11 acres and accommodates 21,000 cubic yards.

Sediment from upper portions of Sabin Pond would be placed in Fill Areas D and E. Sediment would be graded smoothly over the existing impoundment bed in Fill Area D and against existing impoundment side slopes in Fill Area E. Fill Area D covers 2.88 acres and accommodates 23,700 cubic yards. Fill Area E covers 1.12 acres and accommodates 22,700 cubic yards. Figure 4-7 illustrates typical cross-sections through Fill Areas.

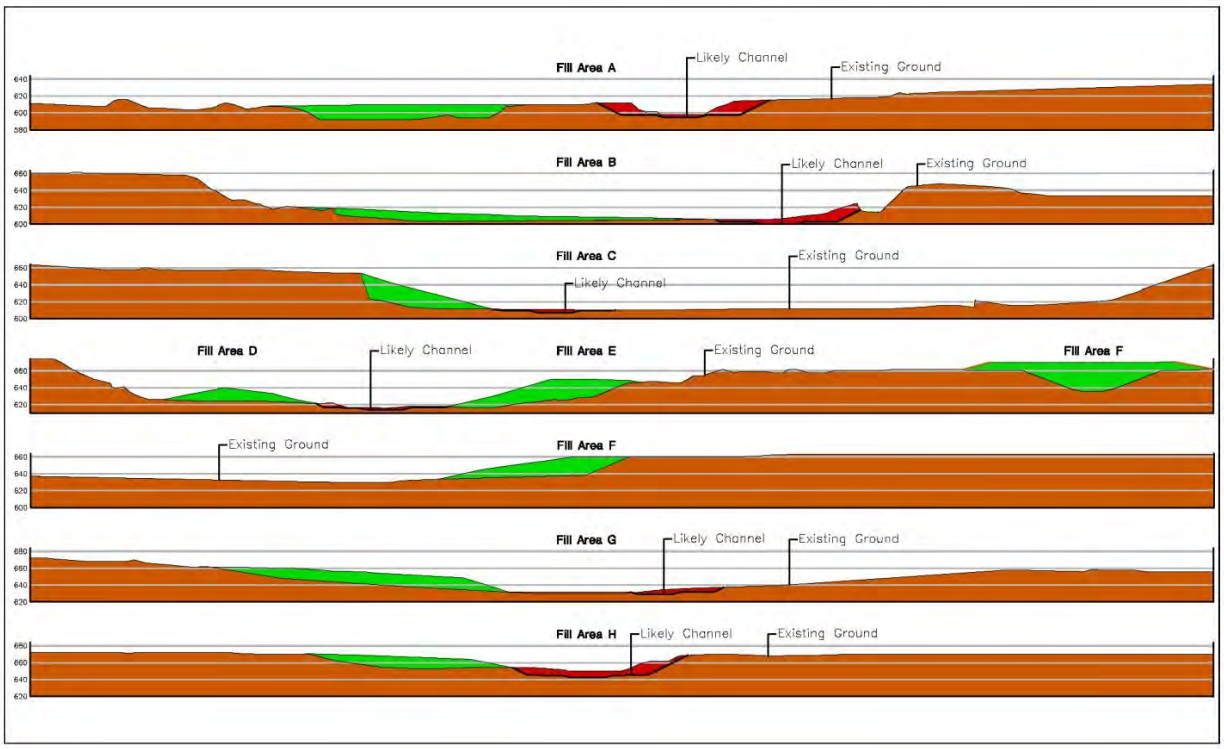

Figure 4-7: Proposed cross-sections through fill areas

5 Structural Evaluation of Dams

To assess costs associated with the No Action Alternative, each of the dams was inspected and future maintenance related to structural integrity and regulatory requirements was identified. This task used existing information, such as as-built drawings for each dam, existing soil borings, well logs, soil maps, utility crossings, and previous analyses performed during the BRDC Engineering and Feasibility Study.

Each dam was inspected by a qualified engineer during the BRDC process. Prein and Newhof inspected the Sabin and Boardman Dams and STS Consultants inspected the Union Street Dam. Inspections focused on major dam safety issues and the operation and maintenance costs to keep the dams in place.

5.1 Union Street Dam

5.1.1 Background

The Union Street Dam is a low-head, high hazard potential dam located 1.1 miles from the mouth of the Boardman River. The dam is located near downtown Traverse City. A dam was originally built in this location in 1867 to provide power to a flour mill. Modifications made in 1955 and 1965 brought the dam to its current condition. The concrete fish ladder was added in 1987.

The dam is used to provide stable water level control to Boardman Lake, which was raised approximately seven to nine feet as a result of the dam; to block the passage of ANS; to provide a pedestrian crossing point; and to support a 12-inch water main. In addition, there are fishing platforms above and below the dam and the site is part of a City park.

5.1.2 Operation

The Union Street Dam consists of three main components. The main 250-foot earthen embankment includes two spillways and fish ladder. The principal spillway consists of five 10.5-foot intake bays that are connected to 48-inch corrugated metal pipe (CMP) that extend 81 feet to the downstream toe of the dam. Stop logs and a slide gate control inflows into each bay. The auxiliary spillway consists of three stop log bays connected to a single 48-inch CMP that extends 130 feet through the embankment and discharges to a separate channel that connects to the Boardman River.

The fish ladder is six feet wide and 110 feet long. It consists of five baffles and is designed to pass a variety of fish species with high burst speed.

5.1.3 Existing Conditions of Structure

The Union Street Dam is in good condition. The dam is inspected by City staff regularly and by Professional Engineers as required by State Law. The most recent inspection conducted by STS found the dam to be in good condition with some minor repairs required (STS 2008). The repairs suggested included:

- Adding an expansion sleeve to one of the 48-inch CMPs that convey flow through the embankment to cover a joint that had separated. This repair was completed during the inspection.
- Adding a toe drain to the embankment to reduce seepage and the potential loss of soil. This repair has not been completed by the City of Traverse City.

In addition, the U.S. Fish and Wildlife Service (USFWS) inspected the stop logs in 2010 in the principal and auxiliary spillways to determine if they were stopping the passage of sea lamprey. This inspection identified several gaps between the stop logs and between the stop logs and concrete sill. These gaps are sufficient for passing sea lamprey. Because of the gaps and evidence of Sea Lamprey passing through them, the USFWS has requested that the Sabin Dam not be removed until repairs have been completed. The repairs suggested in the dam inspection report and by the USFWS have been completed as of April 2014.

5.2 Sabin Dam

5.2.1 Background

The Sabin Dam is the second dam upstream from Grand Traverse Bay, at river mile 5.3, and is an earthen dam consisting of a left earthen embankment, a powerhouse, an intermediate earthen embankment, a stop log spillway section, a tainter gate spillway section, and a right earthen embankment (Figure 5-1). The dam has a high hazard potential. It was originally constructed in 1906 for the Boardman River Light and Power Company, and then was completely rebuilt in 1930. In 2006, power generation operations were terminated and the dam was decommissioned. Power generation equipment has been removed from the dam.

Figure 5-1: The Sabin Dam powerhouse and spillway from east side of spillway looking west

5.2.2 Operation

Water at the Sabin Dam continues to pass through the right vertical shaft and outlets from the powerhouse into the Boardman River. In addition, the tainter gate is open and water flows through the tainter gate spillway. The stop logs in the powerhouse are manipulated to regulate water flow. Stop logs have been removed from the spillway and the water level in the Sabin Dam has been reduced to the maximum extent possible without beginning deconstruction of the dam.

5.2.3 Existing Condition of Structure

The following general observations of the structural condition of the dam were presented in previous reports and observed during the April 25, 2011, site visit:

- Minor cracks were observed in the brick superstructure of the powerhouse and the concrete walls of the spillway.
- Concrete deterioration and spalling were noted on the downstream side of the powerhouse, and were previously reported in Federal Energy Regulatory Commission Operations Reports.
- The roof of the powerhouse appears to leak. This is evidenced by retrofitted gutters located on the inside of the building.
- Deterioration and/or minor corrosion were observed at brick mortar joints, many of the window lintels, and angle brackets at door and window framing.

No issues were observed during the site visit that would require major rehabilitation to maintain dam safety. However, routine operation and maintenance, including roof, brick, and concrete maintenance would be required to prevent further deterioration of the dam structure and powerhouse. None of the observations made during the evaluation of Sabin dam preclude or cause concern when considered in context of the proposed removal approach or sequence.

5.3 Boardman Dam

5.3.1 Background

The Boardman Dam is the third dam upstream from Grand Traverse Bay, at river mile 6.1. The site consists of an earthen embankment to the left of the dam, an emergency spillway in the left bank, a concrete spillway structure and the penstock intake (Figures 5-3 and 5-4), and a short right embankment. A short middle embankment is located between the spillway chute and the powerhouse. In addition, the Cass Road bridge goes over top of this dam (Figure 5-2) and the bridge substructure is directly tied to the dam structure. The dam has a high hazard potential. It was originally constructed in 1894 for the Boardman River Light and Power Company, and then was completely rebuilt in 1930. In 2007, power generation operations were terminated and the dam was decommissioned. The power generation equipment has been removed from the dam.

Figure 5-2: Top of the Boardman Dam inlet structure looking west; inlet is to the left and outlet is to the right

Figure 5-3: The Boardman Dam inlet structure from the north side of Cass Road looking south

Figure 5-4: Boardman Dam inlet structure from the south side of Cass Road looking north

5.3.2 Operation

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

Because hydropower is no longer being generated, the dam is operated as a run-of-the-river dam. At the date of the inspection on April 25, 2011, all of the flow was being discharged through the penstocks. The spillway was dry, except for some minor seepage.

The MDEQ determined that the spillway capacity of this dam does not meet the requirements for the high-hazard potential classification. In 2007 MDEQ required Grand Traverse County, the owner of the dam, to lower the water level behind the dam. This was done to stabilize the structure. At the time of the site visit, the water level appeared to be at or close to this drawn down level (approximately 17 feet lower than previous water levels).

5.3.3 Existing Condition of Structure

The following general observations of the structural condition of the dam and bridge were presented in previous reports and observed during the April 25, 2011, site visit:

- There is significant cracking in the walls of the dam structure, which also serve as the substructure supports for the bridge. Leeching and efflorescence can be seen on the concrete walls and underside of the bridge superstructure (Figure 5-5).
- The concrete beams that form the bridge superstructure are cracked and there is significant spalling on the fascia beams. The superstructure is constructed of steel beams encased in concrete. The spalling concrete has exposed portions of the steel girders in the fascia beams (Figure 5-6).
- The bridge barrier railing is in significant disrepair and is protected by a temporary concrete barrier.
- The bridge is posted for 10 Tons – 10 Tons – 20 Tons (1 unit – 2 unit – 3 unit vehicles) depending on the number of units that make up the truck.
- The bridge deck has been patched with hot mix asphalt multiple times.
- Many of the door and window frames on the powerhouse are corroded.
- The roof of the powerhouse is leaking and needs either replacement or significant repairs.
- Seepage was noted in multiple locations along the earthen embankment in previous reports.
- A few cracks in the grout around the brickwork in the powerhouse were noted, especially on the downstream side of the powerhouse.

Based on the Federal Highway Administration sufficiency rating system, this bridge received a score of 4 out of 100 according to an April 24, 2011, article in the Traverse County Record Eagle newspaper. The article stated that if the score went any lower, the bridge would be closed to traffic. If the deck condition gets any worse in the near future, the score for the bridge would go lower. The structural evaluation, deck geometry, and width of roadway insufficiency scores are already low.

Repairs to this bridge would be cost-prohibitive for the long-term benefits that would be achieved. This bridge, if it is not already, should be on the County's short list of projects to be completely replaced. This work should be coordinated with the complete or partial removal of the dam.

If leaving portions of the existing dam and/or powerhouse in place is desirable for construction of the new bridge, routine operation and maintenance, including roof, brick, and concrete repair would be required to prevent further deterioration of the dam structure and powerhouse. The poor condition of the existing bridge makes it unsuitable for prolonged use as a construction access point. Once the dam has been breached and the river rerouted the existing bridge should be demolished replaced with a road.

Figures 5-5 and 5-6 illustrate the deteriorated condition of the Cass Road bridge over the Boardman Dam.

Figure 5-5: Underside of the Cass Road bridge / Boardman Dam showing spalling, efflorescence and deterioration of safety rails

Figure 5-6: Example of significant spalling with steel girders exposed

5.4 Geotechnical Investigations

As part of the design phase it would be necessary to gather additional geotechnical data to evaluate soil and groundwater conditions prior to finalizing designs. This section summarizes those geotechnical needs at each dam.

5.4.1 Union Street Dam

5.4.1.1 Purpose

The purpose of the geotechnical investigation at the Union Street Dam is to determine concrete thickness and underlying material characteristics at the location of the existing auxiliary spillway. The existing spillway and downstream culverts would be removed and replaced to accommodate downstream sturgeon passage and maintain current sea lamprey protection. Prior to removal of the existing concrete spillway, a combination of coring and auger drilling techniques would be utilized to develop a subsurface profile of the spillway structure and underlying soils. Auger drilling techniques would also be employed upstream of the spillway to determine soil characteristics as they pertain to design of temporary sheet piling, for dewatering during construction.

5.4.1.2 Scope

A truck mounted drill rig would access the existing auxiliary spillway area by way of the parking lot to the south. Rock coring technology would be utilized to begin drilling a boring located within the inlet structure to the concrete auxiliary spillway (B-13 on Figure 5-7). Once the full thickness of concrete in the inlet structure has been penetrated, hollow stem auger technology would be utilized to advance the boring to a depth of approximately 30 feet below the bottom of the structure.

A truck mounted drill rig would access the existing earthen dam area by way of the parking lot to the north. Hollow stem auger drilling technology would be utilized to advance a single soil boring [B-14 (Alt. A) on Figure 5-7 in the area leading to the auxiliary spillway inlet structure. Soil boring B-14 (Alt. A) would be advanced to a depth of approximately 30 feet below the bottom of the impoundment bottom at this location. As an alternative, the soil boring in the area leading to the auxiliary spillway inlet structure would be advanced in a location to the south [B-14 (Alt. B) on Figure 5-7].

Soil samples would be collected in all borings at 5 to 10 foot intervals utilizing split spoon samplers and/or Shelby (thin wall) tubes. Laboratory testing of select samples from B-13 and B-14 may include such routine tests as direct shear, unconfined and triaxial compression, sliding friction, modulus of elasticity, tensile strength, natural and dry density, moisture content, consolidation, Atterberg Limits, grain-size analysis, and permeability. Standard Penetration Test (SPT) values would be recorded in all borings. A geologist would record a field log of all borings and collect relevant information as the soil borings are advanced.

Figure 5-7: The Union Street Dam geotechnical soil boring locations

5.4.2 Sabin Dam

5.4.2.1 Purpose

The purpose of the geotechnical investigation at the Sabin Dam is to determine concrete thickness and underlying material characteristics at the location of the existing spillway and to determine subsurface material characteristics of the earthen dam embankment located directly east of the spillway. The existing concrete spillway would be removed in order to create a channel for the Boardman River to pass through the dam and flow to the north. Prior to removal of the existing concrete spillway, a combination of coring and auger drilling techniques would be utilized to develop a subsurface profile of the spillway structure and underlying soils. Auger drilling techniques would also be employed at the location of the earthen dam embankment to the east of the spillway in order to determine subsurface characteristics for planned removal of the material adjacent to the spillway.

5.4.2.2 Scope

A truck mounted drill rig would access the existing dam area by way of the two track road that enters the site from the east. Rock coring technology would be utilized to drill the upper portion of the borings located in the concrete spillway (B-1 and B-2 on Figure 5-8). Once the full thickness of concrete in the spillway has been penetrated, hollow stem auger technology would be utilized to advance the borings to a depth of approximately 10 feet below the pre-dam river channel bottom.

Hollow stem auger drilling technology would be utilized to advance a single soil boring (B-3 on Figure 5-8) in the earthen dam embankment located east of the spillway to a depth of approximately 60 feet below existing grade.

Soil samples would be collected in all borings at 5- to 10-foot intervals utilizing split spoon samplers and/or Shelby (thin wall) tubes. Laboratory testing of select samples from B-1, B-2, and B-3 may include such routine tests as direct shear, unconfined and triaxial compression, sliding friction, modulus of elasticity, tensile strength, natural and dry density, moisture content, consolidation, Atterberg Limits, grain-size analysis, and permeability. Standard Penetration Test values would be recorded in all borings and depth to groundwater would be recorded. A geologist would record a field log of all borings and collect relevant information as the soil borings are advanced.

Figure 5-8: The Sabin Dam geotechnical soil boring locations

5.4.3 Boardman Dam

5.4.3.1 Purpose

The purpose of the geotechnical investigation at the Boardman Dam is to determine subsurface material characteristics of the earthen dam embankment located to the south of the proposed bridge location. The pre-dam river channel would be restored through the earthen dam berm and would flow to the north toward Cass Road and continue on beneath the planned bridge span.

Prior to the design of the proposed breaching method auger drilling techniques would also be employed at the location of the earthen dam embankment to the south of the planned bridge in order to determine subsurface characteristics for planned removal of the material in the location of the proposed restored river channel.

5.4.3.2 Scope

A truck mounted drill rig would access the existing dam area by way of the two track road that enters the site from the parking area to the east. Hollow stem auger drilling technology would be utilized to advance four soil borings (B-9, B-10, B-11, and B-12 on Figure 5-9) in the earthen dam embankment in the area where the Boardman River channel would be restored. The earthen dam embankment borings would be advanced to a depth of approximately 60 feet below the top of the existing embankment.

Soil samples would be collected in all borings at 5- to 10-foot intervals utilizing split spoon samplers and/or Shelby (thin wall) tubes. Laboratory testing of select samples from all borings may include such routine tests as direct shear, unconfined and triaxial compression, sliding friction, modulus of elasticity, tensile strength, natural and dry density, moisture content, consolidation, Atterberg Limits, grain-size analysis, and permeability. Standard Penetration Test values would be recorded in all borings and depth to groundwater would be recorded. A geologist would record a field log of all borings and collect relevant information as the soil borings are advanced.

Figure 5-9: The Boardman Dam geotechnical soil boring locations

6 Engineering Analysis of Dam Breaching and Removal Options

Conceptual layouts for dam breaching and removal options have been developed and are presented in this section. These include a conceptual construction plan that addresses such issues as water diversion, earth moving, concrete removal, slope stability, and shoreline protection. Quantity take-offs are provided for use in estimating costs for the alternatives.

In 2009, Prein and Newhof completed a dam breach/drawdown study of each dam for the BRDC. The analyses found that each dam could be drawn down either by pumping the river around the dam or by constructing a temporary stop-log structure. While these options remain feasible, additional breaching options for the Sabin and Boardman Dams were developed in an effort to achieve the same results with less risk and/ or lower costs.

6.1 Union Street Removal Option Evaluation

The non-Federal sponsor wishes to retain the hydraulic control provided by the Union Street Dam. This structure raises the water level of Boardman Lake approximately 9 feet. Boardman Lake is a natural lake, which the Union Street Dam makes larger. Significant infrastructure is dependent on the water level in Boardman Lake, including discharge of the regional wastewater treatment plant and road crossings. Plus, the Union Street Dam is an important barrier to sea lamprey in the Boardman System. For these reasons, full removal of the Union Street Dam was not considered. All partial removal or modification alternatives considered for Union Street must maintain the existing Boardman Lake level and provide sufficient barrier to invasive species. Modification options are considered in the following section.

The partial removal of the Union Street Dam would involve converting the dam from a gate-controlled, flow-through dam to a free-flowing, flow-over dam. To accomplish this, a new concrete core wall would be installed upstream of the current dam. This wall would be supported upstream and downstream with fill as well as a rock ramp downstream. The rock ramp would be constructed at a shallow enough gradient to accommodate the passage of all desired fish species. A barrier to ANS would be necessary downstream of the proposed rock ramp.

The proposed Union Street Dam flow over modification measure would consist of a 600-foot engineered slope (rock ramp) that is composed of large rocks and cobble to small gravel. The slope of the engineered structure would vary along its length and have a maximum slope of 2 percent. A 2 percent slope was selected because it was comparable to the slopes of riffles upstream of the study area and simulated velocities at 2 percent slope were less than fish burst speeds. Approximately 10,000 cubic yards of fill material and 100 cubic yards of structural concrete would be needed to construct the engineered riffle. Figure 6-1 illustrates the proposed removal option and rock ramp construction in plan view, while Figure 6-2 illustrates the profile view of the proposed rock ramp.

The fish barrier associated with this alternative would be installed at the location of the current MDNR trap-and-transfer facility between Front Street and the northern Union Street crossing. This location was selected because it provides a barrier for Kids Creek and allows for use of the MDNRs existing trap-and-transfer facility. The trap-and-transfer facility would be modified to

accommodate the passage of the sturgeon past the barrier. According to the U.S. Fish and Wildlife Service, the barrier would be required to be a permanent structure with no moving or temporary components.

An evaluation of the proposed barrier was conducted using HEC-RAS to evaluate the rise of the water surface elevation. The design criterion of the lamprey barrier is to provide an 18-inch drop from the top of the barrier to the downstream water surface, during a 10-year storm event. Additionally, a minimum 4-inch ledge is required on the downstream face of the barrier to prevent lamprey from climbing over the barrier. The results of the preliminary analysis indicate that the flood elevations between the proposed barrier and the Union Street Dam would increase significantly during the 10, 100 and 500 year design events. Because of this increase in flood stages, LOMRs would be required and property acquisition would likely be necessary to mitigate potential flood hazards.

Removal of the dam would require a multi-step process. The first component of the dam removal would be to remove (and reroute) the water main that is currently on top of the dam. The flow of the river would then be diverted the northern half of the river channel and allowed to continue to flow through the culverts. This would be accomplished with sheet piling in the river. During this first step, the south half of the core wall would be constructed and the south half of the existing dam (including the fish ladder) would be removed to the elevation necessary for the rock ramp. Additional fill would be placed as necessary and the rock and hard armoring would be placed.

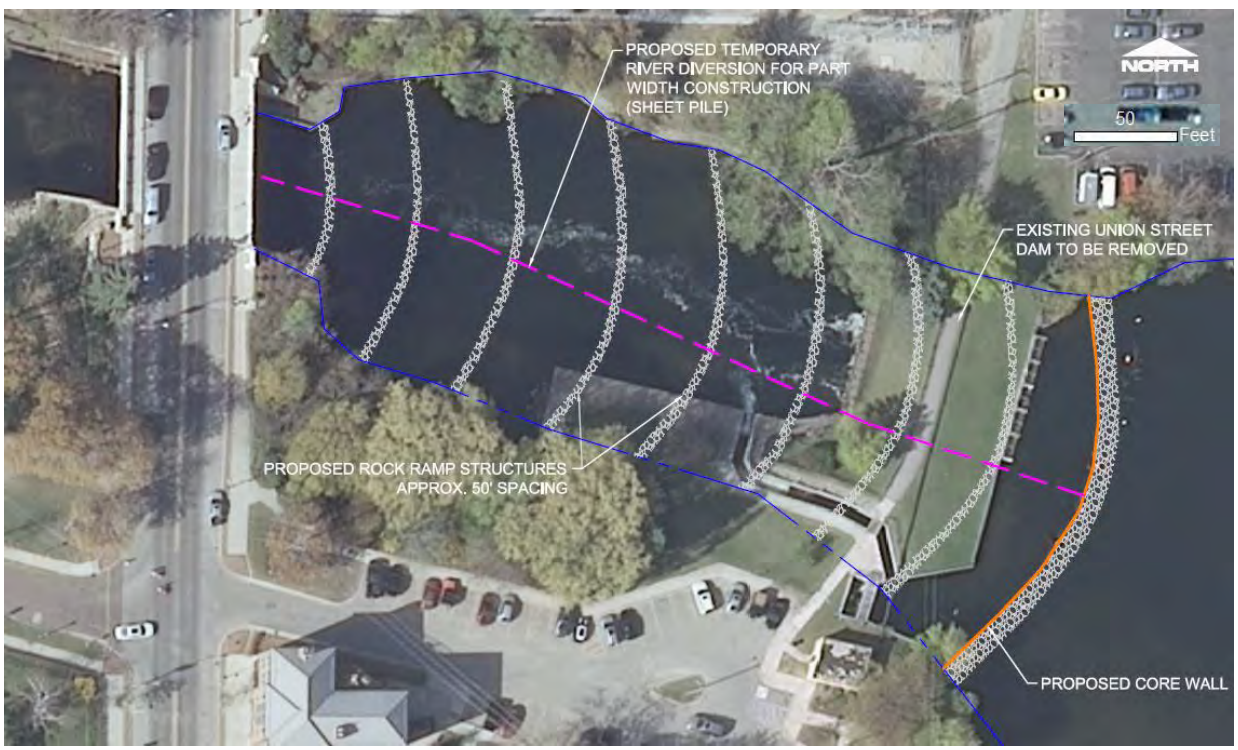

Figure 6-1: Plan view of proposed Union Street rock ramp

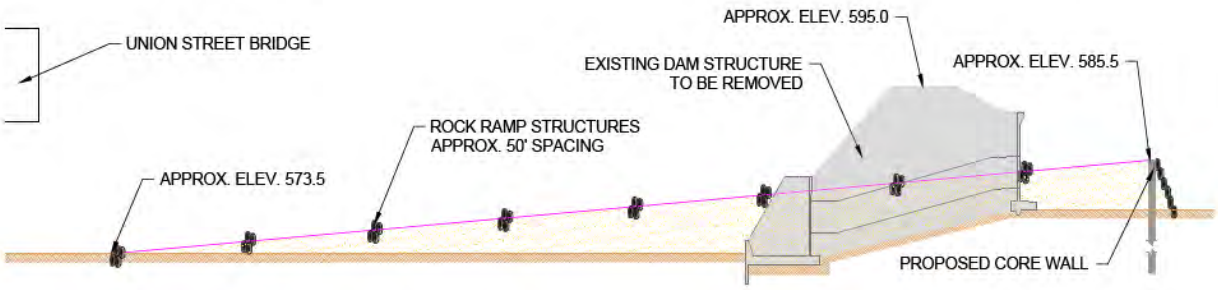

Figure 6-2: Profile view of proposed Union Street rock ramp

During this part of the process, the flow of the river would be diverted to the southern half, over the newly constructed rock ramp. The northern half of the core wall would be constructed and tied into the southern half. The earthen dam would be removed to the extent necessary for the rock ramp grades, and the culverts would be filled in and capped. Additional fill would be placed as necessary, and the rock and hard armoring would be placed. Finally, the channel diversion measures would be removed, and the river would flow naturally over the new rock ramp structure.

The construction of the sea lamprey barrier would consist of a sheet pile wall below the surface of the channel, to prevent undermining, with a concrete cap. Installed on top of the cap would be a pre-fabricated stop log structure that would allow the barrier to be removed outside of the sea lamprey spawning season. The existing walkway over the river would need to be either modified or replaced to accommodate a mechanical lift system for the gates. Additionally, a lift system would need to be installed to assist with moving the fish upstream of the weir. Initially, this would require lifting the sturgeon to trucks for transport to locations upstream of Boardman Lake. Once sturgeons become established in the river, the fish would only need to be lifted above the weir.

6.2 Sabin Dam Removal Option Evaluation

One of the options under consideration for the restoration of the Boardman River is the removal of the Sabin Dam. Several characteristics of the Sabin Dam may impact this alternative. The water flow is split between the existing spillway and the powerhouse. Using the stop logs and a controlled drawdown, the spillway can be removed in stages to facilitate sediment management goals. The current dam was constructed in the 1930s, and from the existing plans appears to have been keyed into portions of the existing dam built in 1906. These existing drawings are difficult to read and the contractor could encounter unknown site conditions that cannot be interpreted from the plans. Finally, some of the embankments around the dam are quite steep, which might affect construction access.

Dam removal would remove the concrete spillway and a floodplain through the earthen dam. The exposed bottomlands would be restored to a free-flowing channel through the former impoundment. The river would be allowed to form its own path during the drawdown process. In doing so, it would move sediment and self-armor with existing gravel, cobble, and boulders and is expected to follow the pre-dam river channel.

Currently, Sabin impoundment has been drawn down approximately four feet from its normal pool elevation to prepare the dam for removal. This drawdown was accomplished by removing all of the stop logs at the powerhouse and spillway structures. Under low-flow conditions, all of the flow passes through the chutes under the auxiliary spillway (elevation 600.3 feet). Under higher flow conditions some of the flow passes through the powerhouse (elevation 608.9 feet).

The breach point for the Sabin Dam is proposed to be at the current spillway location (Figure 6-3). The breaching would be performed in one-foot intervals and complete drawdown is anticipated to take 20 to 30 days. The spillway is constructed of reinforced concrete with extensive energy dissipating structures in the form of large concrete chunks. These structures would be re-purposed during construction to build a downstream sediment trap during the drawdown process.

The drawdown would be accomplished by notching down the concrete spillway using an excavator-mounted hydraulic jack hammer. The contractor would notch down the spillway incrementally to drawdown the impoundment at a maximum rate of one foot per day. This drawdown increment was estimated based on the difference between the capacity of the breaching channel and the average daily flows. The actual drawdown rate would be determined in the field, based on observed sediment movement and hydrologic conditions. The incremental drawdown would continue until the breach elevation is two feet below the proposed engineered riffle. The engineered riffle would then be keyed into the remaining substructure.

Sediment management during the drawdown operation would be accomplished through a series of sediment traps and active excavation of the channel and floodplain. Initially when the drawdown begins, the impoundment itself would operate as a large sediment trap, with the majority of sediment settling in the impoundment and a secondary sand trap would be constructed immediately below the auxiliary spillway where the breach is occurring (Figure 6-3). As the water level continues to drop sediment traps would be placed within the impoundment area to trap sediment migrating from upstream. The sediment traps would be re-excavated as needed based on maintaining a minimum depth of five feet or as deemed necessary by downstream sediment migration. In addition to the sediment traps, the channel and floodplain would be actively shaped from the upstream direction to downstream to insure that it meets the design criteria. This would result in sediment being removed to disposal sites within the impoundment that would not be subject to erosion and transport. Turbidity monitoring would be necessary downstream of the breaching operations throughout the duration of the project.

Figure 6-3: The Sabin Dam breaching plan

6.3 Sabin Dam No Action Option Evaluation

As mentioned previously, no issues were observed during the site visit or detailed in previous reports that would require major rehabilitation to maintain dam safety, if the decision is made to leave the existing dam in place. Annual maintenance costs to Grand Traverse County for this dam are $20,000. An additional amount (approximately $20,000) could also be spent on repairing some of the minor cracks in the brick superstructure of the powerhouse, fixing the roof leak, and repairing some of the minor deterioration of the brick mortar joints. This would help prolong the life of the structure if the No Action Alternative is pursued.

6.4 Boardman Removal Option Evaluation

One of the options being considered for the restoration of the Boardman River is the partial or complete removal of the Boardman Dam. Dam removal would remove the concrete spillway, and provide a properly sized floodplain through the earthen dam. The exposed bottomlands would be restored to a free-flowing channel through the former impoundment. The river would

be allowed to choose its own path, which is expected to follow the path of the historic river channel. In doing so, it would move sediment; self-armor with existing gravel, cobble, and boulders; and expose the former channel bed. Excavation of the river channel would provide removal of sediment from the channel, as needed, as well as provide appropriate sized floodplain. This would occur during and after the drawdown process.

The Boardman Dam breaching operation is planned for the earthen embankment in the location of the pre-dam river alignment. The breaching would be accomplished by pumping the water over the earthen embankment and removing the earthen dam in the dry. The earthen embankment is composed of fill material and a reinforced concrete core wall. A sheet pile curtain wall extends a minimum of 10 feet below the concrete core wall. The native soils below the embankment are a mixture of sands and clays.

The breaching operation would begin with the removal of the top of the embankment and core wall to within five feet of the existing water surface elevation in the impoundment. Portable pumps would be installed on this newly created "work pad" on the west side of the embankment. Fused high density polyethylene (HDPE) pipes would be connected to the pumps for suction and discharge lines. The total capacity of the pumping system would be 400 cubic feet per second (cfs). This would provide ample capacity to meet the desired drawdown rate of one foot per day under mean flow conditions (approximately 270 cfs) (Prein and Newhof 2009). This flow rate also exceeds the 10 percent exceedance flow of 390 cfs (for the months of June, July, August, and September). As a redundant safety measure, the contractor would have onsite flexible hard armor mats (ArmorFlex) to place in a constructed channel across the embankment, in the event that the pumps fail or capacity is exceeded. Additionally, the contractor would always maintain a minimum of five feet of freeboard on the earthen berm until the impoundment level is within three feet of the proposed river profile. At such time, the contractor would complete removal of the earthen dam. A float activated alarm system would be installed on the upstream side of the impoundment to notify the contractor if the water level begins to rise. Figure 6-5 illustrates the lowering of the earthen embankment in cross section view. Figure 6-6 provides a plan view of the drawdown operation.

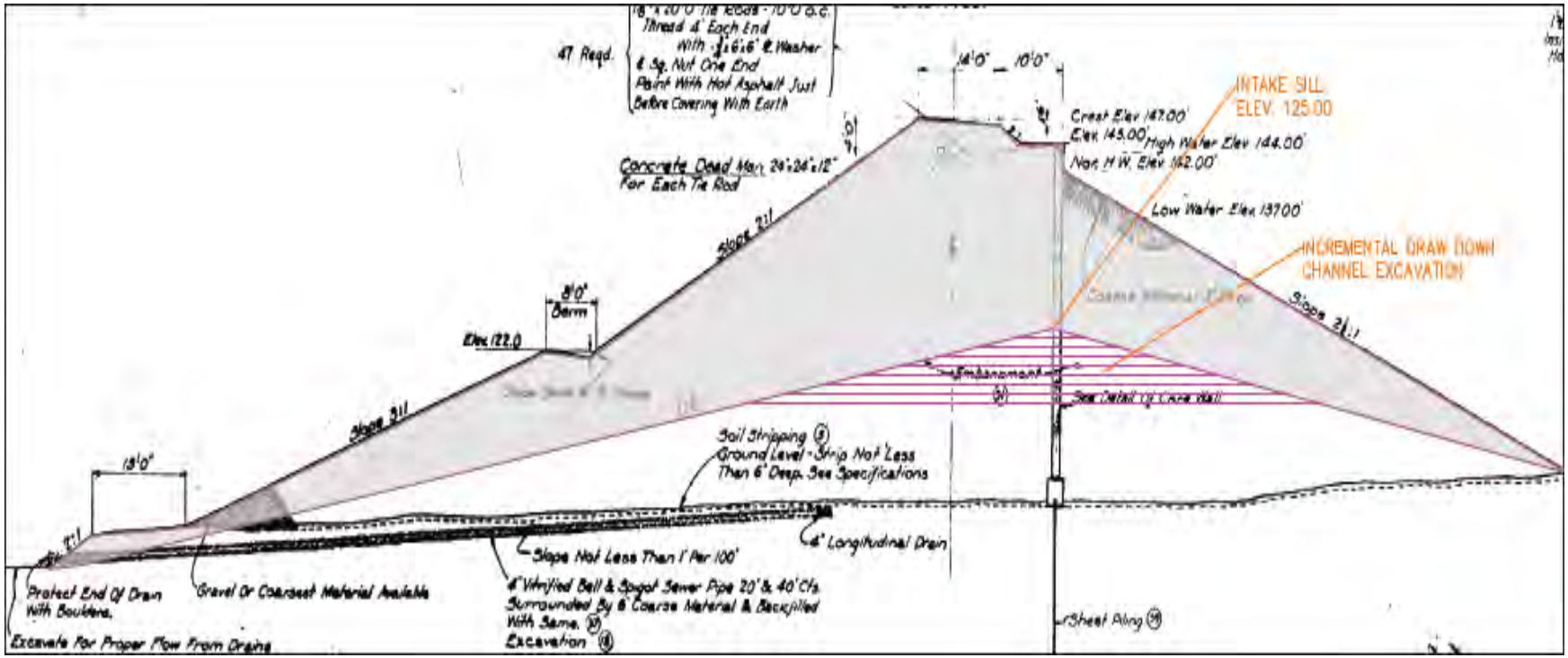

Figure 6-4: Profile of the Boardman Dam breaching operation

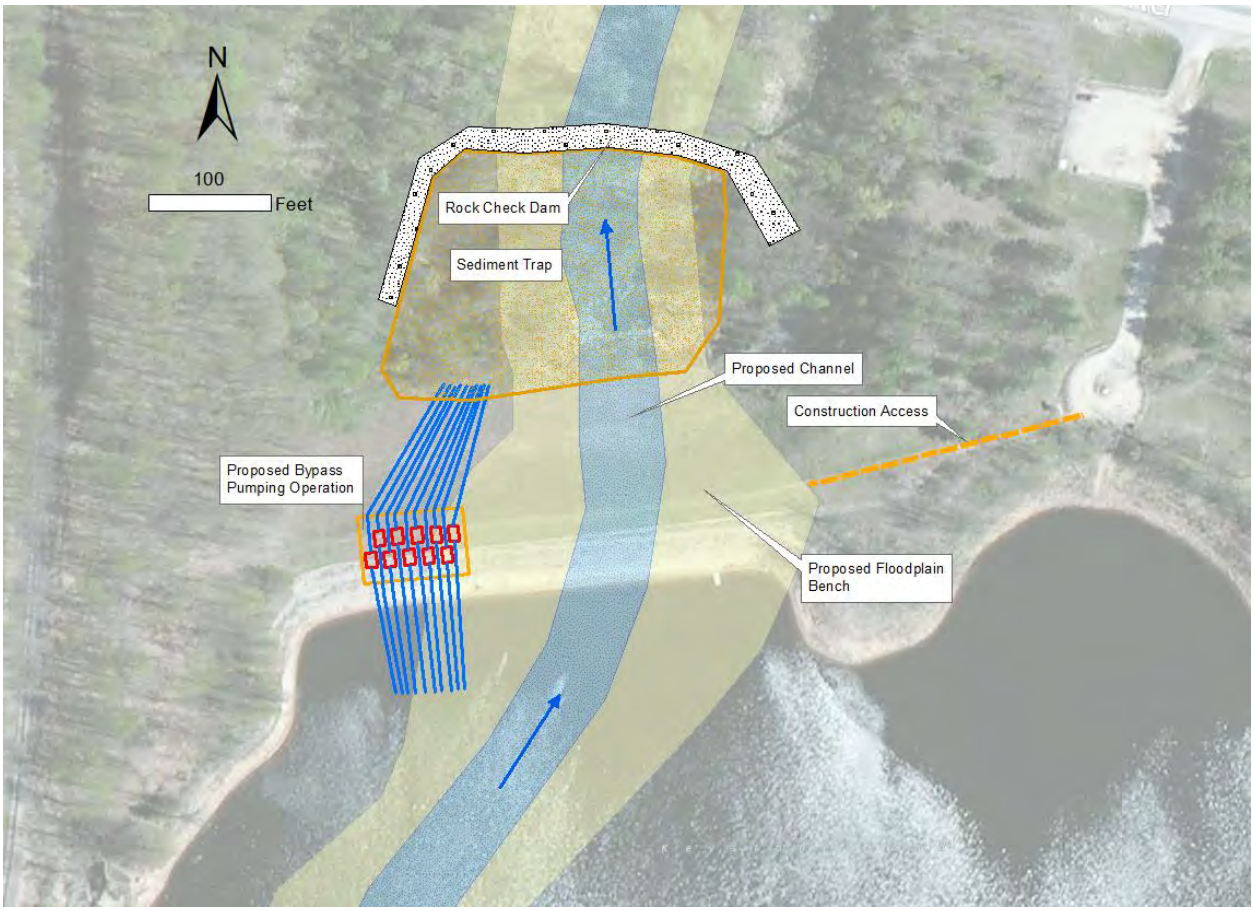

Figure 6-5: Plan view of the Boardman Dam breaching operation

Sediment management during the drawdown operation would be accomplished through a series of sediment traps and active excavation of the channel and floodplain. Initially when the drawdown begins, the impoundment itself would operate as a large sediment trap, with the majority of sediment settling in the impoundment and a secondary sand trap would be constructed immediately below the earthen embankment, where the breach is occurring. As the water level continues to lower, sediment traps would be placed within the impoundment area to trap sediment migrating from upstream. The sediment traps would be re-excavated on an as needed basis. They would be a minimum of five feet deep and would be cleaned of material when they have an average sediment depth of two feet. In addition to the sediment traps, the channel and floodplain would be actively shaped to insure that it meets the design criteria. This would result in sediment being removed to disposal sites within the impoundment that would not be subject to erosion and transport. Turbidity monitoring would be necessary downstream of the breaching operations throughout the duration of the project.

Traffic and transportation impacts to Cass Road would need to be considered during final design if removal of the Boardman Dam is part of the preferred alternative. The bridge should be closed

once removal of the Boardman Dam, existing bridge and related structures begins. The bridge is in poor condition and any vibrations caused during the removal of the other portions of the dam could cause significant further damage to the bridge.

6.5 Boardman No Action Alternative

The Boardman Dam has been drawn down approximately 17 feet to meet MDEQ Dam Safety requirements. This drawdown was required because of insufficient spillway capacity. The drawdown provides sufficient storage so that the primary spillway and existing emergency spillway can safely pass the design storm. The Cass Road bridge is tied into the Boardman Dam structure. The crossing of the Boardman River is a critical piece of the regional transportation infrastructure. It is classified as a minor arterial road and receives an average of 10,000 vehicles per day (TC-TALUS 2009) and is considered a regional transportation corridor of local significance. Under the No Action Alternative, Boardman Pond would likely remain drawn down and no habitat restoration would occur.

7 Engineering Analysis of Dam Modification Options

Measures were conceptualized to accommodate ecosystem restoration for the river reaches downstream of the impoundments in case one or more of the dams are not removed. The two primary concerns to be addressed by these measures are fish passage and water quality (particularly temperature and dissolved oxygen concentration). Three measures have been considered for fish passage. These measures include fish passage channels, trap-and-transfer operations, and fish elevators. Water quality would be addressed with either a bottom draw outlet at the dam or a bubbler system within the impoundment. Each of these measures would accompany necessary repairs and maintenance for each of the dams.

7.1 Union Street

Three alternatives are being evaluated for the Union Street Dam that incorporate modification measures. These include: a trap-and-transfer operation at the MDNR facility with modifications to the Union Street Dam to allow downstream passage, integration of a sturgeon lift-and-sort station at the MDNR facility and a rock ramp at the Union Street Dam, and installation of a new lift-and-sort facility at the Union Street Dam with modifications to accommodate downstream passage. The rock ramp measure has been discussed in depth as part of the removal option.

The trap-and-transfer operation at the MDNR facility would use two fishery technicians to collect the sturgeon and lift the fish and water into a truck to be transported upstream. This operation would require the installation of a lift system at the weir to get the fish to the truck level. Stairs from the MDNR facility down to the water level are recommended for safety. A truck capable of transporting the fish and water and safely discharging them back into the river would also be needed.

The integration of a lift-and-sort station at the MDNR facility would use the existing facility and staff for the upstream passage of the sturgeon over the new barrier. This would require a new lift to be installed into the existing sorting building, which would require structural and foundation work, as well as modification to the sorting station within the facility. The most likely location for the lift would be in the northeast corner of the building, adjacent to the fish ladder entrance. The existing lift within the facility would likely be used with modifications to the rail system. A new discharge chute would also be needed to accommodate sturgeon.

Downstream passage of sturgeon at the Union Street Dam would be facilitated by modifying the existing auxiliary spillway. The modifications would include constructing a permanent concrete sill in place of the current gate. The top of the sill would be even with the elevation of the fish ladder entrance. The approach to the sill, from upstream, would gradually slope up to direct the bottom swimming sturgeon up and over the sill. The spillway intake would need to be reconstructed to provide a plunge pool for the sturgeon, with a minimum depth of 6 feet. In addition the two 48-inch diameter culverts would be replaced at a shallower slope. These modifications would ensure that the channel maintains the current level of protection against upstream sea lamprey passage while better facilitating the downstream passage of sturgeon.

Figures 7-1 and 7-2 illustrate the proposed modifications in plan view and profile view, respectively.

The installation of a lift-and-sort facility at the Union Street Dam would require the construction of a facility similar the existing MDNR facility. This alternative would require USACE to either staff the facility or contract with the MDNR to manage the facility and operations (likely abandoning the current location). Additionally, there could be concerns about available property for this new facility. For this measure, the barrier would likely be installed in the vicinity of the dam.

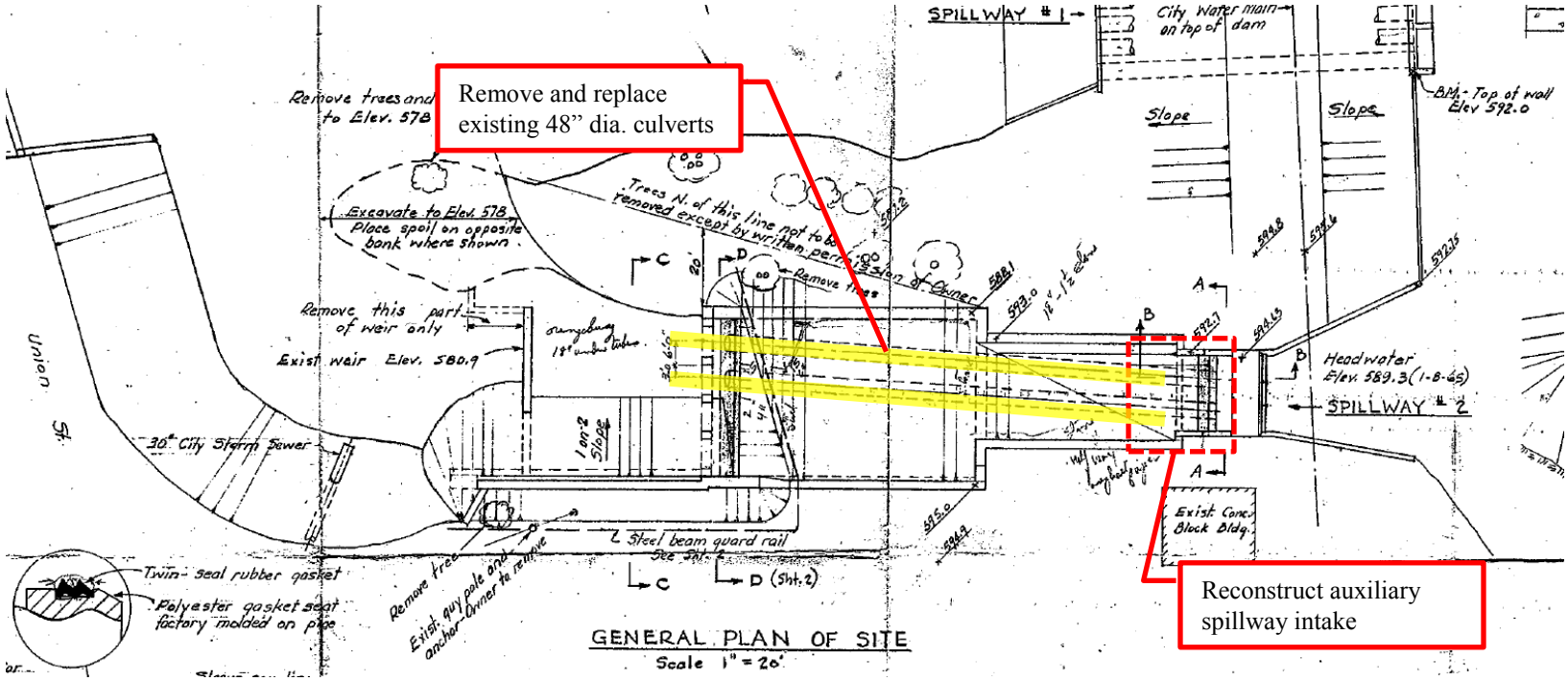

Figure 7-1: Plan view of Union Street Dam modifications (STS 2008)

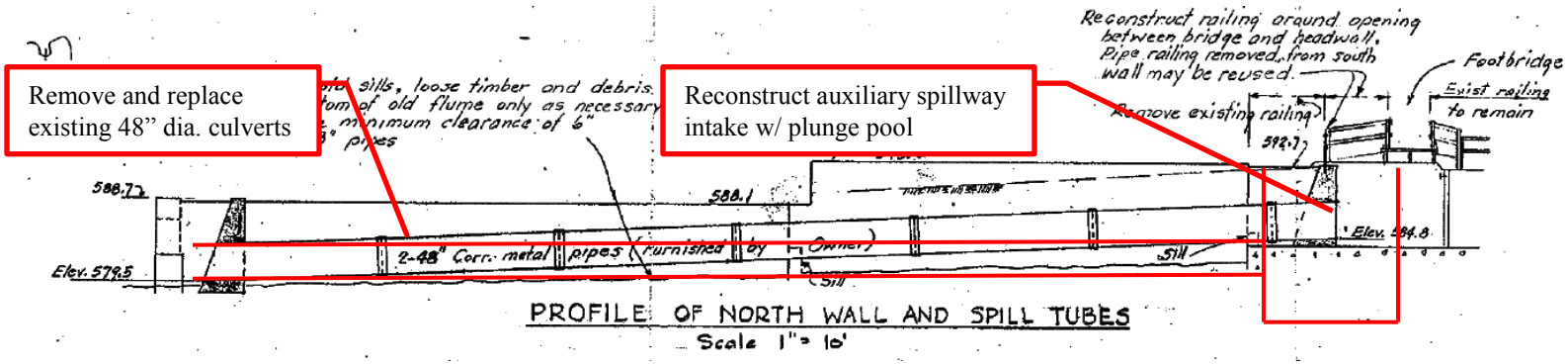

Figure 7-2: Profile view of the Union Street Dam modifications (STS 2008).

7.2 Sabin Dam

The modification measures being evaluated for the Sabin Dam include a fish elevator, a downstream fish passage channel, and water cooling measures, such as bottom draw or bubbler/chiller systems. Dam modification would maintain the existing water level of the impoundment while providing structures to pass fish and provide cooling to the downstream reaches. These measures could be implemented to meet some of the goals of the project. However, sediment, nutrients, and woody debris transport would still be inhibited.

The fish elevator for the Sabin Dam would be constructed adjacent to the powerhouse to provide the highest level of attractant for the fish. The elevator structure would be constructed of a steel frame with the fish collected in hoppers and lifted to a chute that would pass the fish to the upstream side of the dam. Figures 7-3 through 7-5 illustrate the location and configuration of the proposed lift.

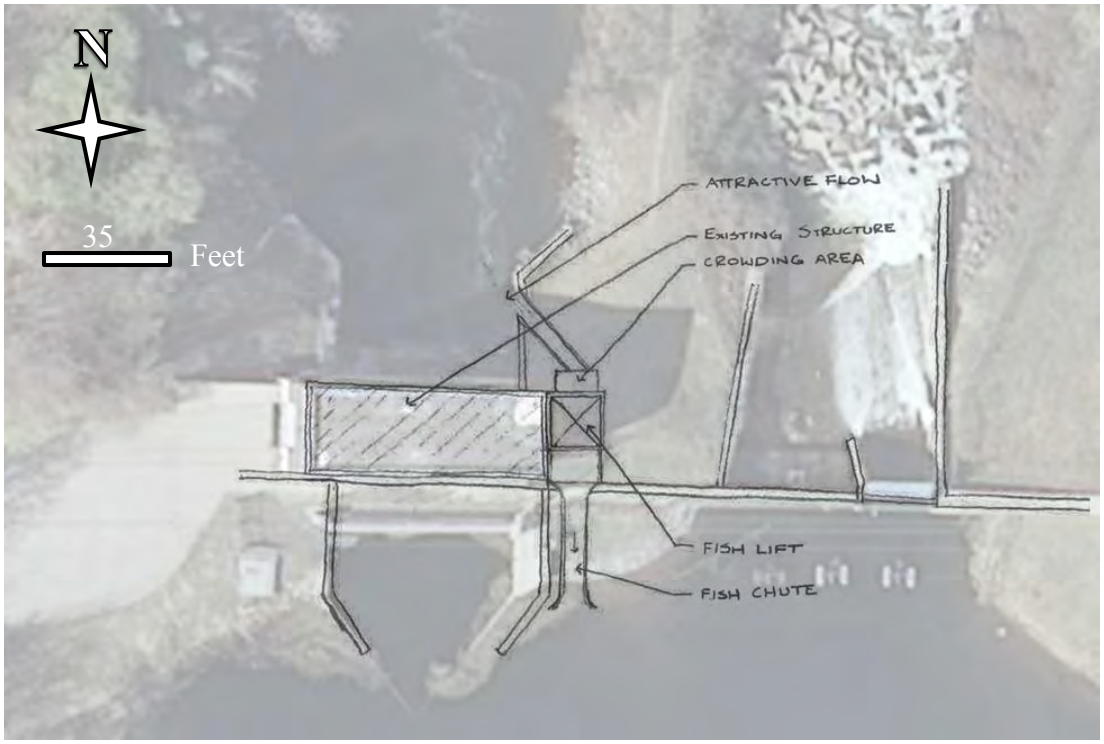

Figure 7-3: Plan view of fish elevator configuration

Figure 7-4: Side view of proposed fish elevator

Figure 7-5: Upstream view of fish elevator and chute

The downstream fish passage for the Sabin Dam and the Boardman Dam is being evaluated as a continuous passage from downstream of the Sabin Dam to upstream of the Boardman Dam. The proposed channel would be eight feet wide with an average wall height of six feet. The overall length of the channel would be approximately 5,345 feet with an average slope of 1.5 percent. The bottom of the channel would be lined with natural channel material. The channel would be constructed along the valley slope to the east of Sabin impoundment. A box culvert would be required to pass the channel under Cass Road. Figures 7-6 and 7-7 illustrate the channel alignment and section.

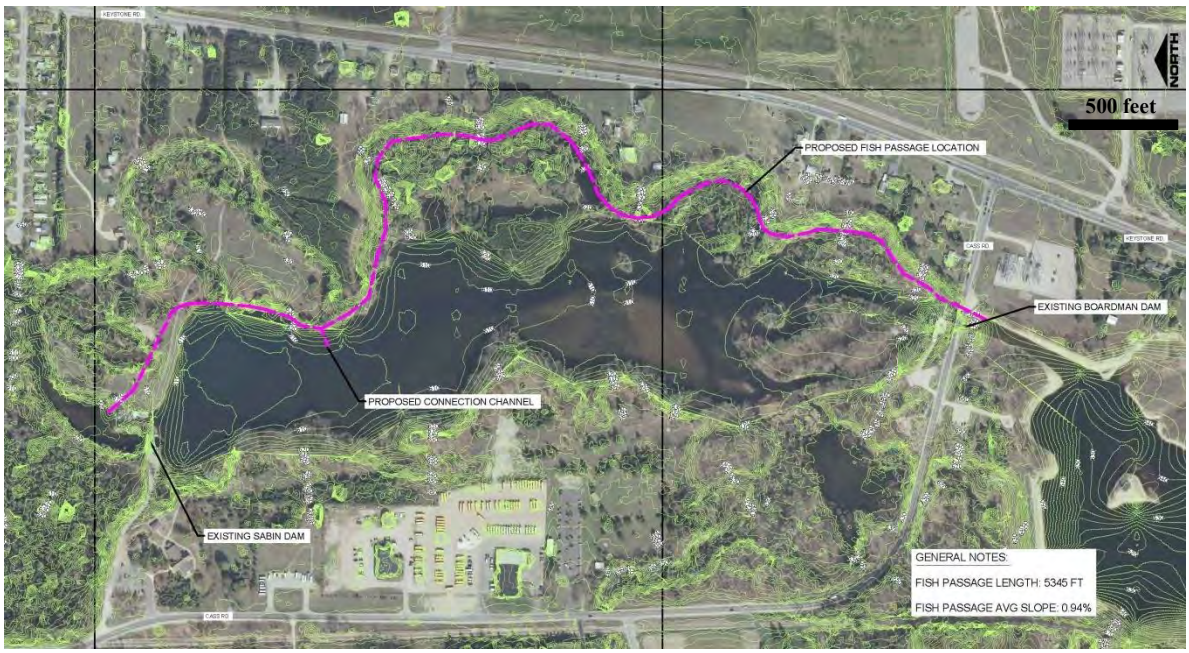

Figure 7-6: Downstream fish passage alignment

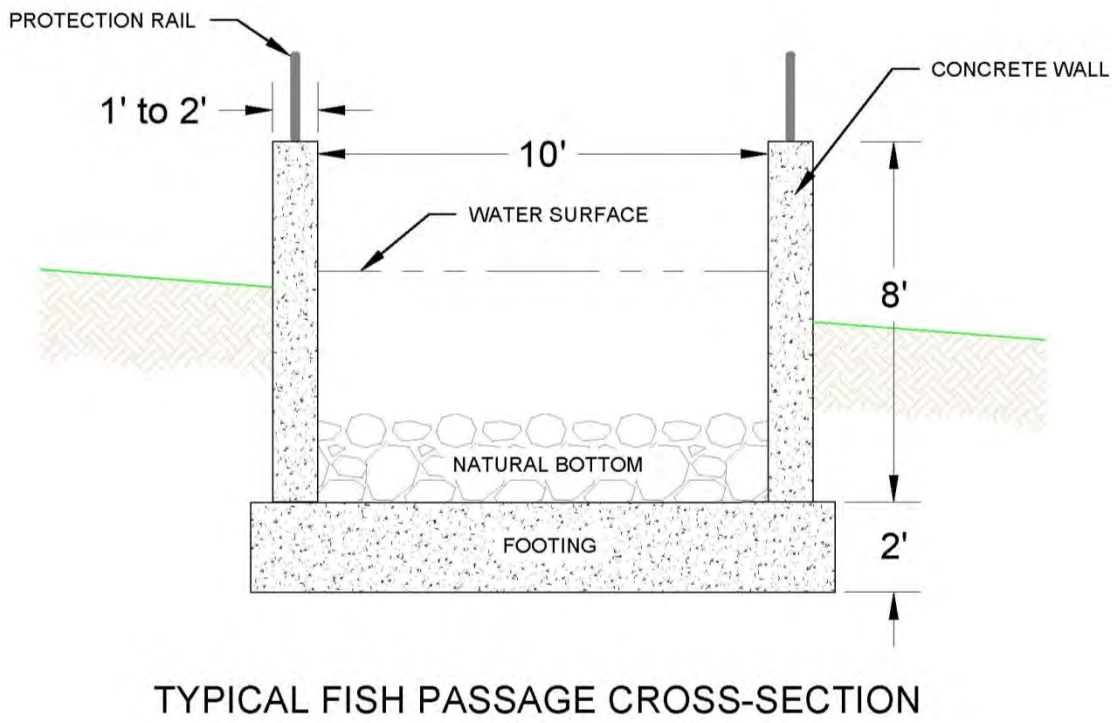

Figure 7-7: Typical downstream fish passage cross-section

Modifications to improve cooling would be partially effective. The coldwater reservoir within Sabin impoundment is likely insufficient to provide cooling during the entire summer and, thus, would provide improved temperatures only during limited periods. Using chillers would alleviate this concern but would require operation and maintenance. This conclusion is based on operational records at reservoirs operated in northern Michigan with these systems (personal communication with David McIntosh 2011). Additionally, there are significant construction concerns associated with the installation of a bottom draw outlet. Particularly regarding safety and stability of the dam during construction and long term as the outlet is tunneled through the earthen embankment and core wall. For these reasons, water cooling is not considered further.

7.3 Boardman Dam

Similar to the Sabin Dam, the modification measures being evaluated for the Boardman Dam include a fish elevator and downstream fish passage channel. Dam modification would maintain the existing water level of the impoundment while providing structures to pass fish. These measures could be implemented to meet some of the goals of the project. However, sediment, nutrient and woody debris transport would still be inhibited. Water cooling measures are not considered for reasons stated above in the Sabin Dam discussion.

The fish elevator for the Boardman Dam would be constructed adjacent to the powerhouse to provide the highest level of attractant for the fish. The elevator structure would be constructed of a steel frame with the fish collected in hoppers and lifted to a chute that would pass the fish to

the upstream side of the dam. The chute would require a box culvert to be constructed under Cass Road adjacent to the Cass Road bridge. The fish elevator would have a similar configuration to that illustrated in the Sabin Dam figures (Figures 7-3 through 7-5).

The downstream fish passage channel for the Boardman Dam would be integrated with the Sabin fish passage. The upstream connection of the fish passage would be into the current intake channel upstream of Cass Road. A gate control structure would be installed at the fish passage entrance to moderate the flow being diverted to the fish passage.

8 Groundwater Impacts

This section documents the anticipated impacts of dam removal and removal of the impoundment on the groundwater table near each of the dams. To this end, the areas around the Sabin and Boardman Dam impoundments were analyzed using existing spatial data related to the uppermost (or first) water table in Grand Traverse County developed by Dr. Lusch of Michigan State University (personal communication Lusch 2011) and other spatial data available from the State of Michigan (MDNR 2000). In addition, water well records provided to the State of Michigan by homeowners and well drillers were reviewed to assess at what elevation water was first encountered.

The Sabin Dam was drawn down during the summer and fall of 2011 to facilitate future removal and the Boardman Dam was drawn down by MDEQ order during March of 2007 for safety reasons. For purposes of this analysis, the drawdown at the Sabin Dam is considered a temporary measure because the water level could be raised if the dams remain. The Boardman Dam drawdown is considered permanent because it was done to alleviate safety concerns related to insufficient spillway capacity. Increasing spillway capacity would be costly and is unlikely to occur. The groundwater contours and groundwater point data developed for this area by the State of Michigan (Figure 8-1) were used to derive conditions for the Action and No Action Alternatives.

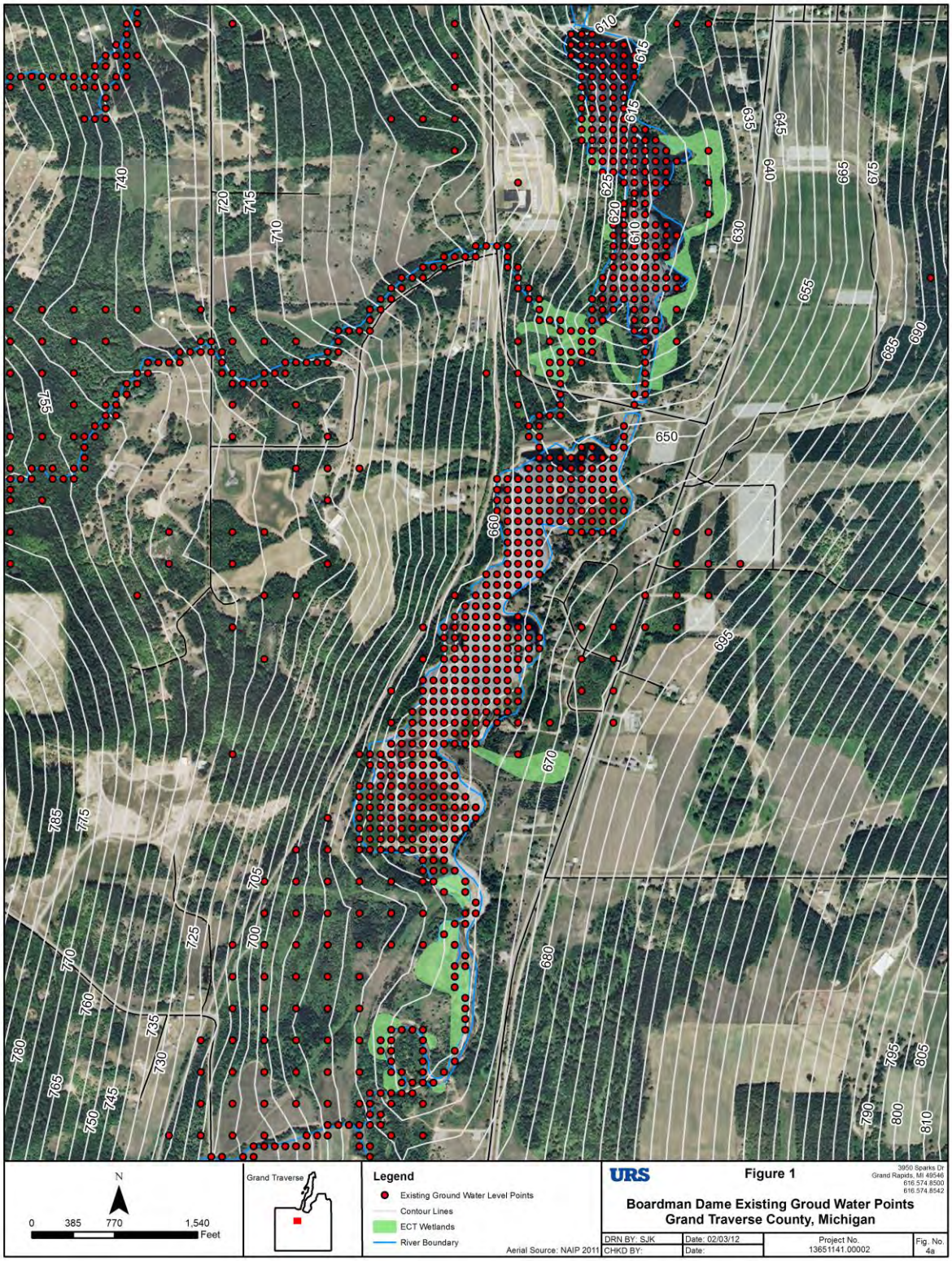

Figure 8-1: Estimated groundwater contours (feet) and first water points that served as the basis for groundwater impact analysis

Alternatives considered for the project include dam removal, modification, or no action. Of these alternatives, only dam removal would impact groundwater surface elevations near the dams because it would permanently decrease the static water level of the Boardman River. Under existing conditions, the impoundments raise the groundwater elevations of the near surface aquifer. If the dams are removed and the impoundments are restored to a river channel, the static water level would be reduced. Modifications to the dams may result in a change in elevation of the impoundment surface, but this change would be small compared to the removal alternative. Thus, only dam removal alternatives need to be compared to existing groundwater conditions to develop an understanding of the worst case change in the water table.

Groundwater surface elevations were estimated for both existing conditions (Figure 8-2) and with the dams removed (Figure 8-3). Existing conditions are defined as including the 17-foot drawdown at the Boardman Dam and at normal pool elevation at the Sabin Dam. The groundwater surfaces were developed using a point file of first water surfaces provided by Dr. Lusch (personal communication 2011) for Grand Traverse County. The water surface points are displayed in Figure 8-1 through Figure 8-4. These points represent measured and estimated groundwater levels in the vicinity of the dams. These are a subset of the data set used to develop the groundwater table maps for the entire State of Michigan (Lusch 2005). These data were manipulated in the vicinity of the dam to reflect existing conditions at the Boardman Dam (i.e., the 17-foot drawdown) and future conditions at the Sabin and Boardman Dams with a restored river in place of the impoundments. In addition, other points near each of the impoundments (representing water well measurements and wetlands) were removed in case these points were influenced by the water surface elevation of the impoundments. These point files were interpolated into a continuous surface using the natural neighbor technique. The two surfaces were compared using the “minus” command in ArcGIS.

The near surface groundwater elevation data (Lusch 2005) reflected full impoundment water levels at each dam prior to 2007. Because the Boardman Dam’s existing conditions are defined for this project to include the 17-foot drawdown, the published data set for Grand Traverse County was modified to reflect the drawdown by subtracting 17 feet from the impoundment points in the groundwater table dataset. Existing conditions at the Sabin Dam did not include changes to the water surface levels per the existing condition assumptions. In addition, information from the wetland analysis (ECT 2008) was included because it shows that some of the riparian wetlands adjacent to the impoundment remained after drawdown.

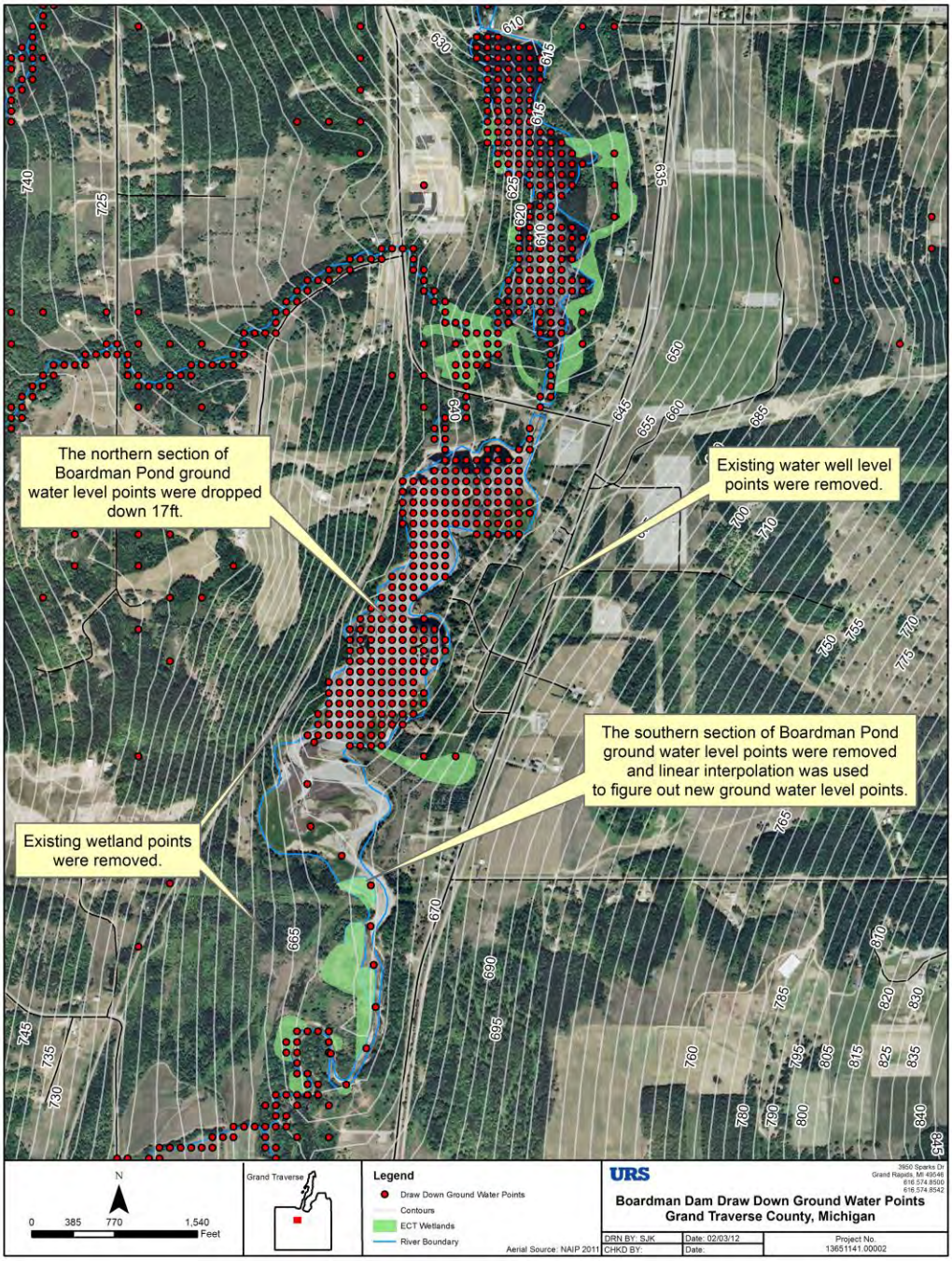

Figure 8-2: Estimated existing conditions groundwater contours (feet) and first water points including 17-foot drawdown at the Boardman Dam

The comparison demonstrated differences only near the dams, as anticipated. The water surface elevation dropped a maximum of approximately 15 feet at the Sabin Dam and 15 feet at the Boardman Dam (32 feet from full pool elevation (Figure 8-4). Based on these values, water wells less than 40 feet deep may be impacted. The water well file for Grand Traverse County (MDEQ 2005) indicates that 3.8 percent (474 of 12,210) water wells in the county are 40 feet or less. No

wells in the immediate vicinity of the dams were identified that have a well screen above the predicted ground water level after dam removal. Thus, based on the analysis and known locations of wells, there should be no impact from dam removal. The results of this analysis are shown graphically in Figures 8-2, 8-3, and 8-4. Figure 8-4 shows the change in first groundwater elevation near the Boardman and Sabin Dams from the existing conditions impoundment water levels.

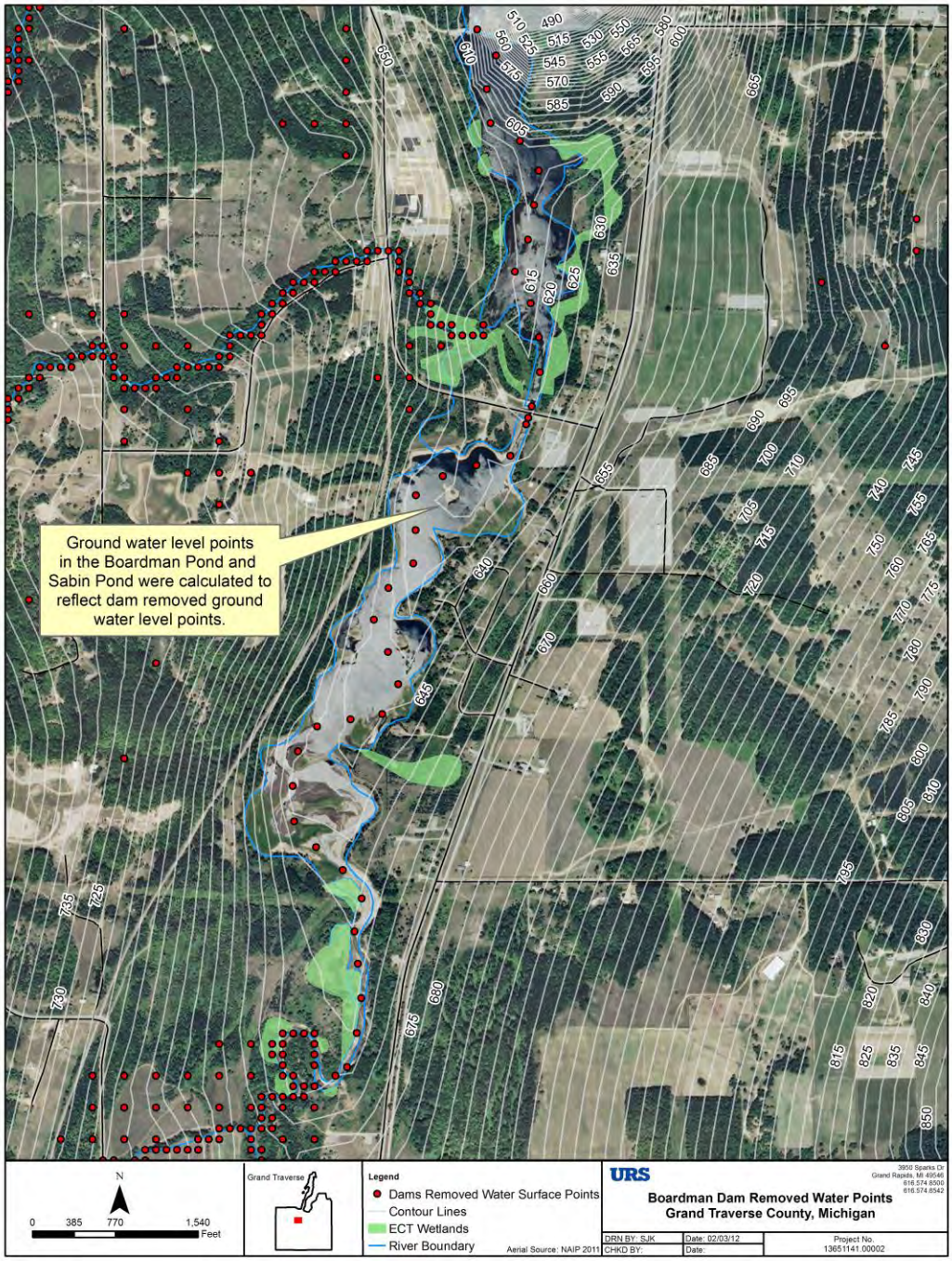

Figure 8-3: Estimated groundwater contours (feet) and first water points for dam removal scenario

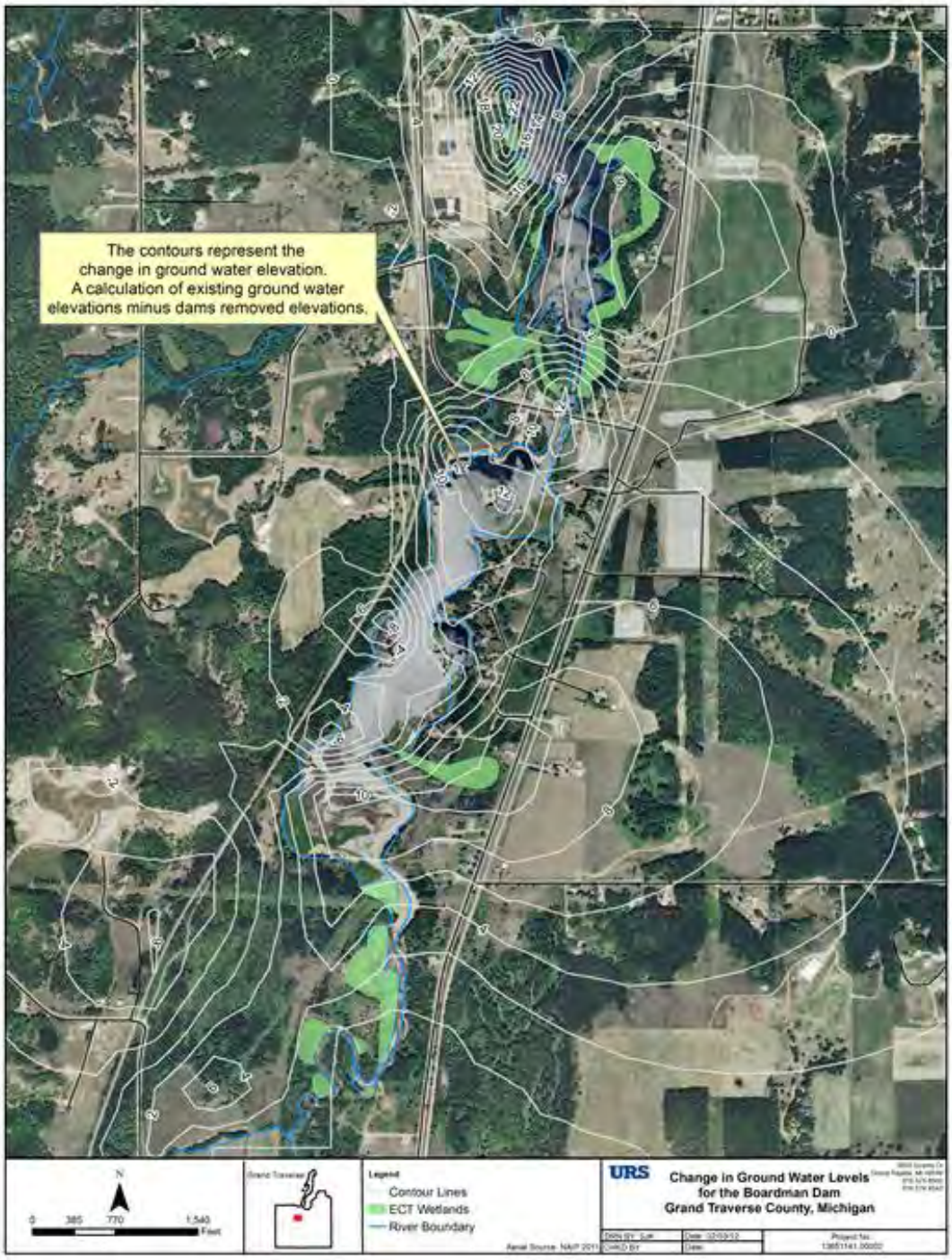

Figure 8-4: Estimated difference between existing conditions and dam removal conditions; contours (in feet) show change from existing conditions (i.e., includes the 17-foot drawdown at the Boardman Dam)

9 Wetland Impact – Restoration Plans

The purpose of this section is to provide a detailed analysis of the proposed alternative fates for the Boardman Dams and their associated impacts on wetlands within and adjacent to Sabin Pond and Boardman Pond in Grand Traverse County, MI. This analysis was accomplished through the review of existing reports, analyses of previously collected field data, and the field data and observations recorded in May 2012. Included in this report are the following items:

- *A description of the proposed alternatives with an emphasis on wetland habitat*
- *A summary of the existing conditions of wetlands within the two impoundments*
- *The likely effects of the proposed alternatives on those wetlands, including net wetland loss/gain values*
- *A watershed-level assessment of the alternatives with a focus on wetland habitat*
- *Identification of data gaps and needed information to complete the Environmental Assessment*

9.1 Document Review

Several documents developed during the Engineering and Feasibility Study and for the BRDC were reviewed for the wetlands impact analysis. These documents include dam inspections, engineering reports, proposed alternatives analyses, wetland reports and analyses, wildlife assessments, terrestrial habitat summaries, fact sheets, fisheries data, breach studies, economic and social analyses, and alternative analysis recommendations. The findings from several of these documents are integrated into this wetland impact assessment. Table 9-1 details the reference documents and sources that proved to be the most useful and provided the majority of the information contained within this section.

Table 9-1: Reference Documents

Title	Author	Date	Information Provided
Boardman River Feasibility Study–Detailed Analysis on the Effect on Wetlands	ECT	January 2009	• Existing Wetland Descriptions • Dam Alternative Descriptions • Alternatives Impact on Wetlands • Wetland gain/loss values

Title	Author	Date	Information Provided
Boardman River Feasibility Study–Wetland Determination Report	ECT	January 2009	• Existing Wetland Descriptions
Boardman River Feasibility Study–Detailed Analysis of Alternatives Report	ECT	January 2009	• Dam Alternative Descriptions • Alternatives Impact on Wetlands
Recommendations Concerning Alternative Futures for the Boardman River Dams	BRDC	December 16, 2008	• Dam Alternative Descriptions • Alternatives Impact on Wetlands
Boardman River Dams Committee Public Opinion Survey	BRDC	September 23, 2008	• Dam Alternative Descriptions
Draft Boardman River Feasibility Study: Alternative 1–Retain and Repair all Dams	ECT	September 10, 2008	• Dam Alternative Descriptions • Alternatives Impact on Wetlands
Draft Boardman River Feasibility Study: Alternative 41–Modify Union Street, Sabin, Boardman Pond, and Brown Bridge Dams	ECT	September 10, 2008	• Dam Alternative Descriptions • Alternatives Impact on Wetlands
Draft Boardman River Feasibility Study: Alternative 81–Modify Union Street Dam, Remove Sabin, Boardman Pond, and Brown Bridge Dams	ECT	September 10, 2008	• Dam Alternative Descriptions • Alternatives Impact on Wetlands
Terrestrial and Aquatic Habitat of the Boardman River Impoundments and Adjacent Land	ECT	–	• Existing Wetland Descriptions
Wetland Field Observations and Data Collection	URS	May 21–22, 2012	• Existing Wetland Descriptions

ECT = Environmental Consulting & Technology, Incorporated
BRDC = Boardman River Dams Committee

9.2 Existing Wetland Habitat

For this wetland habitat analysis, the existing conditions of Sabin Pond includes an impoundment size of 40 acres with approximately 15 acres of aquatic wetland occurs within the impoundment. Currently, the impoundment is somewhat smaller in size as a result of a drawdown in June 2010

in preparation of dam removal activities. The aquatic vegetation existing within the impoundment is dominated by submerged, floating, and emergent vegetation. The plant community within this type of habitat is characterized by relatively low species diversity and comprises floating and sago pondweeds (*Potamogeton natans* and *P. pectinatus*), stonewort (*Chara* spp.), yellow pond-lily (*Nuphar advena*), and hardstem bulrush (*Schoenoplectus acutus*). Approximately 16.7 acres of diverse wetland habitat occur near or adjacent to the Sabin Pond impoundment. This higher quality habitat consists of 0.1 acres of PEM/palustrine scrub-shrub (PSS) wetland, 9.4 acres of palustrine forested (PFO) wetland, 0.3 acres of PFO/PSS wetland, and 6.9 acres of PFO/PSS/PEM/open water wetland. Although some of these wetlands are influenced by inundation from the impoundment, most are primarily fed by groundwater seepage and occur on very poorly drained sapric muck. Dominant forest, shrub, and emergent wetland vegetation species include northern white-cedar (*Thuja occidentalis*), red maple (*Acer rubrum*), common elderberry (*Sambucus canadensis*), common and narrow-leaved cattail (*Typha latifolia* and *T. angustifolia*), spotted joe pye weed (*Eupatorium maculatum*), hardstem bulrush, marsh shield fern (*Thelypteris palustris*), and jewelweed (*Impatiens capensis*). Figure 9-1 is a map portraying the existing wetland habitat associated with Sabin Pond from ECT's *Boardman River Feasibility Study: Wetland Determination Report*.

The impoundment behind the Boardman Dam was originally 103 acres. However, following an emergency drawdown in 2007, during which the water level in the impoundment was dropped approximately 17 feet, the pond is roughly 78 acres. Since this time, wetland habitat associated with the impoundment has changed with the creation and loss of individual wetlands. Approximately 13.1 acres of diverse wetland habitat occur near or adjacent to the Boardman Pond, consisting of predominately PEM wetlands. Although some of these wetlands are influenced by inundation from the impoundment, most occur along the banks of the impoundment and are primarily fed by groundwater seepage. They occur on poorly and very poorly drained mucky sand. While the previous aquatic plant community was characterized by relatively low species diversity and was dominated by floating and sago pondweeds and stonewort, the new emergent plant community developing within the impoundment is characterized by higher species diversity and is dominated by blue vervain (*Verbena hastata*), nodding bur-marigold (*Bidens cernnuus*), nodding smartweed (*Polygonum lapathifolium*), common and narrow-leaved cattail, rice-cut grass (*Leersia oryzoides*), hardstem bulrush, yellow marsh marigold (*Caltha palustris*), three-square (*Schoenoplectus pungens*), spotted joe pye weed, common boneset (*Eupatorium perfoliatum*),and sedges (*Carex* spp.). Figure 9-2 is a map depicting existing wetland habitat associated with Boardman Pond generated from fieldwork performed by URS in May 2012.

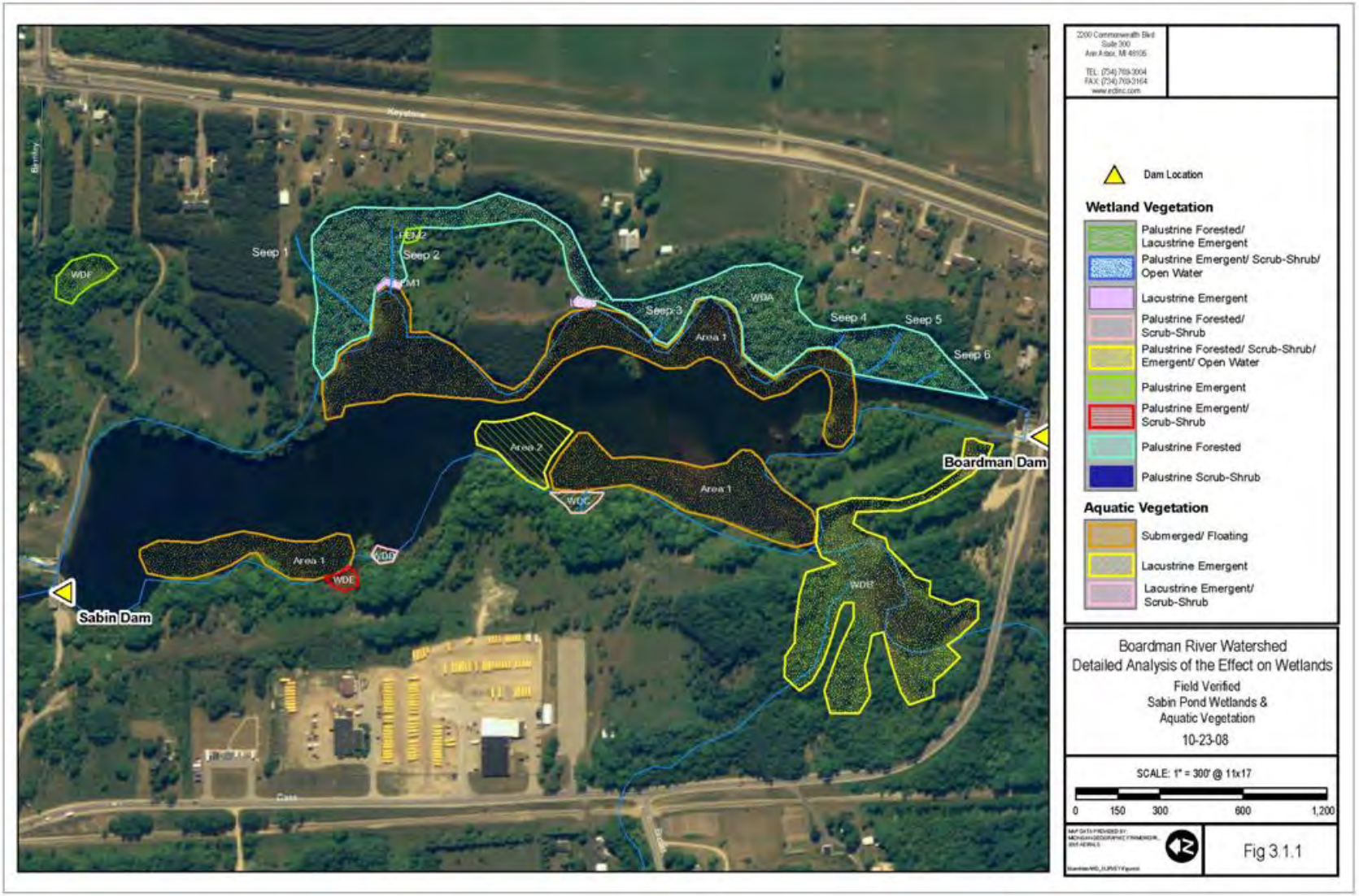

Figure 9-1: Existing wetland habitat associated with Sabin Pond

Figure 9-2: Existing wetland habitat associated with Boardman Pond

9.3 Proposed Alternatives

The three primary alternatives for the Sabin and Boardman Dams are removal, modification, and no action. Each of these alternatives would have different impacts to the size and type of wetland habitat associated with the dam impoundments. The following paragraphs summarize the three primary alternatives and their overall effects on the ecosystem.

9.3.1 Dam Removal Alternative

Removal of the Sabin and Boardman Dams would have an impact on wetland habitat within the impoundment area. Dam removal measures considered would drop the water level until only river habitat exists and have little to no impact on river hydraulics.

9.3.2 Sabin Pond Wetland Effects

Removing Sabin Pond would decrease water levels in the pond and both wetland acreage and type would change within the former Sabin Pond impoundment. Overall, approximately 30.5 acres of new wetland are anticipated to form following drawdown of the impoundment and the necessary sediment disposal.

Former impoundment areas are anticipated to succeed to emergent wetlands initially. New emergent wetlands would likely be dominated by a more diverse set of wetland species, including blue vervain (*Verbena hastata*), swamp milkweed (*Asclepias incarnata*), common and narrow-leaved cattail, black bulrush (*Scirpus atrovirens*), hardstem bulrush, spotted joe-pye-weed, jewelweed, common, sensitive fern (*Onoclea sensibilis*), yellow marsh marigold, swamp goldenrod (*Solidago patula*), northern blue flag (*Iris versicolor*) and beggar-ticks (*Bidens* spp.). Over time, these new emergent wetlands would be expected to convert to and remain emergent/scrub-shrub wetlands. These permanent emergent/scrub-shrub portions would be similar in structure and composition to areas found elsewhere along the Boardman River and would likely be dominated by common elderberry, silky dogwood (*Cornus amomum*), red-osier dogwood (*Cornus stolomfera*), sandbar wouldow (*Salix exigua*), speckled alder (*Alnus rugosa*), blue vervain, swamp milkweed, spotted joe-pye-weed, common boneset, common and narrow-leaved cattail, green bulrush (*Scirpus atrovirens*), sedges, hardstem bulrush, and burreed (*Sparganium* spp.). However, some new emergent wetlands could eventually succeed to forested/scrub-shrub wetlands with dominants such as northern white-cedar, red maple, common elderberry, and marsh fern.

Field observations recorded in May 2012 by URS indicated that existing wetland habitat was unaffected by the recent drawdown of Sabin Pond. Because of the presence of groundwater seepage, these wetlands are unlikely to convert to uplands following drawdown. However, when surface water influences are removed as the water elevation is lowered, these wetlands may shift from emergent/scrub-shrub to a slightly drier species composition with dominance by wetland trees and shrubs.

The 6.9-acre PFO/PFSS/PEM/POW wetland located southwest of the impoundment would be temporarily impacted by construction of the river channel and sediment disposal. Construction

impacts to wetland habitat due to river channel and floodplain construction are expected to be temporary since hydrophytic vegetation would return. Figure 9-3 shows wetland locations and Table 9-2 provides wetland acreages based on estimates from ECT and URS fieldwork. The wetland impacts associated with removal of the Sabin and Boardman Dams are listed separately to highlight the impacts of individual dam removal, which is necessary for project alternative formulation and selection.

Table 9-2: Wetland Impacts for the Sabin Dam Removal

Category	Dam In (acres)	Dam Out (acres)
Impoundment-Open Water	25.0	0.0
Impoundment-Aquatic Vegetation	15.0	0.0
River Channel-Open Water	1.6	6.4
Total Surface Water	41.6	6.4
PEM/PSS	0.1	0.1
PFO	9.4	9.4
PFO/PSS	0.3	0.3
PFO/PSS/PEM/OW	6.9	6.9
Total Wetlands Outside Impoundment	16.7	16.7
PEM/PSS Forming Within Impoundment	0.0	30.5
Total Upland	1.4	6.1
Total Area	59.7	59.7
Wetland Gain/Loss	**0.0**	**+30.5**

PEM = palustrine emergent wetland
PSS = palustrine scrub-shrub wetland
PFO = palustrine forested wetland
OW = open water wetland

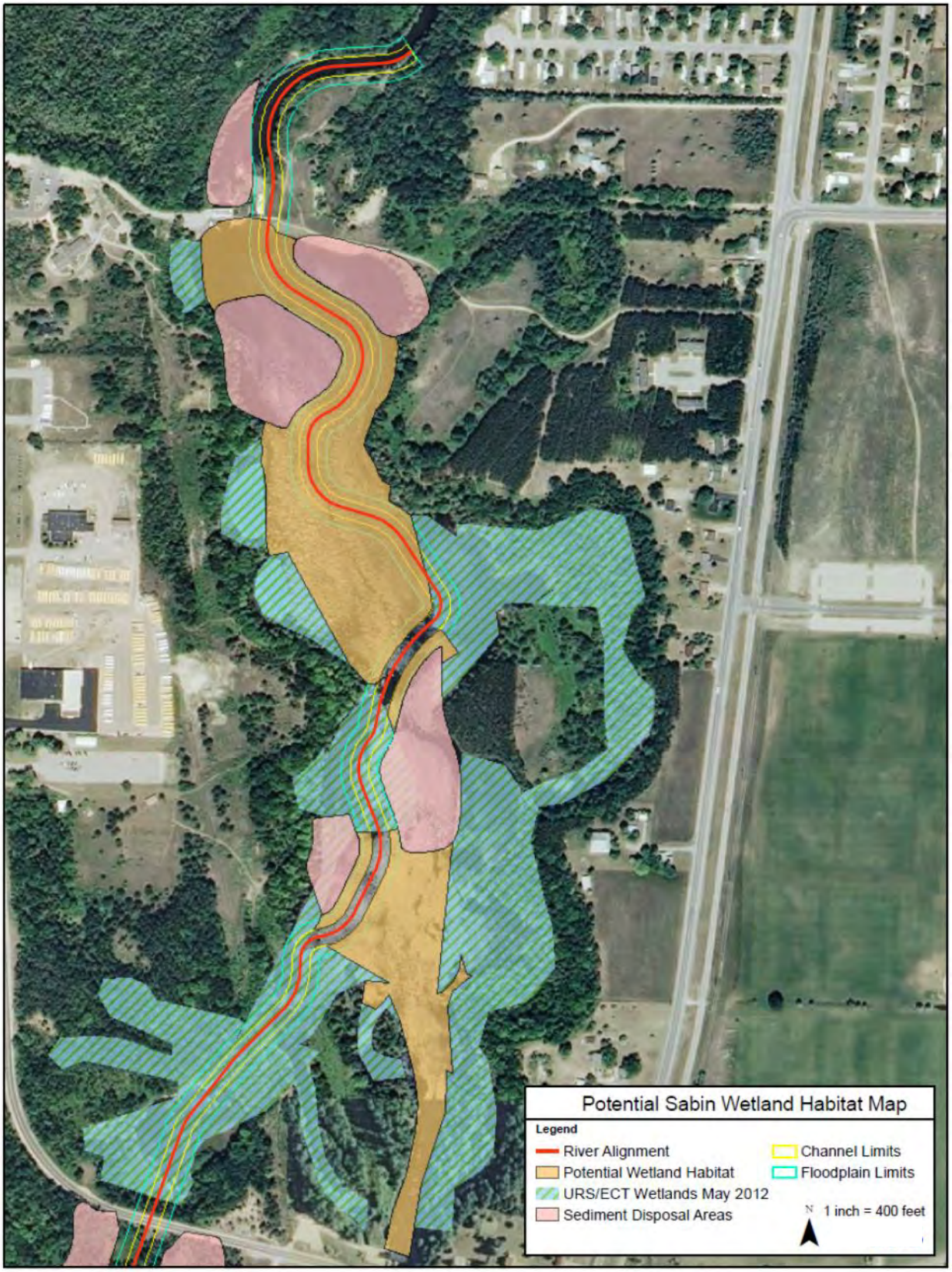

Figure 9-3: Potential wetland habitat associated with Sabin Pond

9.3.3 Boardman Pond Wetland Effects

Removing the impoundment at Boardman Pond would also change the wetland acreage and type within the Boardman Pond impoundment. Overall, approximately 26.5 acres of wetland are anticipated to form in the long term.

The new emergent wetlands would likely be dominated by blue vervain, nodding bur-marigold, nodding smartweed, rice-cut grass, swamp goldenrod, northern blue flag, yellow marsh marigold, common and narrow-leaved cattail, common boneset, spotted joe-pye-weed, hardstem bulrush, common three-square, and sedges. Over time, these new emergent wetlands would be expected to convert to and remain emergent/scrub-shrub wetland. These permanent emergent/scrub-shrub portions would be similar in structure and composition to areas found elsewhere along the Boardman River and would likely be dominated by common elderberry, silky dogwood, red-osier dogwood, sandbar, speckled alder, blue vervain, swamp milkweed, spotted joe-pye-weed, common boneset, common and narrow-leaved cattail, green bulrush, sedges, hardstem bulrush, and bur reed. However, some new emergent wetlands could eventually succeed to forested/scrub-shrub wetlands with dominants such as northern white-cedar, red maple, common elderberry, and marsh fern.

Because of the presence of groundwater seepage, some existing wetlands associated with Boardman Pond are unlikely to convert to uplands following drawdown. When surface water influences are removed as the water elevation is lowered, these wetlands may shift from emergent/scrub-shrub to a slightly drier species composition with dominance by wetland trees and shrubs. However, some wetlands adjacent to the southern central portion of the impoundment that have formed since the 2007 drawdown are dependent on seasonal inundation. When the river channel is restored, these wetlands may no longer have sufficient hydrology and could convert to upland.

The 2.5-acre PEM/PSS/PFO wetland located north of the earthen berm would be temporarily and permanently impacted by construction of the river channel and sediment disposal. The permanent impact would be to approximately 1.4 acres as a result of sediment management along the newly constructed river channel. Construction impacts to wetland habitat due to river channel and floodplain development are expected to be temporary as hydrophytic vegetation would return. Figure 9-4 shows wetland locations and Table 9-3 provides wetland acreages based on estimates from ECT and URS fieldwork after the 2007 drawdown.

Table 9-3: Wetland Impacts for the Boardman Dam Removal

Category	Dam In (acres)	Dam Out (acres)
Impoundment-Open Water	78.0	0.0
River Channel-Open Water	0.0	11.0
Total Surface Water	78.0	11.0
PEM/PSS/PFO*	2.5	1.4
Total Wetlands Outside Impoundment	2.5	1.1
PEM	10.6	0.0
PEM/PSS	0.0	38.5
Total Wetlands Forming Within Impoundment	10.6	38.5
Total Upland	0.0	40.5
Total Area	91.1	91.1
Wetland Gain/Loss	**0.0**	**+26.5**

* Wetland boundaries and size are estimated because of access issues; estimations are based of field observations and map review.
PEM = palustrine emergent
PSS = palustrine scrub-shrub
PFO = palustrine forested

Figure 9-4: Potential wetland habitat associated with Boardman Pond

9.3.4 Summary of Effects on Watershed

Considering the gain in wetland acreage with the conversion of open water areas and the increase in species and structural diversity with the conversion of deep aquatic habitats to emergent and ultimately emergent/scrub-shrub systems, a partial or total removal of these dams would improve the quality of and increase the quantity of wetland habitat available along the Boardman River. Stagnant, low oxygen, deep-water habitats would be replaced by flowing riparian habitats with varying water depths and higher structural and floral and faunal species diversity.

Removal of these dams would allow migrating fish to access the upper reaches of the Boardman River, if allowed to pass the MDNR operated trap-and-transfer facility and the Union Street Dam. Planned fish passage would only include State-threatened lake sturgeon. Other rare species would also be impacted by the increases in wetlands adjacent to sandy upland habitat. Removal of these dams would likely increase the quantity and quality of habitat available for the wood turtle (*Glyptemys insculpta*), Blanding's turtle (*Glyptemys insculpta*), red-shouldered hawk (*Buteo lineatus*), bald eagle (*Haliaeetus leucocephalus*), and ebony boghaunter (*Wouldiamsonia fletcheri*). Additionally, with the lowering of the impoundments, the potential also exists for rare natural communities like northern fen and rich conifer swamp to develop along the numerous groundwater seeps occurring along the banks of Sabin Pond.

One potential negative consequence includes adverse impacts to wildlife and fish species by the introduction of Great Lakes fish and ANS to the upper reaches of the Boardman River. ANS within Grand Traverse Bay, the Boardman River, and its tributaries that could be problematic following dam removal include the zebra mussel (*Dreissena polymorpha*; Boardman Lake and Brown Bridge Pond), sea lamprey (*Petromyzon marinus*; Grand Traverse Bay), fishhook water flea (*Cercopagis pengoi*; Grand Traverse Bay), rusty crayfish (*Orconectes rusticus*; Grand Traverse Bay), spiny water flea (*Bythotrephes cederstroemi*; Grand Traverse Bay), Eurasian ruffe (*Gymnocephalus cernuus*; Grand Traverse Bay), round goby (*Neogobius melanostomus*; Grand Traverse Bay), alewife (*Alosa pseudoharengus*; Grand Traverse Bay), and Eurasian water milfoil (*Myriophyllum spicatum*; Grand Traverse Bay). Additionally, removal of dams or adding fish ladders would allow for the potential movement of Great Lakes contaminants into the wildlife food chains within the Boardman River watershed. Chemical contaminants found in some Great Lakes fish species that could present a threat to certain wildlife species include PCBs, dichlorodiphenyltrichloroethane (or DDT) metabolites, and other chlorinated hydrocarbons. Wildlife species vulnerable to chemical contaminants that could be impacted by chemical contaminants in Great Lakes fish include, but are not limited to, mink, otters, gulls, bald eagles, and snapping turtles.

However, the dam removal option currently has two safeguards against introduction of exotic species. First, the MDNR would continue to operate the fish weir to mitigate the impacts of potential exotic and nuisance species on the Boardman River and its fisheries. Additionally, sturgeon would only pass the Union Street Dam via trap-and-transfer activities. This technique would allow for the passage of only sturgeon and technicians would examine all sturgeon and storage troughs for potential nuisance species. The amount of contamination within sturgeon tissue is dependent on location and the Boardman River Watershed is not known to have

bioaccumulation contaminant problems. Also, according to the MDNR, the passage of Great Lakes lake sturgeon into historic spawning rivers is unlikely to cause contaminant concerns. The species suffers very little mortality from spawning stress, is not a forage item because of its size, and returns to the Great Lakes after spawning.

The loss of open water habitat associated with dam removal would also impact local wildlife. Waterfowl commonly use these impoundments for foraging and breeding areas. Additionally, the impoundments and associated wetlands are known habitat for several rare species, including the common loon (*Gavia immer*). Any displaced wildlife species would need to find alternative breeding and foraging locations. Nearby lakes could provide suitable habitat for several species, for example, the common loon, which has nested and produced young on Boardman Pond and Brown Bridge Pond. A complex of approximately a dozen lakes (Rennie, Arbutus, Perch, Wethea, Spring, George, Spider, High, Chandler, Tibbets, Vandervoight, Indian, Bass, Island, and Muncie Lakes) is five to eight miles east of the Boardman Pond impoundment. Some of these lakes, have less developed, natural shorelines that appear to be potentially suitable for nesting loons.

9.4 Dam Modification Alternative

The modification alternative would consist of modifying the Sabin and Boardman Dams to mitigate the increase in temperature and to provide fish passage, but not to generate hydroelectricity. The modifications would consist of fish passageways at all of the dams, improved capacity at the emergency spillway for Boardman and a bottom draw or bubbler system to mitigate the impacts of warmwater discharge.

9.4.1 Sabin Pond Wetland Effects

Alternatives to modify the Sabin Dam would not change the water level in the impoundment. Therefore, no change in the acreage of wetland habitat is anticipated and no new wetlands would likely to form as a result of this alternative. Wetlands within the impoundment would remain dominated by submerged and floating aquatic and emergent vegetation. Wetlands near or adjacent to the impoundment would remain dominated by forested, scrub-shrub, and emergent vegetation.

9.4.2 Boardman Pond Wetland Effects

The modification alternative would not change the water level in the Boardman Dam impoundment from its current elevation, 17 feet below the original impoundment level. As a result of this decrease, changes due to the 2007 drawdown would become permanent. Overall, wetlands are anticipated to form in the long term because of the drawdown. Wetland habitat would be new emergent wetlands forming in the northeast corner, east central side, and southern end of the original impoundment. The new emergent wetlands would be dominated by blue vervain, nodding bur-marigold, nodding smartweed, rice-cut grass, hardstem bulrush, common and narrow-leaved cattail, three-square, and sedges. Over time, these new emergent wetlands

would succeed to emergent/scrub-shrub wetlands with dominants such as northern white-cedar, black ash, red maple, speckled alder, ninebark, sensitive fern, and marsh shield fern.

9.4.3 Summary of Effects on Watershed

According to the *Boardman River Feasibility Study-Detailed Analysis of the Effect on Wetlands*, this alternative would not change the water level in the Sabin Dam impoundment. Therefore, no change in the acreage of wetland habitat is anticipated associated with Sabin Pond. However, this alternative would retain the water level in the Boardman Dam impoundment at its current elevation after the 2007 emergency drawdown. Considering the gain in wetland acreage with the conversion of open water areas and the increase in species and structural diversity with the conversion of deep aquatic habitats to emergent and ultimately emergent/scrub-shrub systems, the dam modification alternative would improve the quality of and increase the quantity of wildlife habitat available along this stretch of the Boardman River. A portion of the stagnant, low-oxygen, deepwater habitats would be replaced by submerged aquatic, emergent, and forested/scrub-shrub wetland habitats with varying water depths and higher structural and floral and faunal species diversity.

Given increases in wetlands adjacent to sandy upland habitat, the dam modification alternative would likely increase the quantity and quality of habitat available for rare species known to occur within the watershed, such as wood turtle, Blanding's turtle, bald eagle, red-shouldered hawk, and ebony boghaunter. Although a portion of the open water habitat for the common loon has been lost by the 17-foot drawdown, this species was observed within the impoundment following drawdown in 2007 and in the summer of 2012 and would likely benefit from the diversified wetland vegetation forming along the margins of its habitat in Boardman Pond.

With the addition of a downstream fish passage and trap-and-transfer activities, spawning sturgeon would be able to access the upper reaches of the Boardman River. Adverse impacts to wildlife and fish species could result from the introduction of Great Lakes fish and associated contaminants to the upper reaches of the Boardman River. The list of potential risks and mitigative measures would be similar to those associated with the dam removal alternative.

9.5 No Action Alternative

The No Action Alternative would "freeze" conditions in time, so the impoundments would remain at their current water elevations. Therefore, the water level in the Boardman Dam impoundment would not change from its current elevation, 17 feet below the original impoundment level.

9.5.1 Sabin Pond Wetland Effects

Alternatives to retain the Sabin Dam would not change the water level in the impoundment. Therefore, no change in the acreage of wetland habitat is anticipated and no new wetlands would likely form as a result of this alternative. Wetlands within the impoundment would remain dominated by submerged and floating aquatic and emergent vegetation. Wetlands near or

adjacent to the impoundment would remain dominated by forested, scrub-shrub, and emergent vegetation.

9.5.2 Boardman Pond Wetland Effects

The No Action Alternative would not change the water level in the Boardman Dam impoundment from its current elevation, 17 feet below the original impoundment level. As a result of this decrease, changes due to the 2007 drawdown would become permanent. Overall, wetlands are anticipated to form in the long term because of the drawdown. Wetland habitat would be new emergent wetlands forming in the northeast corner, east central side, and southern end of the original impoundment. The new emergent wetlands would be dominated by blue vervain, nodding bur-marigold, nodding smartweed, rice-cut grass, hardstem bulrush, common and narrow-leaved cattail, three-square, and sedges. Over time, these new emergent wetlands would succeed to emergent/scrub-shrub wetlands with dominants such as northern white-cedar, black ash, red maple, speckled alder, ninebark, sensitive fern, and marsh shield fern.

9.5.3 Summary of Effects on Watershed

According to the *Boardman River Feasibility Study-Detailed Analysis of the Effect on Wetlands*, the "without project" option would not change the water level in the Sabin Dam impoundment. Therefore, no change in the acreage of wetland habitat is anticipated associated with Sabin Pond. However, this alternative would retain the water level in the Boardman Dam impoundment at its current elevation after the 2007 emergency drawdown. Considering the gain in wetland acreage with the conversion of open water areas and the increase in species and structural diversity with the conversion of deep aquatic habitats to emergent and ultimately emergent/scrub-shrub systems, the No Action Alternative would improve the quality of and increase the quantity of wildlife habitat available along this stretch of the Boardman River. A portion of the stagnant, low-oxygen, deepwater habitats would be replaced by submerged aquatic, emergent, and forested/scrub-shrub wetland habitats with varying water depths and higher structural and floral and faunal species diversity.

Given increases in wetlands adjacent to sandy upland habitat, the No Action Alternative would likely increase the quantity and quality of habitat available for rare species known to occur within the watershed, such as wood turtle, Blanding's turtle, bald eagle, red-shouldered hawk, and ebony boghaunter. Although a portion of the open water habitat for the common loon has been lost by the 17-foot drawdown, this species was observed within the impoundment following drawdown in 2007 and in the summer of 2012 and would likely benefit from the diversified wetland vegetation forming along the margins of its habitat in Boardman Pond.

9.6 Data Gaps

Despite the available literature, data gaps still remain concerning the wetland impact of the proposed alternatives for the Boardman River dams. Adequate information is available to allow for an approximate determination of the effects on wetlands resulting from the various alternatives. Current data are sufficient to determine the relative amount of wetland acreage and

proportion of wetland ecological types anticipated to be gained or lost with each alternative. However, the information necessary to accurately depict the exact location and extent of new wetland development or wetland loss on a map is lacking, except in the broadest sense. Data critical to the mapping of future wetland locations, such as topographic survey data, surface water elevations, groundwater data, and impoundment depth contours, have not been collected or analyzed,. Therefore, the wetland development predicted for the various alternatives that have been depicted graphically for reporting documents is only a generalized estimate.

Another data gap in the available literature is the restoration, monitoring, and management of newly formed wetland habitat associated with the dam removal alternative. Currently, the majority of the documents suggest a passive restoration, which allows the existing seed bed to establish wetland vegetation for the previously submerged areas. The existing seed bed would be a diverse, native seed source and would allow for the natural succession from new emergent wetland to forested floodplain habitat, where appropriate. However, the literature does not detail potential monitoring and management issues that could arise once the new wetlands are established. The most problematic issue would be invasive wetland plants. Invasive species, such as reed canary grass (*Phalaris arundinacea*), common reed (*Phragmites australis*), and purple loosestrife (*Lythrum salicaria*), has been known to exist along the edges of the impoundments. No information is currently available that provides a framework or recommendations to control and eliminate invasive species from the newly formed wetlands. Other issues also need to be addressed, such as seeding/planting bare areas, wetland monitoring requirements, and providing habitat structure for wildlife.

9.7 Summary of Impacts

In general, wetland loss adjacent to or near the impoundments as a result of alternatives proposing the lowering of water elevations is anticipated to be minimal, because the majority of existing wetlands are sustained by groundwater inputs within the Boardman River Valley. There are no scenarios involving a significant loss of wetlands. Under the No Action and dam modification alternatives, newly developed emergent wetlands formed within Boardman Pond in 2007 and 2008 following the 2007 emergency drawdown would not be impacted since the water level would remain at its current state. Alternately, the dam removal alternative, which proposes a reduction in water elevation within an impoundment, is predicted to result in a gain in wetland acreage with the conversion of open water areas to wetlands and an increase in species and structural diversity with the conversion of deep aquatic habitats to emergent and ultimately emergent/scrub-shrub systems. Such a shift in wetland type and extent is anticipated to improve the quality of and increase the quantity of rare species and overall wildlife habitat available along Boardman River. The effects on wetlands associated with the impoundments are summarized for each of the three alternative scenarios in Table 9-4.

Table 9-4: Wetland Habitat Impacts for the Boardman River Project

Category	Remove Dam	Modify Dam[1]	No Action[1]
Sabin Pond Wetland Gain/Loss (acres)	+30.5	0	0
Boardman Pond Wetland Gain/Loss (acres)	+26.5	0	0

[1] Leave impoundment at current water level, post-2007 emergency drawdown.

10 Site Layout for Existing Conditions and Alternatives

A site visit was conducted to determine the existence of any facilities (e.g., offices, parking lots, roads) of relevance in the project area. These areas were photographed, with features documented and incorporated into drawings of existing conditions. These drawings are provided in the Project Plates (Attachment 4). Preliminary drawings depicting dam removal and modification alternatives, including habitat enhancement measures, such as wetland creation are also provided in the Project Plates (Attachment 4). Site constraints and property impacts identified for each of the project locations are discussed in detail below.

10.1 Union Street Dam

Under the modification and removal plans for the Union Street Dam, both the dam site and the MDNR trap-and-transfer facility may be impacted by construction activities. Grand Traverse County provided parcel data along the Boardman River corridor. As shown in Figure 10-1, there is ample access and public property (shaded in red) along the west bank of the river at the MDNR facility. This would accommodate improvements at the facility. If a new barrier is placed in the river at this facility, a construction easement may be necessary along the east bank from the private property. Geotechnical investigations would be necessary to properly design the proposed barrier. Additionally, the flood stage impacts due to the installation of a new barrier would require real estate acquisition for flood mitigation. These acquisitions have been deemed cost prohibitive.

Figure 10-1: Public property at MDNR trap-and-transfer facility

At the Union Street Dam, access to the dam and adjacent work areas is sufficient, as shown in Figure 10-2. Although there is enough real estate to accommodate a new trap-and-transfer facility at the dam, this would likely be poorly received by the non-Federal sponsor because of the loss of park space and parking lot. Access to the river could be difficult as a result of the grades and utilities along the north side of the river if a rock ramp would be constructed. Access for modifications to the fish ladder appears ample. Geotechnical investigations would be necessary to properly design the proposed core wall for the rock ramp alternative as well as for the foundations of the trap-and-transfer alternative.

Figure 10-2: Public property (shaded) at the Union Street Dam

10.2 Sabin Dam

Construction access at the Sabin Dam and its impoundment would be available from the west off of Cass Road and from the East off of Keystone Road. Both of these access points use only public property and provide access to the entire impoundment and dam site. Multiple haul road access points would be feasible within the impoundment. If the fish passage alternative is selected, the downstream fish pass channel would likely require an easement from the adjacent properties along the southeast corner of the Boardman Dam impoundment. For the recommended alternative overhead utilities in the southwest corner of the Boardman Dam impoundment would need to be temporarily removed or protected. No property acquisition is expected. Geotechnical investigations would be necessary for soil bearing strengths, whether for haul roads, fish passage channels, or fish elevators. Public lands and utility conflicts for Sabin Dam are shown in Figure 10-3.

Figure 10-3: Public property (shaded) at the Sabin Dam

10.3 Boardman Dam

Access for the Boardman Dam and its impoundment is currently limited to the northern end where a public parking lot and boat launch exist. Additional access (haul roads) may need to be constructed at the west end of the earthen dam (from Cass Road) and at the south end of the impoundment, near the Lone Pine Trailhead parking lot. This access would be sufficient for all alternatives considered. Spatial constraints that would need to be factored into final design plans (but are not expected to impact costs) are the east side private property and electrical substation and the railroad tracks on the west side of the impoundment. Within the impoundment bearing capacities for construction roads are expected to be suitable based on the high sand content; however, geotechnical investigations are necessary to verify soil bearing capacities for either a fish elevator at the dam or haul roads within the impoundment. Utilities within the area that would need to be temporarily removed or protected include the overhead lines along Cass Road

and near Hoch Road. Public lands and utility conflicts for Boardman Dam are shown in Figure 10-4.

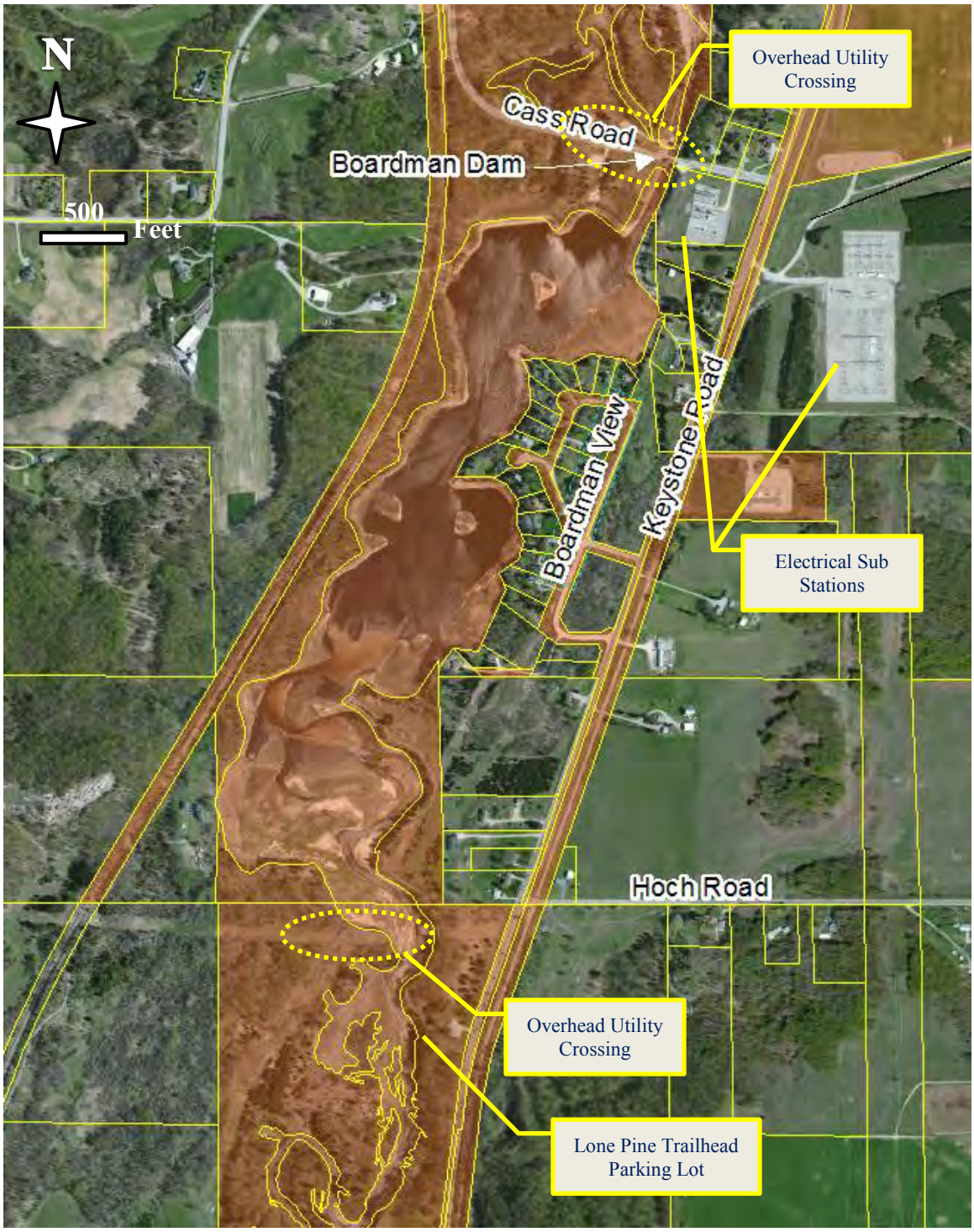

Figure 10-4: Public property (shaded) at the Boardman Dam

11 Value Engineering

A Value Engineering (VE) study was conducted for this project because it is expected to exceed $10 million in total cost, per USACE policy (ER11-1-321). The VE Team undertook the task using the VE work plan and approach. Complete documentation of the VE study is provided in Attachment 5.

During the speculation phase of this VE study, 37 creative ideas were identified; 12 of these ideas were developed into VE recommendations and 14 were developed into design comments with cost implications where applicable. Many of the ideas represent changes in design approach, reconsideration of criteria, and in some cases, modification of the project scope. In general, the idea evaluation took into account the economic impact, other benefits obtained, and the effect on the overall project objectives. The VE study report (Attachment 5) presents the ideas developed into recommendations and design comments with cost implications. Since cost is an important issue for comparison of VE proposals, the costs presented in the VE report are based upon original design quantities with unit rates obtained from the estimate as prepared by the Design Team and included in their submission, published cost databases, and VE Team member experience.

After further review and discussion with the Design Team and non-Federal sponsor, the following VE Team recommendations were accepted and implemented into the recommended alternative Feasibility Study design:

- Retain the Boardman and Sabin Dam powerhouses in lieu of removal.
- Route the restored Boardman River alignment through the existing Sabin Dam spillway in lieu of the historic channel to the East of the Sabin Dam spillway and powerhouse.
- Optimize the designed floodplain width in the restored segment of the Boardman River to narrow it where possible in order to reduce excavation costs.
- Improve sediment management efficiency by using fewer and larger disposal areas.
- Increase the use of targeted restoration using live stakes on steep banks and slopes in lieu of passive and/ or seeding restoration options.

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US Army Corps
of Engineers
Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

GRAND TRAVERSE COUNTY, MICHIGAN

ATTACHMENT 1

H&H MODELING REPORT

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

US Army Engineer District, Detroit
477 Michigan Avenue
Detroit, MI 48226-2523

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EXECUTIVE SUMMARY

The study area from the upstream extent of Boardman Pond to the mouth of the Boardman River at Grand Traverse Bay currently has three dams impounding water: the Boardman Dam, the Sabin Dam, and the Union Street Dam. The Boardman and Sabin Dams were originally for hydropower generation; however, generation has ceased at these locations. Studies have commenced to examine several different alternatives related to the fate of these dams. The purpose of this portion of the report is to complete a feasibility level comparison of hydraulics and sediment fate and transport of the existing conditions to the proposed alternatives.

The existing hydraulic model was modified to better represent the current conditions within the study area through field observations and modifications to the dam configurations in the model. These modifications included updates to spillway and intake structures to simulate current conditions of gate positions and the removal of hydropower generation equipment. Modifications to the Boardman and Sabin Dams included modification of intake and outfall parameters as observed in the field. The Union Street Dam was modified to include an inline stoplog structure as the original U.S. Army Corps of Engineers (USACE) (2008a) model assumed all stoplogs were removed. These modifications were applied to the existing conditions model and the alternative modeling where applicable.

As part of the alternatives selection process, several alternatives were screened out during preliminary analysis and design. Under the proposed alternative, the Sabin and Boardman Dams would be removed; the Union Street Dam would remain in place as it is an important barrier for the system to invasive species from Lake Michigan. A preliminary natural-channel design was developed for the currently impounded areas where the new channel is anticipated to flow following full removal. This includes a 60-foot-wide bankfull channel with floodplain storage on either side. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) model was used to optimize the floodplain width for the existing impounded areas under the proposed alternative with the Sabin and Boardman Dams removed; for this modeling, basic channel geometry was applied throughout the existing impoundments. As part of the Value Engineering process, a 30-foot-wide floodplain on either side of the channel was chosen; this channel configuration allowed flow through the existing areas without causing water level rises under the 100-year event within the study area.

Preliminary flooding analysis was conducted to compare water levels and inundation areas under the 100-year and 500-year events between existing conditions and the preferred alternative. Water levels did not go up upstream or downstream of the existing impoundments in the flood model. Preliminary flood extents within the two impoundments were mapped; the floodway under the proposed alternative did not extend beyond the existing conditions except where the new channel is anticipated to flow in a different location than where it currently flows (e.g., through the Boardman earthen berm as opposed to the existing powerhouse).

Multiple sediment sampling efforts within Boardman and Sabin Ponds over the course of several years indicated slightly elevated levels of arsenic and cadmium, but other contaminants were not of levels to be of concern. Sampling methods and locations varied across the sampling period, making direct comparisons of results difficult. Arsenic and cadmium results showed some samples with results above the threshold effect concentration; however, no results were above the probable effect concentration. Communications were held with the Michigan Department of Environmental Quality (MDEQ) for guidance on proceeding with sediment management based on the sample results; MDEQ suggested sampling should be conducted on dewatered sediments to reassess contaminant levels in the future.

The proposed alternative channel through Boardman and Sabin Ponds would require some excavation of sediments and disposal locations within the currently impounded areas. To estimate the volume of sediment that might be mobilized under the proposed alternative, the basic channel geometry was applied to a channel profile through the existing impoundments based on the most current (2007) bathymetry data available. Included in these calculations were estimates of the amount of earth removal required for breaching existing earthen impoundments. Sediment disposal areas within the existing impoundments were chosen based on storage area available and as to not impact future wetland areas. These results are preliminary and must be refined during final design with updated, higher resolution bathymetry data and depth of refusal data within the impoundments.

Sediment fate and transport modeling exercises compared the existing conditions of the system with the proposed alternative. An initial baseline conditions study looking at sediment surpluses and deficits using Sediment Impact Analysis Methods (SIAM) suggested that the river was largely in a graded state; however, there were sediment deficits downstream of dams and impoundments were acting as sinks for sediments. A drawdown on the Boardman River dams resulted in downstream movement of some of these impounded sediments.

Sediment transport models simulating 15 years of the flow record were used to compare existing conditions and the proposed alternative alignment through the existing impoundments. Results compared the patterns of deposition and incision throughout the study reach. Under existing conditions, a large wedge of accumulated sediments within Boardman Pond has moved downstream, while areas directly downstream of the Boardman and Sabin Dams experience sediment deficits. Restoration of the channel results in more consistent restored conditions throughout the study reach. However, the area of channel from the Sabin Dam to Airport Road becomes a location of net deposition given the history of sediment deficit and relatively flat channel slope. Sediment management efforts should be focused on this area of the channel following removal. These model results are for feasibility level planning purposes, are uncalibrated, and should be used for comparison purposes only as they are uncalibrated. Updated bathymetry, sediment cores, and depth to refusal data should be collected for analysis in final design.

1 Review of Existing Studies

Recent studies and literature (since completion of that last comprehensive literature review, USACE 2008a) relevant to the Boardman River Dams removal project were gathered and reviewed. A complete list of literature reviewed can be found in the References section of the report. The material assembled here focuses on hydraulics, hydrology, and sediment fate and transport in the Boardman River system. A summary of the data from each report relevant to the current study is also listed for reference.

Boardman River Feasibility Study Boardman Dams Breach/Drawdown Study, January, 2009 (ECT) (Prein & Newhof 2009).

The purpose of the breach/drawdown study on the Boardman River Dams was to evaluate appropriate methods and estimate the costs to produce a controlled dam breach and/or draw down the reservoir levels at each of four dams on the Boardman River in Grand Traverse County, MI. The breach/drawdown would be performed aiming to remove at least one of the river's dams. The report analyzed how each dam could be safely breached to restore pre-dam river flow. The methods that were evaluated to achieve pre-dam flow conditions were emptying each reservoir by pumping or construction of a stop-log drawdown control structure. Each dam was considered separately, identifying existing hydraulic structures and seasonal flow probabilities. Sediment management, river restoration, and demolition site restoration were not considered in this report.

It was determined that it is feasible to safely breach each of the four Boardman River dams. The breach could be performed by either using a constructed, temporary drawdown structure or by-pass pumping the river over the embankment, emptying the impoundments. The drawdown structures were estimated to cost between $200,000 and $1,900,000 depending on the dam. The by-pass pumping was estimated to cost approximately $650,000 and $1,500,000 for the same corresponding dams.

Data Included

- *Dam Information*
  - *Michigan Department of Environmental Quality (MDEQ) Dam Safety ID#*
  - *Hazard Potential Rating*
  - *Dammed Water Body*
  - *Pool Surface Area*
  - *Height*
  - *Drawdown Height*
- *Hydraulic Control Structures Available*
  - *Embankment Elevation*
  - *Various Spillway Sill Elevations*

    - *Penstock Intake Sill Elevation*
  - *Fish Ladder Upstream Invert Elevation*
  - *Downstream Toe Elevation*
- *Hydraulic Information*
  - *10-percent Exceedance Flow*
  - *Mean Flow*
  - *Design (200-Year Flood) Flow at Dam*
  - *Drainage Area*
- *MDEQ Flow Data (Appendix 1)*
- *Maps (Appendix 2)*
- *Hydrologic Engineering Center's River Analysis System (HEC-RAS) Cross-Section at Each Dam (Appendix 3)*

Boardman River Feasibility Study Preliminary Evaluation of Existing Structures, January, 2009 (USACE 2009b).

The purpose of the report was to summarize historical information on each of the four dams including observations from an inspection performed by the U.S. Army Corps of Engineers (USACE) and Environmental Consulting & Technology, Inc. (ECT) engineers in September of 2007. The existing conditions inspection included both Structural and Geotechnical aspects of the dams. This report focused on the constructability of the dams including site alternatives and restrictions. The general categories discussed are: Existing Operations, Breach or Removal, and Modifications. The dams were also analyzed to determine if they meet the Federal Energy Regulatory Commission (FERC) and MDEQ spillway criteria.

The report concluded that only the Sabin Dam was determined to meet the FERC criteria whereas all dams except the Boardman Dam meet the MDEQ criteria. Because of the Boardman Dam's failure to comply with standards, action was required to address dam safety issues. The Brown Bridge Dam also had some safety concerns that would need to be addressed in the future. All dams must undergo routine operation and maintenance to remain in accordance with safety regulations.

Based on the observations of the dams, the authors made some recommendations for future work. As of the report drafting, the City of Traverse City was pursuing additional evaluations of the Union Street Dam and the Brown Bridge Dam. Any issues that should arise from further assessment would have to be addressed. The authors also recommended long-term operation and maintenance with dam left in places, along with modifications to operation of dam for the Brown Bridge Dam. No immediate action was required for the Sabin Dam, but some preliminary engineering cost estimates were suggested for long-term operation and maintenance with dam left in place and modifications to dam operation. The Boardman Dam did not comply with MDEQ regulations; therefore, immediate action was recommended. Establishing preliminary

engineering cost estimates for the following alternatives was recommended: modification to the existing spillway, modification to the emergency spillway, and modification to the detached embankment. The authors also recommended that preliminary engineering cost estimates be established for long-term operation and maintenances, as well as modifications to operation of dam. Structural evaluation of the Boardman Dam was suggested, particularly at the Cass Road Bridge and access deck.

Data Included

- *Union Street Dam*
  - *Descriptions of Dam*
  - *Results from 2005 Safety Inspection*
  - *Onsite Observations from 2007 Joint Inspection*
  - *Impactions to Existing Operations (Conditions Without Project)*
  - *Potential Impacts to Breach/Removal of Dam*
  - *Potential Impacts to Construction of a Fish Passage*
- *Sabin Dam*
  - *Description of Dam*
  - *Results of 2006 FERC Operation Report*
  - *Onsite Observations from 2007 Joint Inspection*
  - *Impactions to Existing Operations (Conditions Without Project)*
  - *Potential Impacts to Breach/Removal of Dam*
  - *Potential Impacts to Construction of a Fish Passage*
  - *Potential Impacts to Rerouting River and Leaving Dam in Place*
- *Boardman (Pond) Dam*
  - *Description of Dam*
  - *Results of 2006 FERC Operation Report*
  - *Onsite Observations from 2007 Joint Inspection*
  - *Impactions to Existing Operations (Conditions Without Project)*
  - *Potential Impacts to Breach/Removal of Dam*
  - *Potential Impacts to Construction of a Fish Passage*
- *Existing and required spillway capacities*
- *Photographs of all four dams*

Boardman River SIAM Modeling Base-case Scenario, May, 2009 (USACE 2009a).

The purpose of this report was to analyze and numerically model the existing sediment budget at the Boardman River and its four dams. The model was developed using field observations, field data, historic data, and current data. The river's flow was modeled using an adjusted model of the annualized flow time series from the U.S. Geological Survey (USGS) stream gauge located at the upstream portion of the study area. The stream flow data were then used to develop the Sediment Impact Analysis Methods (SIAM) model for the entire study area. The project site was divided into distinct sediment reaches with similar hydraulic and sediment characteristics.

The results of the SIAM model exhibited minor supply limitations of less than 2 inches per year along most of the Boardman River. While these results showed a slight shortage, it was still considered to be within the range of stable conditions. Although the areas below the Brown Bridge Dam and a steep section of the river had much larger supply limitations, the sections were still determined to be stable. The reach near the Sabin Dam showed the potential for scouring, but it was still balanced as Sabin Pond, located immediately downstream of the Boardman Dam, was a sediment sink. At Brown Bridge and Boardman Ponds, supply exceeded the transport capacity with annual sediment excesses ranging from 0.3 to 1.2 inches per year and 1.5 to 2.9 inches per year, respectively. The results indicated that the sediments in most sections of the Boardman River were in a graded or balanced state, except the delta of Brown Bridge Pond, sections of the river below the Brown Bridge Dam, and the impoundments behind the dams.

Bank erosion was rarely observed on the Boardman River, but still included in the SIAM sediment budget analysis. Over the two time periods, sediment from bank erosion simulated as point source loads showed very little impact on the total sediment volume for Boardman Pond. However, the results of bank erosion were based on limited data and simple estimates, not calibrated model results or erosion measurements. Although the results showed that the sediment budget in the river was relatively stable (minimal observations of erosion or deposition outside of impounded areas), any alterations to structures may drastically change the sediment dynamics, especially considering that a large volume of sediment began accumulating in the early 1900s. Any dam removals could result in increased shear and potential mobilization of the deltas in the ponds. The authors noted that SIAM is a sediment budget model, rather than a sediment transport model. These results would be best used as a screening tool to determine if the potential future dam modifications or removals would be possible. More detailed modeling would be necessary before any modifications are made.

Data Included

- *Watershed Areas of Major Tributaries Downstream of the Brown Bridge Dam*
- *Particle size distributions of bed sediments*
- *Daily Sediment Load over time*
  - *Cumulative Sediment Load*
  - *Cumulative Sediment Load w/ Flows <200 cubic feet per second*

- *Annual precipitation*
- *Annual water yields*
- *Retention time and theoretical minimum particle sizes for sediment retention*
- *Longitudinal Profiles of the Boardman River* Hydrologic Engineering Center's River Analysis System *(HEC-RAS) model*
- *Cross-sections of specific points along the Boardman River*
- *Estimated annual sediment loading rates*

Boardman River Field Reconnaissance and Survey Data, 2008 and 2009 (USACE 2009c, unpublished data).

Extensive field data were collected by the USACE in the study area. Data were relevant to field conditions, sediment characteristics, and geomorphology of the region.

Data Included

- *Bed and bank grain-size distributions*
- *Photographs of changing conditions with drawdowns*
- *Photographs of eroding banks*
- *Photographs of sediment characteristics*
- *Channel sinuosity measurements*
- *Channel cross-section surveys*
- *River longitudinal profile*
- *Checking in with URS about any other data that has been collected by the Corps during these years*

Boardman River Hydraulic Model Report, Grand Traverse County, MI. U.S. Army Corps of Engineers, Section 506 Great Lakes Fishery and Ecosystem Restoration, April, 2008 (Note: Relevant to Existing Conditions) (USACE 2008a)

The USACE developed a complete hydraulic model for the Boardman River using a hydraulic model called HEC-RAS (USACE 2002, ver. 3.1.3). This model was developed using a combination of existing hydraulic and flood models for the river and additional topography and structure data. HEC-RAS is a one-dimensional hydraulic model developed by the USACE for natural and constructed channels. The model can compute both steady and unsteady flow, sediment transport capacity, and water quality. Several functions are built into the model to calculate sediment transport.

The Boardman River HEC-RAS model was developed under the USACE Section 506 Great Lakes Fishery and Ecosystem Restoration program. The hydraulic model included approximately

25 miles of the river from its mouth at Grand Traverse Bay to almost 6,000 feet upstream of Brown Bridge Road (upstream of the Brown Bridge Dam). This model was developed using the existing conditions, including Boardman Pond being at full-pool.

Data for model development came from a variety of sources: the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) within Traverse City, survey data collected by Gourdie Fraser and Gosling Czubak, geographic information system (GIS) contour data from Grand Traverse County, USACE bathymetry data of the impoundments, design drawings of bridges and structures, and the MDEQ Boardman River hydraulic model.

Four dams were represented in the hydraulic model: the Union Street Dam, the Sabin Dam, the Boardman Dam, and the Brown Bridge Dam. While the actual dam structures were not surveyed for the hydraulic model, the river around them was. Bridges were also integrated into the model using FEMA FIS HEC-2 (predecessor to HEC-RAS) data or field surveyed data. The multiple data sources were all used to model over 25 miles of the Boardman River. The model was intended to be used as existing conditions to compare for future modification of dams. An evaluation of the post-2007 drawdown conditions was included in this analysis.

Data Included

- *Hydraulic Data*
  - *Channel cross-section surveys*
  - *Dam survey and hydraulic characteristics*
  - *Longitudinal profile survey*
  - *Flood-frequency discharge data for several locations throughout the study area*
- *CHECK-RAS Output*

2 Survey and Mapping

Extensive survey, field work, and map data were generated previously to characterize the baseline conditions of the Boardman River and dams. This included survey efforts along approximately 24 miles of stream, beginning at Medalie Park just upstream of Boardman Lake and ending approximately 2 miles upstream of the Brown Bridge Dam impoundment. River survey, geomorphic, and bathymetric data and reconnaissance were conducted by USACE Detroit and W.F. Baird and Associates personnel. Stream survey cross-sections were taken at a minimum spacing of 1,000 feet, except for a 2,000-foot stretch upstream of Boardman Pond where survey cross-sections were taken at a minimum spacing of 500 feet. Survey data were also collected at all bridge overpasses, culverts, piers, and other stream crossings. Survey cross-sections extend to 200 feet into both the left and right overbanks.

Specific data collected include stratified bed material and sediment sampling along the Boardman River and within the ponds, numerous field photographs to document river condition, and establishment of reference reaches along the Boardman River. The reference reaches represent stable sections of river and include full riffle/pool sequences. Survey to monument benchmarks ties all elevation data to common datum. The information collected was determined to be suitable for developing a hydraulic model of existing conditions and conducting analyses required for this study.

Flow measurements and sediment transport data were collected by the USGS at its gauging station at Ranch Rudolph above Brown Bridge Pond. Analyses of all sediment samples and development of sediment transport rating curves were also completed by the USGS. Sediment samples were analyzed for size class and weight, by discharge interval. The sediment samples and data analyses conducted thus far are suitable to provide a screening level understanding of sediment sources and sinks within the project area.

The data previously collected are critical to establishing the base case, existing conditions scenario, and project alternatives for the Boardman River and the Union Street, Sabin, Boardman, and Brown Bridge Dams. These data characterize the hydraulic, sediment, and geomorphic regime of the current system. Review of these data indicates they are sufficient for the SIAM base-case and sediment transport modeling. The data have been used to develop the SIAM study and more detail sediment transport modeling. Results from analyses of the data collected include the *Boardman River Hydraulic Model Report* and the *Boardman River Sediment Impact Analysis Methods (SIAM) Modeling Base-Case Scenario* reports (USACE 2008a and 2008b).

3 Hydraulic Studies

3.1 Assessment of Existing Structures

All three study dams within the Boardman River were assessed during a site visit in April 2011 to examine functionality and existing conditions to previous modeling efforts. Engineering drawings were obtained and reviewed for the Boardman Dam; drawings for the remaining two dams were not immediately available from the local government offices. Drawings for the Sabin Dam were later obtained for examination. Intakes, outlet, spillways, and existing flow conditions were examined to inform future modeling and design work for the study area. A summary of the observations from document review and site visits is listed below.

3.1.1 Boardman Dam

The Boardman Dam was visited on April 25, 2011. Spillways, intakes, outfalls, and the interior of the pumphouse were observed. Engineering plans from 1930 were obtained for the Boardman Dam to examine details of intakes and spillways. An informational poster in the dam depicted a conceptual drawing of flow through the dam (Figure 1).

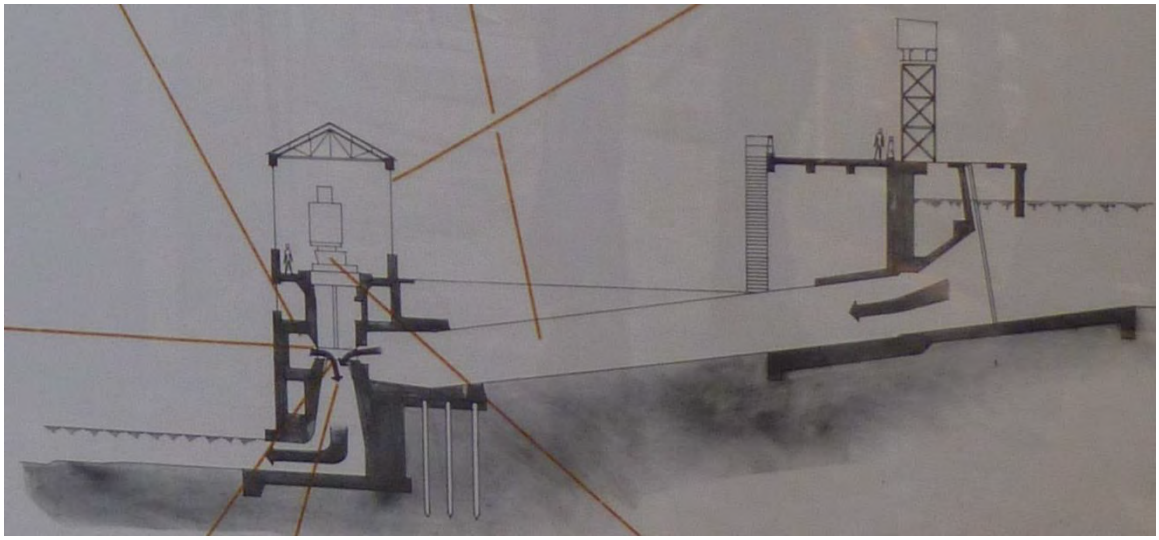

Figure 1: Conceptual drawing of the Boardman Dam illustrating flow paths (Source: Display within dam pumphouse)

At the time of the visit, flow was going through both intakes, but none through the spillways (Figure 2). The channel upstream of the dam was filled with sediment up to the level of the concrete sill of the intakes.

Figure 2: Spillway and intakes on the upstream side of the Boardman Dam. No flow through spillway (left) at time of field visit, but flow through intakes (right). Note that sediment in channel leading up to dam is filled up to concrete sill, visible in the photo.

The large detached earthen embankment to the west of the existing structure is shown in Figure 3. The earthen embankment was largely sand and gravel on the upstream side with a large concrete wall. The downstream side was a steep grassy embankment.

Figure 3: Earthen berm with concrete wall west of the existing dam structure

3.1.2 Sabin Dam

The Sabin Dam was visited on April 25, 2011. Engineering plans for the dam from 1930 were obtained after the field visit. Spillways, intakes, outfalls, and the interior of the pumphouse were observed. An informational poster in the dam depicted a conceptual drawing of flow through the dam (Figure 4).

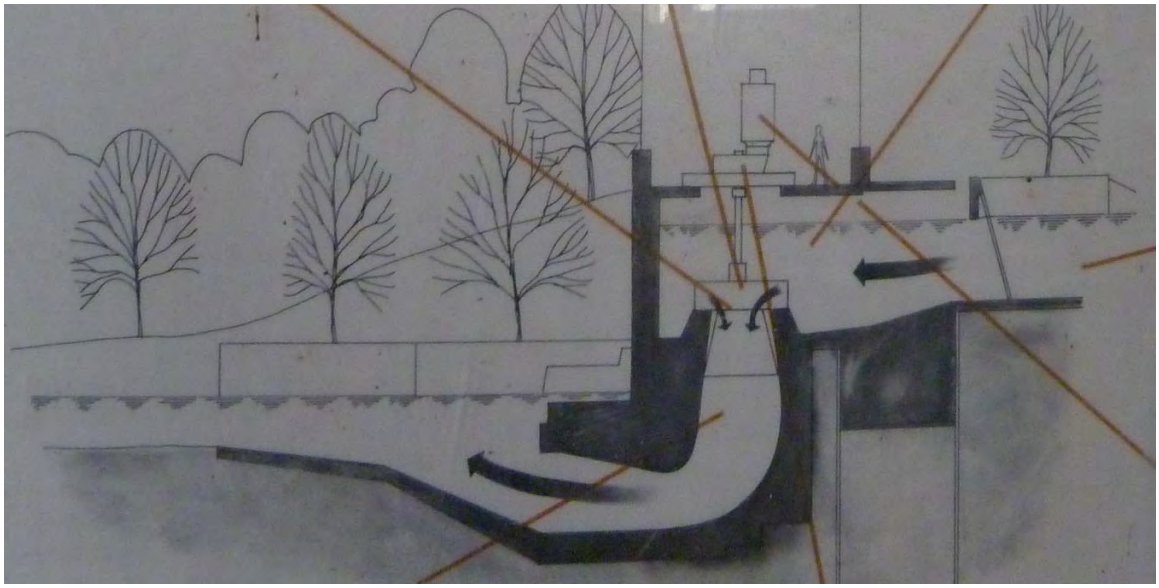

Figure 4: Conceptual drawing of the Sabin Dam illustrating flow through the dam (Source: Display within dam pumphouse)

Photos of the intakes and spillways of the Sabin Dam are shown in Figure 5 through Figure 7. At the time of field observation on April 25th, flow was going through the intakes (Figure 5) and the far right spillway (Figure 6). The water level in Sabin Pond was below the level of the stoplogs of the east side of the spillway, preventing overtopping. The steep slope of the spillway and the energy reducing blocks within the channel downstream of Sabin Dam are shown in Figure 7, looking downstream from the walkway.

Figure 5: Trash racks at intake of the Sabin Dam

Figure 6: Upstream (left) and downstream (right) views of the Sabin Dam spillway

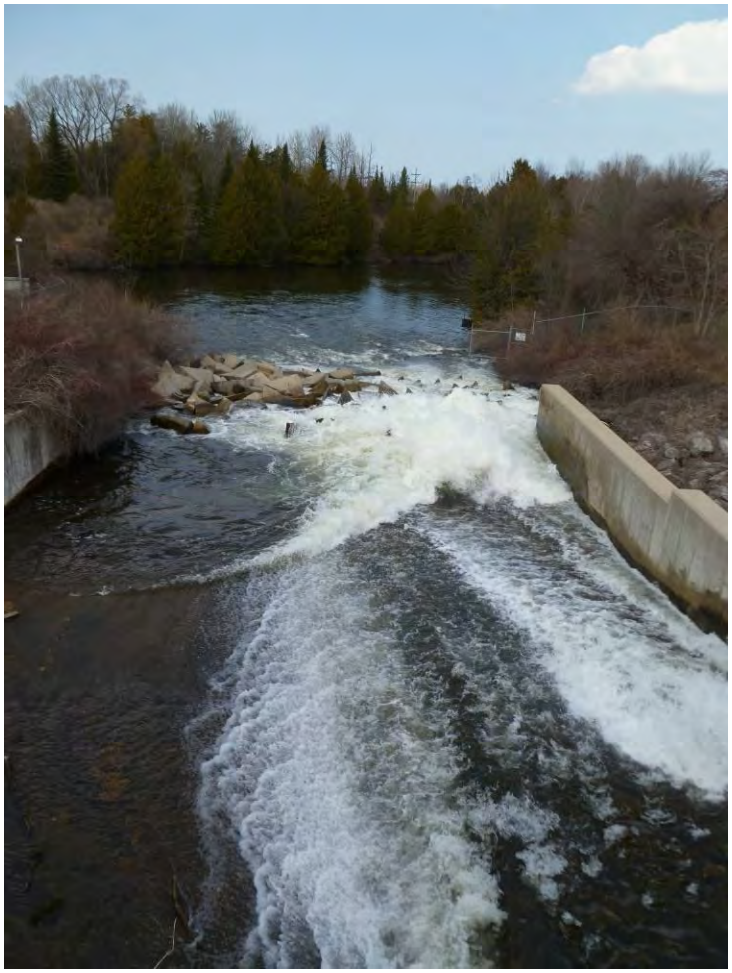

Figure 7: Spillway chute looking downstream from the Sabin Dam; energy reducing blocks at bottom of chute

The remains of an old spillway structure to the east of the existing spillway exist on the downstream side of the earthen embankment (Figure 8), indicating previous alternative channel alignment.

Figure 8: Remains of old spillway structure for the Sabin Dam east of the existing structure (looking downstream)

3.1.3 Union Street Dam

The Union Street Dam was visited on April 26, 2011. No engineering plans were available from the local government offices at the time of the visit. Intakes, outfalls, and the fish ladder were observed. At the time of observation, flow was going through the intakes and the fish ladder, located on the left side of the dam.

Figure 9: Photo of the Union Street Dam, from downstream looking upstream (Source: ECT 2008)

Figure 10: Photo upstream of the Union Street Dam looking downstream (Sources: STS 2008)

3.2 Model Revisions/Updates

Previous hydraulic and sediment transport models for the study reach were examined and compared to field observations of the existing structures in Section 3.1. These models include the original hydraulic model developed for the Boardman River Hydraulic Model Report (USACE 2008a) and the Boardman River SIAM model (USACE, 2009a), which built upon the previous model for sediment budget analyses. Based on these comparisons, model revisions were completed for this study in the following sections for each of the structures in the study area.

3.2.1 Boardman Dam

The Boardman Dam structure in HEC-RAS is shown in Figure 11. The original model developed by USACE only accounted for the principal spillway. The model was modified to include the intakes open as in existing conditions to allow flow through the dam.

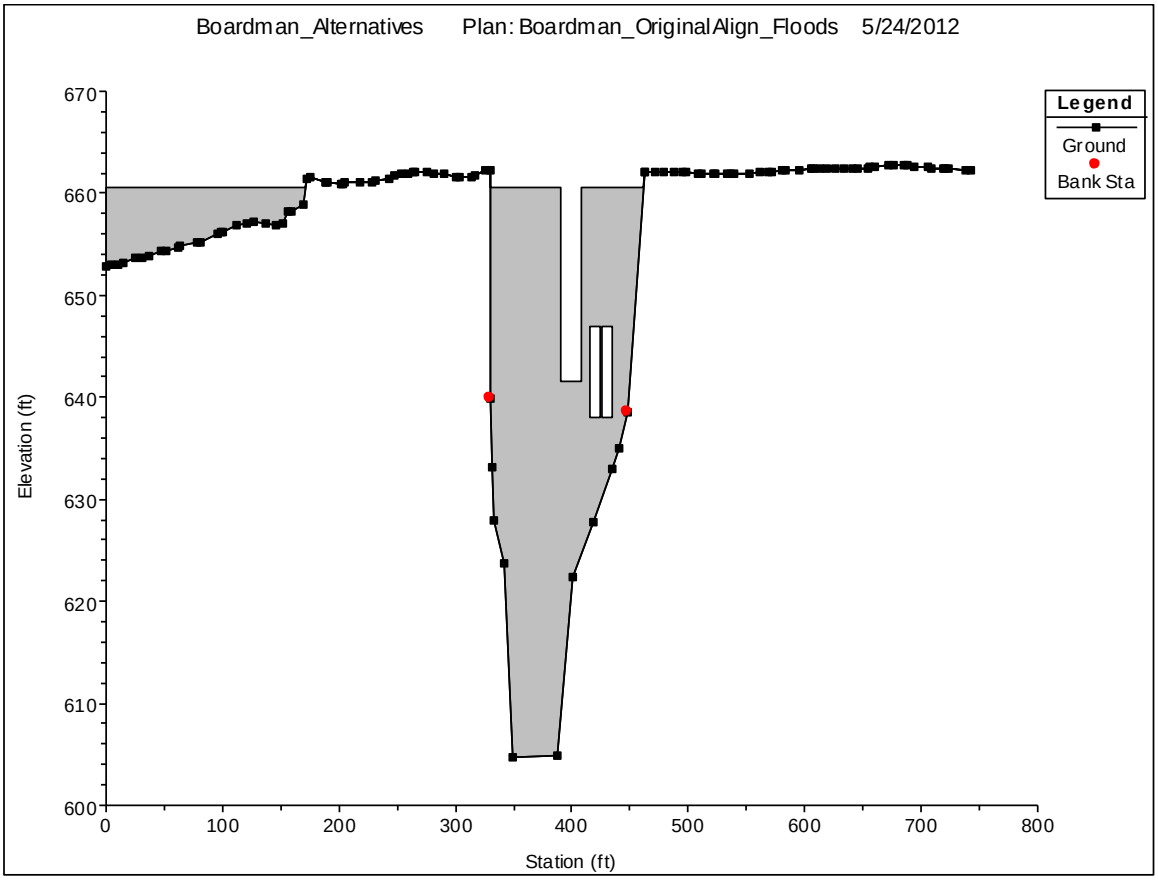

Figure 11: Configuration of the Boardman Dam in the existing HEC-RAS model. Note that in the previous model developed by USACE, the principal spillway was included but not intakes (two gates on the right side shown above). Earthen berm (grayed area on the left) is shown as illustrated in the model on the left.

3.2.2 Sabin Dam

The Sabin Dam structure configuration for the HEC-RAS model is shown in Figure 12. The original model developed by USACE accounted for the far east spillway and the existing

stoplogs but did not include intake dimensions. The model was updated to include the dimensions of the intake along the left side of the dam to reflect existing conditions allowing flow through the dam.

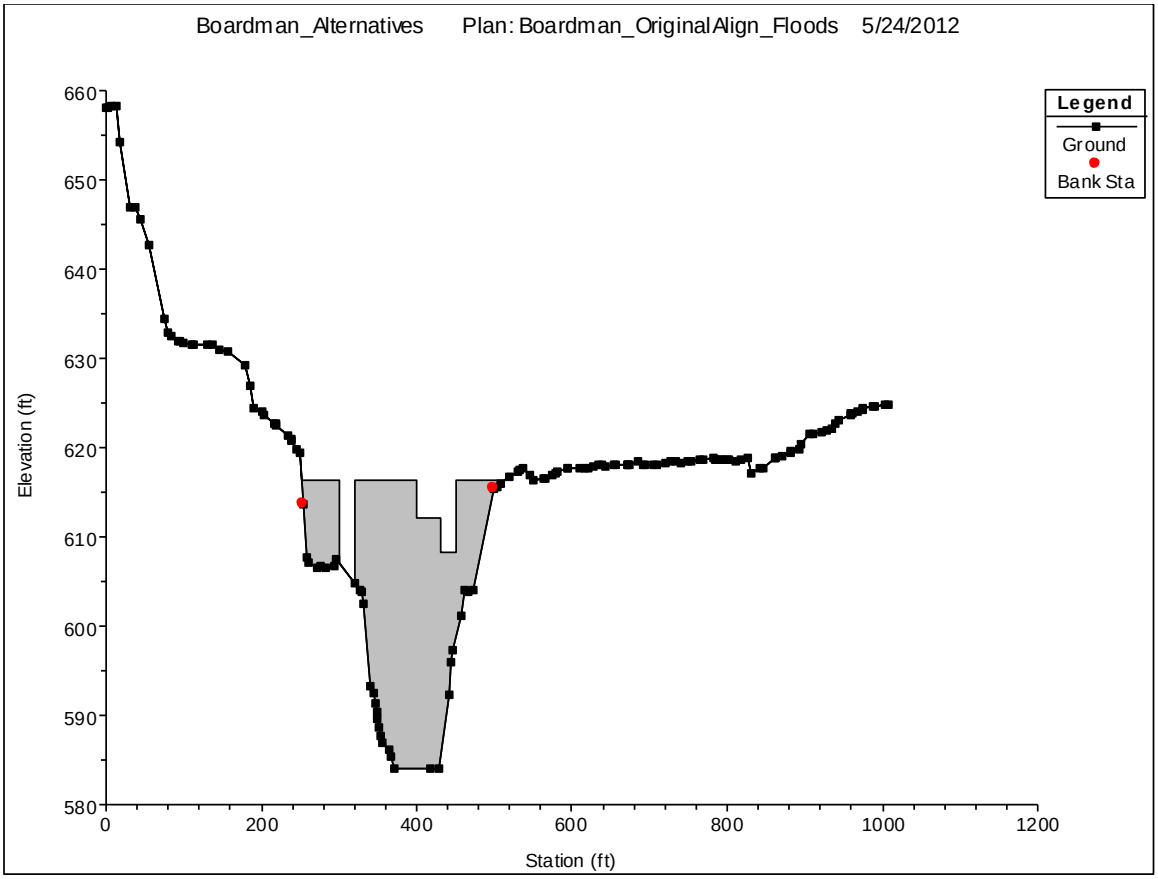

Figure 12: Configuration of the Sabin Dam in the existing HEC-RAS model. Note that principal spillways and stoplogs were included in the original USACE model but intakes were not. The intakes (left side of the dam) have been added to the model to reflect existing conditions.

3.2.3 Union Street Dam

The configuration of the Union Street Dam in the existing HEC-RAS model is shown in Figure 13. The Union Street Dam was modeled as a bridge instead of an inline structure in the model as a result of the use of culverts as spillways in the dam. The structure was slightly altered from the true structural configuration of the dam because of culvert number limitations for bridge design within HEC-RAS. The model does not account for the fish ladder on river left of the structure. The original model (USACE 2008a) simulates the Union Street Dam as if all stoplogs were removed. In order to simulate the stoplogs while keeping the ability to model the culvert-style spillways of the dam, an inline structure of elevation 589.3 feet was placed in the model just upstream of the dam structure in HEC-RAS. The height was determined based on the pool level of 589.3 feet from the Union Street Dam safety report (STS 2008).

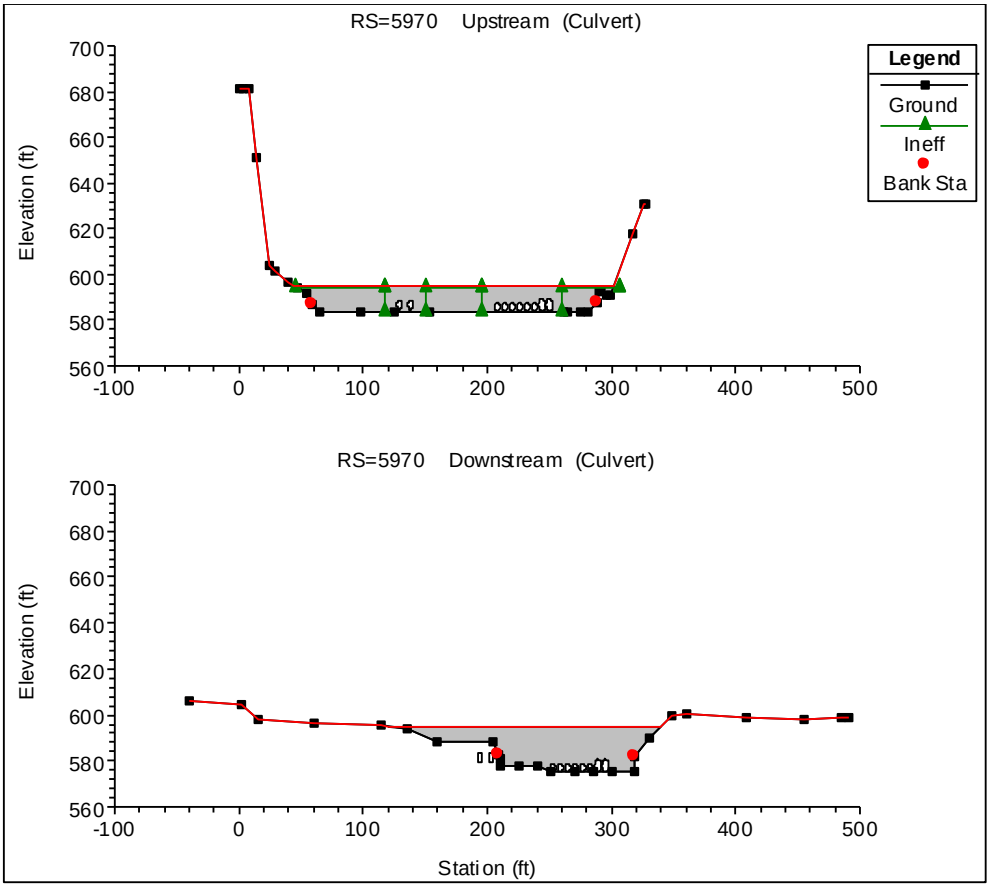

Figure 13: Configuration of the Union Street Dam in the existing HEC-RAS model. Note that the Union Street Dam was modeled as a *bridge* as a result of the use of culverts for spillways in the structure. An inline structure of elevation 589.3 feet was added just upstream of this structure to simulate the stoplogs.

3.3 Alternatives Analysis

Over 80 possible decommissioning and restoration scenarios have been suggested as part of the Boardman River dams decommissioning project. A preliminary screening was conducted to identify which alternatives are actually feasible and best balance overall project goals for such amenities as fish passage, recreation, socioeconomics, and local community benefits. Following completion of the screening and recommendation of the most likely/viable alternatives, the final proposed alternative was identified as removal of the Boardman and Sabin Dams, and but no removal of the Union Street Dam as it provides crucial barrier for the river to invasive species. These are fully described in the main body of the Detailed Project Report and Environmental Assessment. The reader is directed to those documents for complete descriptions of the proposed alternative.

The natural channel design approach was used to estimate future conditions for the design of stream cross-sections, planform, and profile. Natural channel design methodology employs geomorphic measurements from reference streams as a template for designing the restored stream. Measurements from the reference stream are converted to dimensionless ratios by

dividing by various bankfull characteristics, allowing the transference of characteristics from reference streams of difference sizes to the restoration area.

The reference reaches for Boardman River included detailed areas where detailed geomorphic surveys had been conducted by USACE and were provided as field notes and digital data on river and sediment characteristics. The geomorphic assessments in this survey included developing longitudinal profiles, rifle cross-sections, pool cross-sections, riffle pebble counts, and a reach average pebble count.

In addition, numerous additional river segments were analyzed for sinuosity and slope in areas upstream of Boardman and Sabin Ponds. These data were used to guide estimates of likely river sinuosity and slope following dewatering of the ponds. An example of the longitudinal profile of the natural channel structure in the Boardman River from a detailed geomorphic study completed by USACE can be seen in Figure 14. Analysis of typical channel sinuosity calculations within the Boardman River corridor as part of the geomorphic study is shown in Figure 15. An example of the conceptual riffle-pool structure with sinuosity through the proposed channel near the Boardman Dam is shown in Figure 16. Results of the natural channel design were used to develop the river metrics and conditions in the proposed conditions HEC-RAS model, for flood and sediment modeling analyses, and sediment budget and volume computations. These are described in section 4.2.

Note that these designs are preliminary and for feasibility level planning purposes only. During final design, detailed geomorphic assessment and analysis including detailed modeling and design of river hydraulics and sediment transport processes should be conducted.

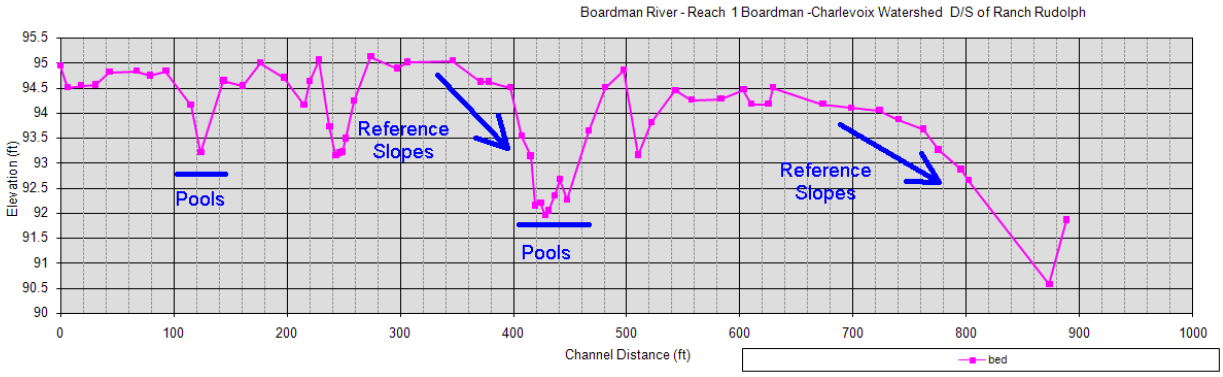

Figure 14: Example of the Boardman River's natural channel profile from the geomorphic survey conducted by USACE. Short areas of steep descents represent typical riffles observed in the river.

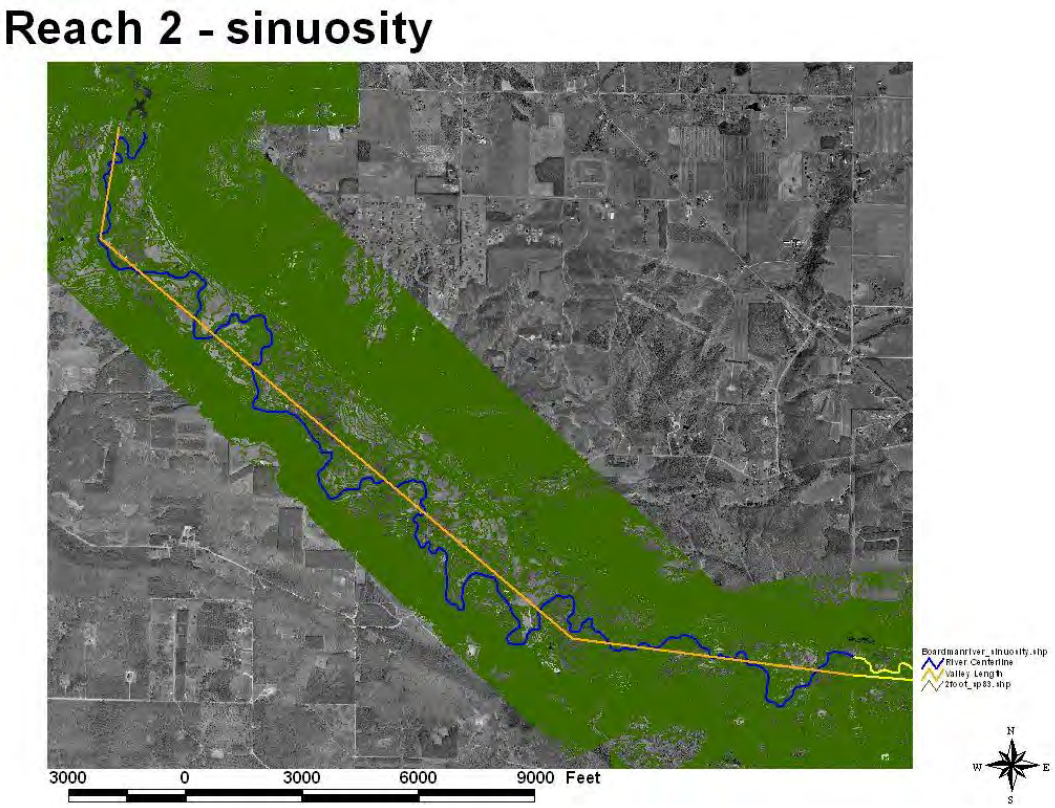

Figure 15: An example of sinuosity measurements within the Boardman River corridor used as guidance for potential channel alignment (Source: USACE unpublished graphic)

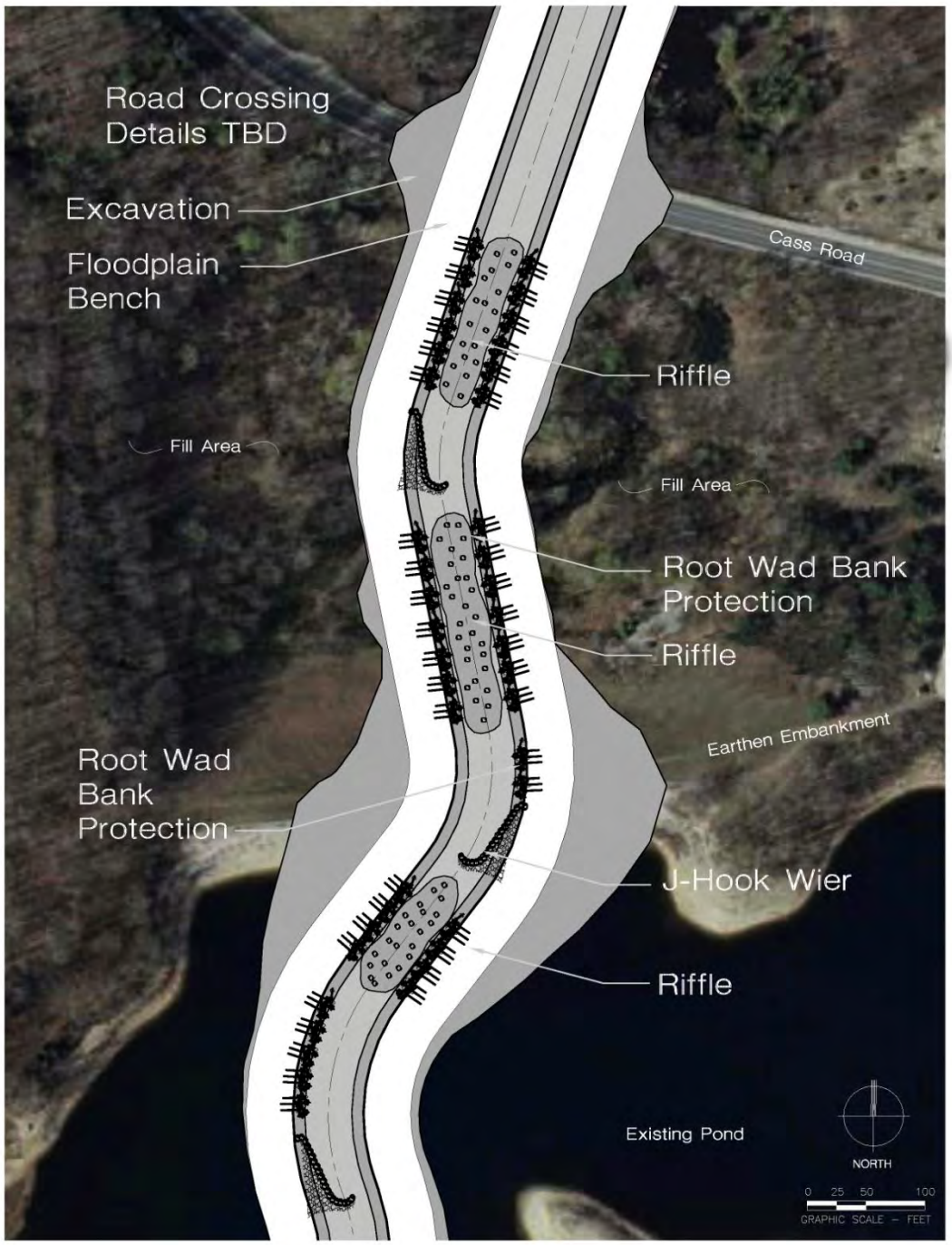

Figure 16: Example of a proposed natural channel through the Boardman Dam following removal

3.3.1 Boardman

Once the Boardman Dam is removed, the water would flow through the channel cut through the earthen berm west of the existing powerhouse. The proposed channel alignment is shown in Figure 17 and explained in further detail in Section 4.2.1.

3.3.2 Sabin

Currently, an alternative channel alignment has been developed to support the Sabin Dam removal. The proposed alternative is to run the river through the historic channel to the east of the existing powerhouse. An overview of the proposed channel thalweg is shown Figure 17 and explained in further detail in Section 4.2.2 .

3.3.3 Union Street

The Union Street Dam is the only dam that would not be removed from the project area, as it provides a critical hydraulic barrier to the upstream passage of invasive species from Lake Michigan into the Boardman River.

Figure 17: Likely channel alignment through existing Boardman Pond and Sabin Pond following removal of both dams

3.4 Flooding Analysis

3.4.1 Baseline Conditions

The previously described HEC-RAS model was used to conduct low flow, spawning conditions flow, and flooding conditions analyses for the existing baseline conditions of the Boardman River and three project dams. Results of the low flow and spawning conditions flow were used to support development of the Habitat Suitability Index models and are described in the Engineering Appendix. Results of the flood conditions are described below.

Flood analyses included hydraulic modeling of the 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent-annual-exceedence probability events (2-, 5-, 10-, 25-, 50-, 100-, and 500-year events). Flow data for these events were developed and provided by MDEQ as part of the original HEC-RAS model developed by USACE (USACE 2008a). A summary of water levels for the 1-percent (100-year) and 0.2-percent (500-year) floods are presented in Table 2 and Table 3, with cross-section locations shown in Figure 19 under existing conditions with current dams in place and under the proposed alternative with dams removed in Figure 20.

Note that the flows along the river for the events listed previously were gathered from MDEQ as part of the original HEC-RAS model that spanned from the USGS gage upstream of Brown Bridge Dam to the mouth of the Boardman River in Traverse City (USACE 2008a); these flows were obtained from the MDEQ flood discharge database (http://www.deq.state.mi.us/flow/hflowqry.asp). The method used by MDEQ at the study area is a drainage area ratio method using USGS gage number 04127000 (Email communications, MDEQ). Within the impounded areas shown in Table 2, the only flow change location is at the Boardman Dam, as indicated by the “discharge” column. No modification of the flood flows from the original HEC-RAS model was deemed necessary for this analysis, however for final design phase and permit application, requests must be re-submitted to MDEQ as flows are only valid for one year for permit applications. Full results of the flooding analysis by cross-section are provided in Section 8 – Hydraulic Model Results.

Additional modeling of baseline hydraulic conditions of the river was conducted to support the Habitat Suitability Index (HSI) model, further described in Appendix A – Engineering Appendix. In order to simulate flow conditions during spawning periods, monthly 50% discharge values were obtained from the MDEQ low-flow database (http://www.deq.state.mi.us/flow/lflowqry.asp). Recent inquiries to the low-flow database were used and input to the existing conditions HEC-RAS model, as shown in Figure 18. Results of velocity and mean thalweg depth were reported by HSI segment for both spring and summer to support habitat modeling. A summary of the results is shown in Table 1. Note that the results of this low-flow analysis were completed using a model developed for flood conditions and were not calibrated for this application. Results were used only to supply estimates of thalweg depths and velocities averaged over large sections of river for habitat suitability modeling.

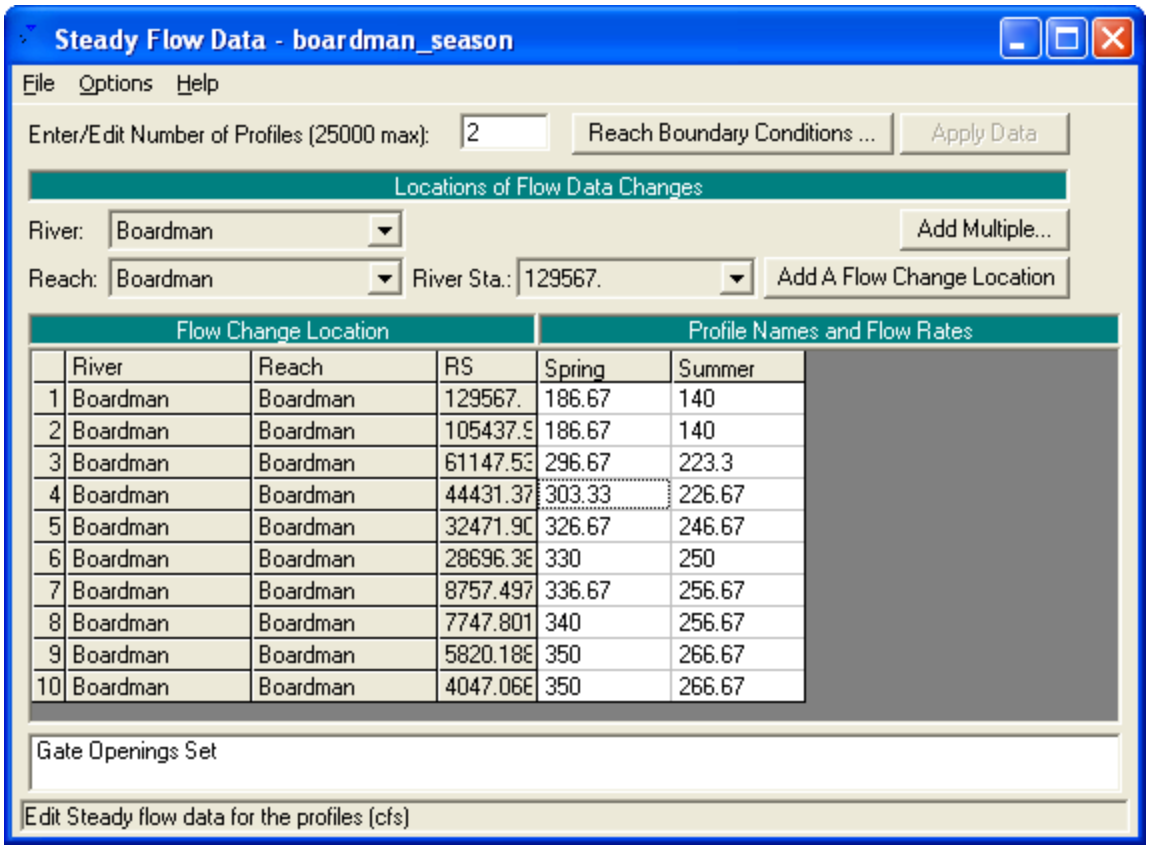

Figure 18: Steady flow input data for HSI modeling

Table 1: of HEC-RAS modeling results in support of HSI modeling

	Spring		Summer	
HSI Segment	Mean Channel Velocity (ft/s)	Mean Thalweg Depth (ft)	Mean Channel Velocity (ft/s)	Mean Thalweg Depth (ft)
5	1.6	11.1	1.5	10.7
4	1.6	6.1	1.6	5.8
3	1.4	4.4	1.2	3.9
2	0.5	20.1	0.4	19.8
1	0.6	11.9	0.5	11.7

3.4.2 Floodplain Optimization

As part of the Value Engineering (VE) study, the initial flood plain of 40 feet was narrowed through an optimization process to minimize sediment removal required while not observing flood level increases or impacts on sediment transport for a feasibility level study. Floodplain widths varying from 40 feet on either side of the bankfull to channel to 20 feet on either side of the bankfull channel were tested with the HEC-RAS model to determine what the optimum floodplain width was without causing water level rises upstream or downstream during any event

from the 2-year flow and higher. Additionally, sediment transport was compared between the models to reduce the floodplain width without adversely impacting sediment transport. Results indicated that a 30-foot floodplain on either side of the bankfull channel could be applied within the currently impounded area. It is important to note that the hydraulic and sediment transport models are uncalibrated; detailed floodplain widths and geomorphologic assessments should be conducted during final design with the addition of updated sediment data from within the impoundments.

3.4.3 Proposed Conditions

A hydraulic analysis was conducted to determine future flow conditions with the proposed removal of the Boardman and Sabin Dams. The 1-percent and 0.2-percent annual chance exceedance events were analyzed for changes in water levels and flood extents for feasibility level planning purposes. Comparisons of water levels were made with the baseline conditions and are presented for the 1-percent event in Table 2 and the 0.2-percent event in Table 2. The water level impacts of the removal of the Sabin and Boardman Dams with the anticipated channel alignment through the existing impoundments as compared to the existing conditions are illustrated in Figure 21 for the 1-percent event and Figure 22 for the 0.2% event. Flood extents under the proposed conditions decreased dramatically with the removal of the dams within the impoundment areas. These preliminary flood extents were created using available 2-foot contours for the river valley; a triangulated irregular network (TIN) was developed for the alternative condition with the anticipated channel alignment and flood channel built in. Only minor differences between the flood extents occur:

- Near the Sabin Dam, the new channel is planned to flow just to the right of the existing intake structures;
- The new channel is planned to go through the earthen impoundment for the Boardman Dam and flow into the existing Sabin impoundment from the west instead of the existing powerhouse structure;
- The TIN for the upstream extent of Boardman Pond under the alternative includes the anticipated channel, while the existing conditions TIN only includes the water surface. Therefore differences in this location do not reflect increased flooding in this area, rather differences in available datasets.

The baseline conditions model represented the dams as per their configuration and operation through the 2007 baseline conditions study. The dams were operated in “run of river” mode, for hydropower generation. This means discharge release was equal to incoming flows, to maintain stable pond elevations (no change in storage) in the reservoirs. In addition, the dams were not designed or constructed for flood control therefore, had no flood pool capacity. For this reason, model simulations of flood flow under baseline conditions showed no rise in pool level. Consequently, removal of the dams resulted in no loss of flood storage, and downstream water levels were estimated to not increase. Within the existing impoundments, the water levels

decrease significantly as a result of the draining of the reservoirs. Note that these results are uncalibrated. Anticipated channel alignment is preliminary for feasibility level planning purposes and should be optimized during final design.

Table 2: Changes in Water Levels from Baseline Conditions to the Proposed Alternative under the 100-yr event Upstream, Downstream, and within the Sabin and Boardman Impoundments

Location	Description	Discharge	Water Surface Elevation (feet) (100-year event)		
		100-year (cfs)	Original	Alternative	Difference (feet)
Upstream of Airport Road	Approximately 600 feet upstream of bridge centerline	1,700	593.67	593.67	0
Downstream of Sabin Dam	Approximately 1,500 feet downstream of existing spillway	1,700	596.26	596.26	0
Lower Sabin Dam	Just upstream of existing dam structure	1,700	612.96	604.54	-8.42
Upper Sabin Dam	Upstream of school bus garage area	1,700	613.06	611.6	-1.46
Lower Boardman Pond	Just upstream of island	1,500	645.45	624.55	-20.9
Mid Boardman Pond	Narrows	1,500	645.45	629.5	-15.95
Upper Boardman Pond	Peninsula point	1,500	645.45	637.43	-8.02
Upstream of Boardman Pond	Meander bend	1,500	657.06	655.31	-1.75
Upstream of Boardman Pond	Upstream of meander bend	1,500	662.06	658.66	-3.4
Downstream of Beitner Rd	First XS downstream of bridge	1,500	669.77	669.77	0

cfs = cubic feet per second, XS = cross section

Table 3: Changes in water levels from baseline conditions to the proposed alternative under the 500-yr event upstream, downstream, and within the Sabin and Boardman impoundments.

Location	Description	Discharge	Water Surface Elevation (ft) (*500-year event)*		
		500-yr Event (cfs)	***Original***	***Alternative***	***Difference***
US of Airport Road	Approximately 600 ft upstream of bridge centerline	1900	594.34	594.34	0
DS of Sabin Dam	Approximately 1500 ft downstream of existing spillway	1900	596.76	596.76	0
Lower Sabin Dam	Just upstream of existing dam structure	1900	613.3	604.74	-8.56
Upper Sabin Dam	Upstream of school bus garage area	1900	613.4	611.85	-1.55
Lower Boardman Pond	Just upstream of island	1700	645.95	624.68	-21.27
Mid Boardman Pond	Narrows	1700	645.95	629.69	-16.26
Upper Boardman Pond	Peninsula point	1700	645.96	637.6	-8.36
Upstream of Boardman Pond	Meander bend	1700	657.31	655.55	-1.76
Upstream of Boardman Pond	Upstream of meander bend	1700	662.3	658.88	-3.42
DS of Beitner Rd	First XS downstream of bridge	1700	670	670	0

cfs = cubic feet per second, XS = cross section

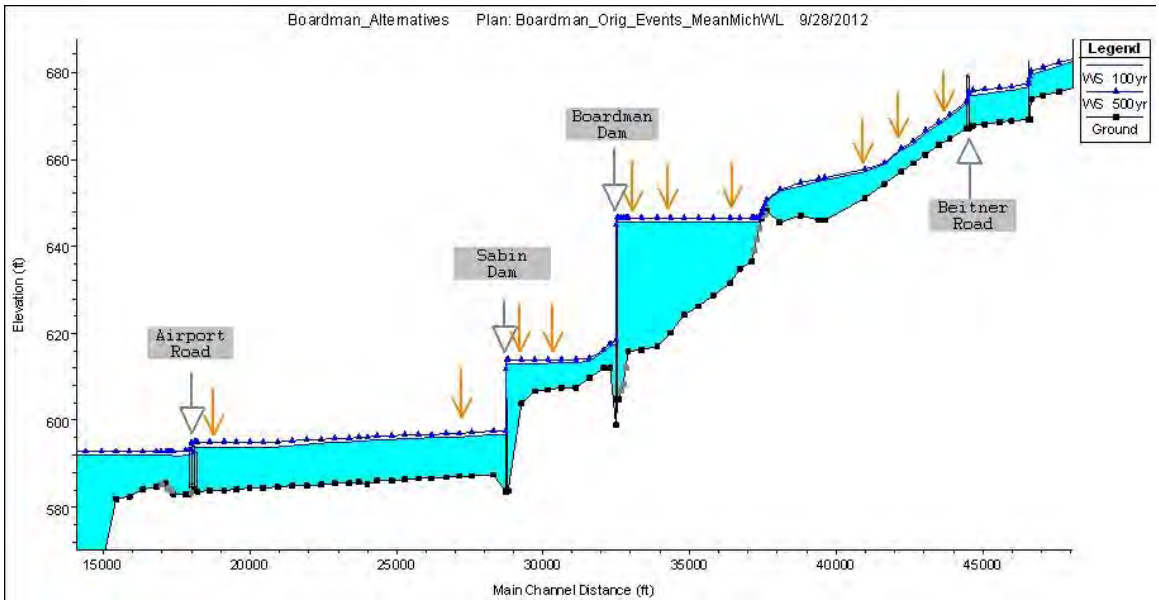

Figure 19: Longitudinal profile of the existing conditions of the Boardman River from Beitner Road to the upstream extent of Boardman Lake under the 100-year event (solid blue fill) and 500-year event (blue triangles). Orange arrows relate to the locations listed in Table 1.

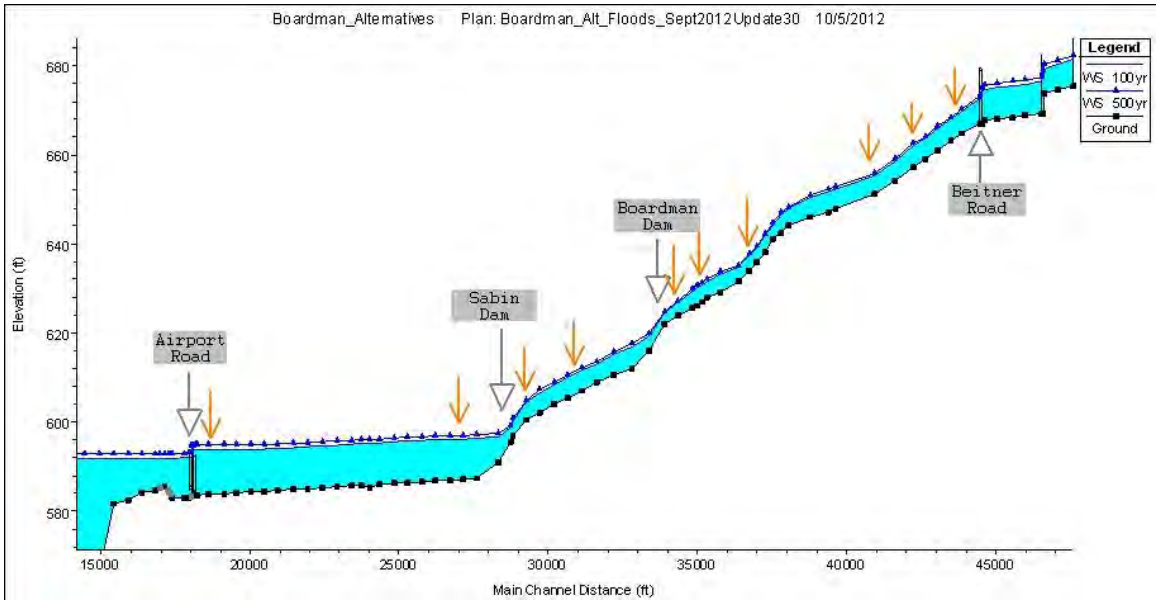

Figure 20: Longitudinal profile of the dam removal alternative removing the Sabin and Boardman Dams from Beitner Road to the upstream extent of Boardman Lake under the 100-year event 100-year event (solid blue fill) and 500-year event (blue triangles). Orange arrows relate to the locations listed in Table 1.

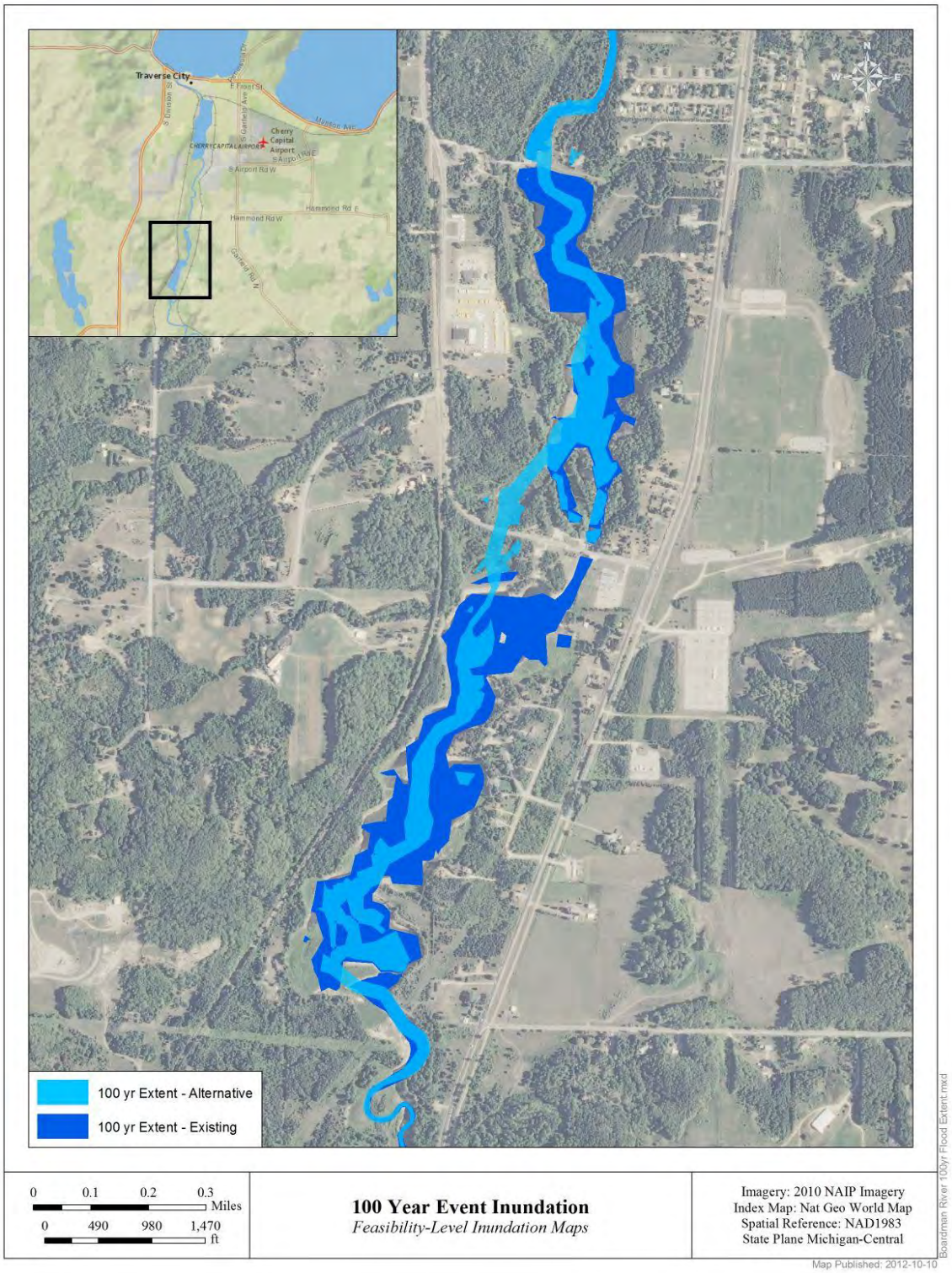

Figure 21: Estimated 100-year flood extents under existing and anticipated alternative

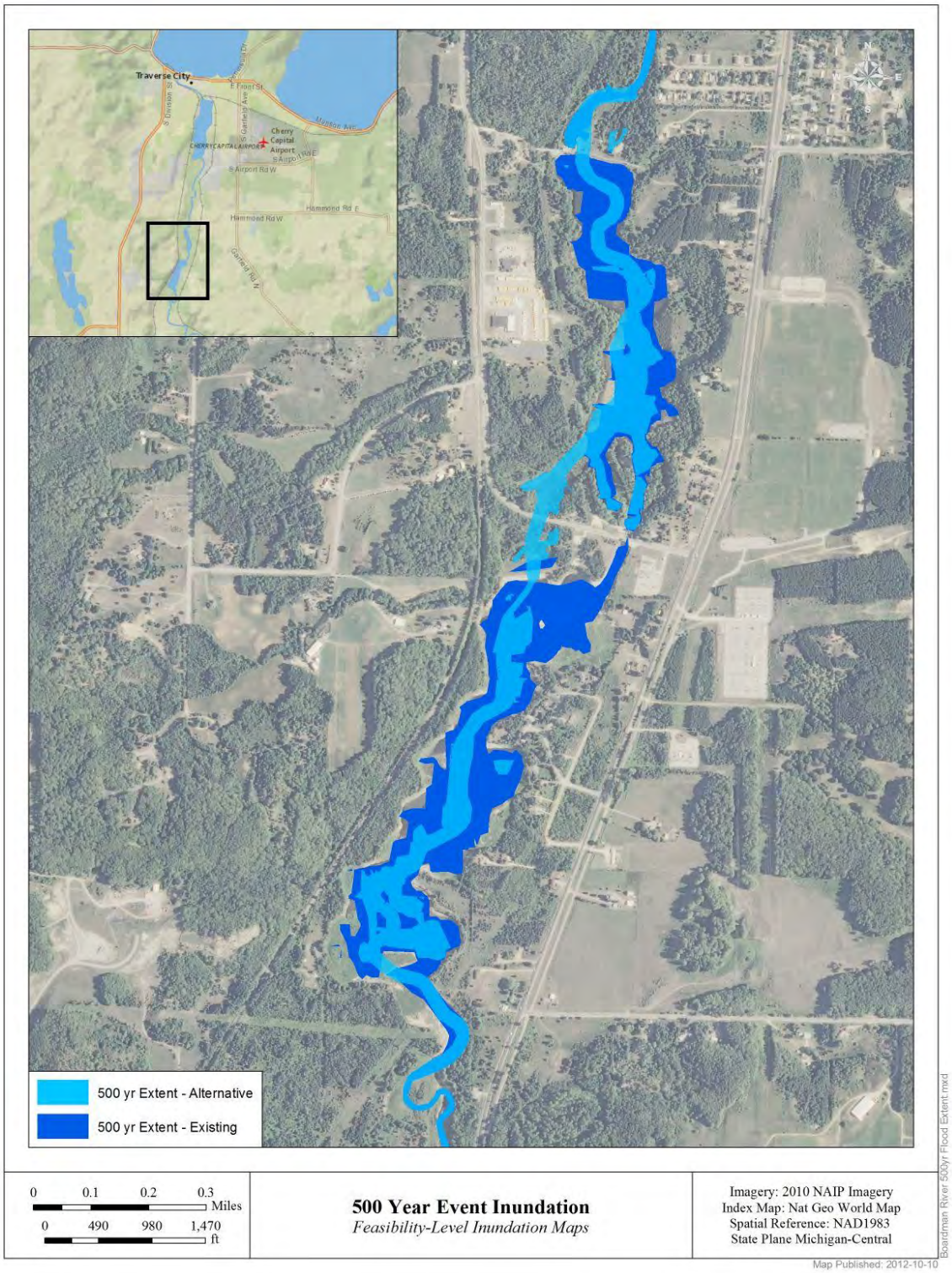

Figure 22: Estimated 500-yr flood extents under existing and anticipated alternative

4 Sediment Fate and Transport

4.1 Assess Contamination Level

Sediment sampling studies have been performed within the Boardman River ponds by various organizations in 1997, 2003, 2005, 2010, and 2012. The study design varied between projects as to which metals, chemicals, and specific sites were sampled. Guidance from MDEQ indicates levels of arsenic in Boardman and Sabin Ponds sediments are not considered to be a problem because concentrations are quite low. Once these sediments are dewatered and reworked during the restoration process, they would need to be sampled and within criteria for soil exposure. In addition, any dredged sediments (e.g., sand removed from the proposed sand trip) would also need to be sampled in compliance with MDEQ standards. A brief summary of each study follows below. Details on which sites sampled, sampling techniques used, and laboratory tests that were performed can be found in each of the individual reports.

4.1.1 1997 Sampling

The MDEQ, in conjunction with the U.S. Environmental Protection Agency (USEPA), has been conducting sediment contamination surveys on the Boardman Lake since 1997. Sediment sampling on Boardman Lake focused on commercial, industrial, and municipal sites along the lakeshore. A detailed project summary can be found in the MDEQ Sediment Contamination Survey Report of 1997.

Seventeen different locations were sampled in Boardman Lake and results were analyzed using the USEPA Ecological Screening Levels standard. Sampling results show various locations within the lake where the severe effect levels were exceeded for copper, iron, lead, mercury, zinc, fluoranthene, phenanthrene, pyrene, and several polynuclear aromatic hydrocarbons (PAHs). Lowest effect levels were exceeded for arsenic, manganese, mercury, PAHs, cadmium, chromium, and manganese.

Bioaccumulative chemicals, such as polychlorinated biphenyls (PCBs), and pesticides, such as DDT that can cause human health impacts, were not detected in sediments collected during the survey.

4.1.2 2002 Sampling

As a follow-up study to the MDEQ 1997 study, additional sampling was conducted in 2002 by the Great Lakes Environmental Center (GLEC) (Great Lakes Environmental Center, 2002). This study involved the collection and analysis of surficial sediment samples from three different sites within the same vicinity of the 1997 MDEQ study. A detailed project summary can be found in the GLEC Sediment Report of 2002.

Results of this study indicate there are elevated concentrations of contaminants in the sediments of the Boardman Lake and River at the sampled locations and that the sediments in some areas are toxic to sediment dwelling freshwater organisms. Phenanthrene, fluoranthene, pyrene,

chrysene, and benzo(a)pyrene were found above the probable effect concentrations in most sediment samples.

4.1.3 2005 Sampling

An expanded sampling effort was conducted by MDEQ in 2005 and the results were summarized and analyzed by ECT (ECT 2009). Six sites were sampled within Boardman Pond, four sites within Sabin Pond, and six sites within Brown Bridge Pond. Sediment samples were analyzed by the MDEQ Environmental Laboratory to determine concentrations of pesticides, PCBs, PAHs, and 10 trace metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, silver, and zinc). A detailed project summary can be found in the Boardman River Feasibility Study: A Report on Boardman River Existing Sediment Chemistry Data (ECT 2009). Note that all of the organic samples and the mercury samples from this sampling effort were flagged as they were analyzed beyond the maximum allowed holding time. Consequently, results are questionable and follow up sampling was conducted in 2010.

Chemical analysis of the sediments sampled showed:

<u>Boardman Pond</u>
Arsenic, barium, and selenium were present in sediments at concentrations slightly exceeding the USEPA Ecological Screening Levels for soils in some or all of the six core samples. Arsenic also exceeded the statewide default background level and MDEQ Residential Direct Contact Criterion in all six samples.

<u>Sabin Pond</u>
Barium exceeded the USEPA Ecological Screening Level in one sample and selenium exceeded the Apparent Effects Threshold in another sample.

4.1.4 2010 Sampling

The 2010 sampling study on the Boardman River ponds was conducted by Great Lakes Environmental Center, Inc. in 2010 under contract by the Grand Traverse Band of Ottawa and Chippewa Indians in coordination with the Boardman River Dams Implementation Team. Sediment samples were collected from 14 sites on Brown Bridge Pond, six sites on Boardman Pond and six sites on Sabin Pond. The primary sampling sites matched those from the 2005 sampling with additional sites selected to provide additional data within the water body. Samples were collected using a standard Ponar dredge in submerged sites. A detailed project summary can be found in the Final Report: Boardman River Ponds Sediment Sampling, Analysis, and Data Comparison (GLEC 2011).

Guidance from MDEQ provided concentration criteria to be used for exposed soils, as opposed to aqueous sediments. However, this guidance can still be used to interpret results and the likelihood that, once exposed, dewatered, and reworked sediment residual concentrations in the newly formed soils might require some level of remedial action or disposal (e.g., capping or Phase II land fill). Sample results show that only arsenic and cadmium exceeded the USEPA's threshold effect concentration (TEC) in Boardman Pond from the 2010 sampling but no metal concentrations were above probable effect concentration (PEC). A TEC is a concentration where

harmful effects on sediment dwelling organisms are not expected to occur and the PEC is a concentration where harmful effects to sediment dwelling organisms are expected to occur frequently (USEPA 2003). All other metal concentrations in Boardman Pond, in both 2005 and 2010, were below PEC standards. In Sabin Pond all metals were below TEC standards. Additionally, laboratory analysis did not detect organochlorine pesticides, PCBs, and semivolatile organic compounds in any samples collected from the Boardman River ponds.

Results from the 2010 metals sampling in Boardman and Sabin Ponds are shown in Table 4, with red highlighted cells indicating values exceeding the TEC and red bold text indicating values which exceeded MDEQ background value. The spatial distribution of the results of arsenic and cadmium sampling are shown in Figure 23 and Figure 24, respectively. Note that all sediment values that exceeded the TEC were in the lower part of Boardman Pond.

Criteria for remediation and redevelopment from MDEQ falls under the Part 201 program. While no risk based criteria have been developed for recreational uses, residential and nonresidential criteria are available. The criteria for metals direct contact can be found here: http://www.michigan.gov/deq/0,1607,7-135-3311_4109_9846_30022-101581--,00.html.

Only samples from in-situ aqueous sediments exceeded the residential direct contact levels for arsenic of 7.6 parts per million (ppm) and no samples exceeded the nonresidential criteria of 36 ppm. Since samples are all below the nonresidential criteria, it is likely that once dewatered, soil concentrations would be at levels not requiring special remedial treatment. If sampling does indicate soil arsenic levels above the threshold, MDEQ directs a clean soil cap of 6 inches over any soil not meeting the standard. However, at the levels measured, there are no Phase II or confined disposal requirements (MDEQ Email communication, January 2012).

Table 4: Results of 2010 Metals Sampling in Boardman and Sabin Ponds

Sample ID		Threshold Screening Level	Probable Effect Level	MDEQ Statewide Default	MDEQ Statewide Residential	MDEQ Statewide Nonresidential	BP1	BP2	BP3	BP4	BP5	BP6	SP1	SP2	SP3	SP4	SP5	SP6
Sample Date	Units	TEC[1]	PEC[2]	Background[3]	Criteria[4]	Criteria[4]	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010	2010
Arsenic	mg/Kg	*9.79*	*33*	*5.8*	*7.6*	*37.0*	***13***	***14***	***7.3***	***7.9***	***11***	***11***	***6.4***	3.9	2.5	5.4	5.1	1.9
Barium	mg/Kg	*NA*	*NA*	*75*	*37,000.0*	*130,000.0*	***130***	***140***	73	57	***110***	***86***	***99***	46	38	53	40	20
Cadmium	mg/Kg	*0.99*	*4.99*	*1.2*	*550.0*	*2,100.0*	***1.7***	***1.3***	0.94	0.69	***1.4***	1	0.64	0.41	0.27	0.54	0.42	0.19
Chromium (III)	mg/Kg	*43.4*	*111*	*18*	*2,500.0*	*1,000,000.0*	***24***	***21***	13	10	***20***	14	9.3	6.5	4.1	7.1	5.5	2.5
Copper	mg/Kg	*31.6*	*149*	*32*	*20,000.0*	*73,000.0*	24	24	14	11	20	14	8.2	5.2	2.9	6	4.7	1.7
Lead	mg/Kg	*35.8*	*128*	*21*	*400.0*	*900.0*	***28***	***23***	17	9.4	***22***	17	10	6.1	3.2	7.8	5.8	2.4
Manganese	mg/Kg	*NA*	*NA*	*440*	*25,000.0*	*90,000.0*	***1800***	***2300***	***490***	***670***	***1100***	***1100***	***940***	***780***	430	***570***	***450***	200
Mercury	mg/Kg	*0.174*	*1.06*	*0.13*	*160.0*	*580.0*	***0.17***	***0.16***	0.081	0.048	0.12	0.11	0.055	0.03	0.019	0.043	0.023	0.013
Nickel	mg/Kg	*22.7*	*48.6*	*20*	*40,000.0*	*150,000.0*	20	18	11	9	17	13	13	7.7	4.7	9.3	7.2	3.8
Selenium	mg/Kg	*NA*	*NA*	*0.41*	*2,600.0*	*9,600.0*	***3.1***	***2.7***	***1.6***	***1.4***	***2.4***	***1.8***	***1.3***	***0.66***	0.37	***0.7***	***0.62***	
Silver	mg/Kg	*0.5*	*NA*	*1*	*2,500.0*	*9,000.0*	0.14	0.1	0.069	0.049	0.15	0.14	0.039	0.027	0.02	0.031	0.023	0.017
Zinc	mg/Kg	*121*	*459*	*47*	*170,000.0*	*630,000.0*	***96***	***82***	***52***	36	***74***	***59***	36	27	14	32	24	9.9

[1] Threshold effect concentration

[2] Probable effect concentration from US EPA, *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volumes III, Dec. 2002*

[3] Statewide default background, *Review Criteria and Detection Limits for Metals* (MDEQ, 2010)

[4] Proposed Draft October 9 2013

Note: Red highlighted cells indicate values exceeding the TEC. Bold red text indicates values that exceeded MDEQ background levels. No results exceeded the PEC. (Adapted from GLEC 2011)

DRAFT

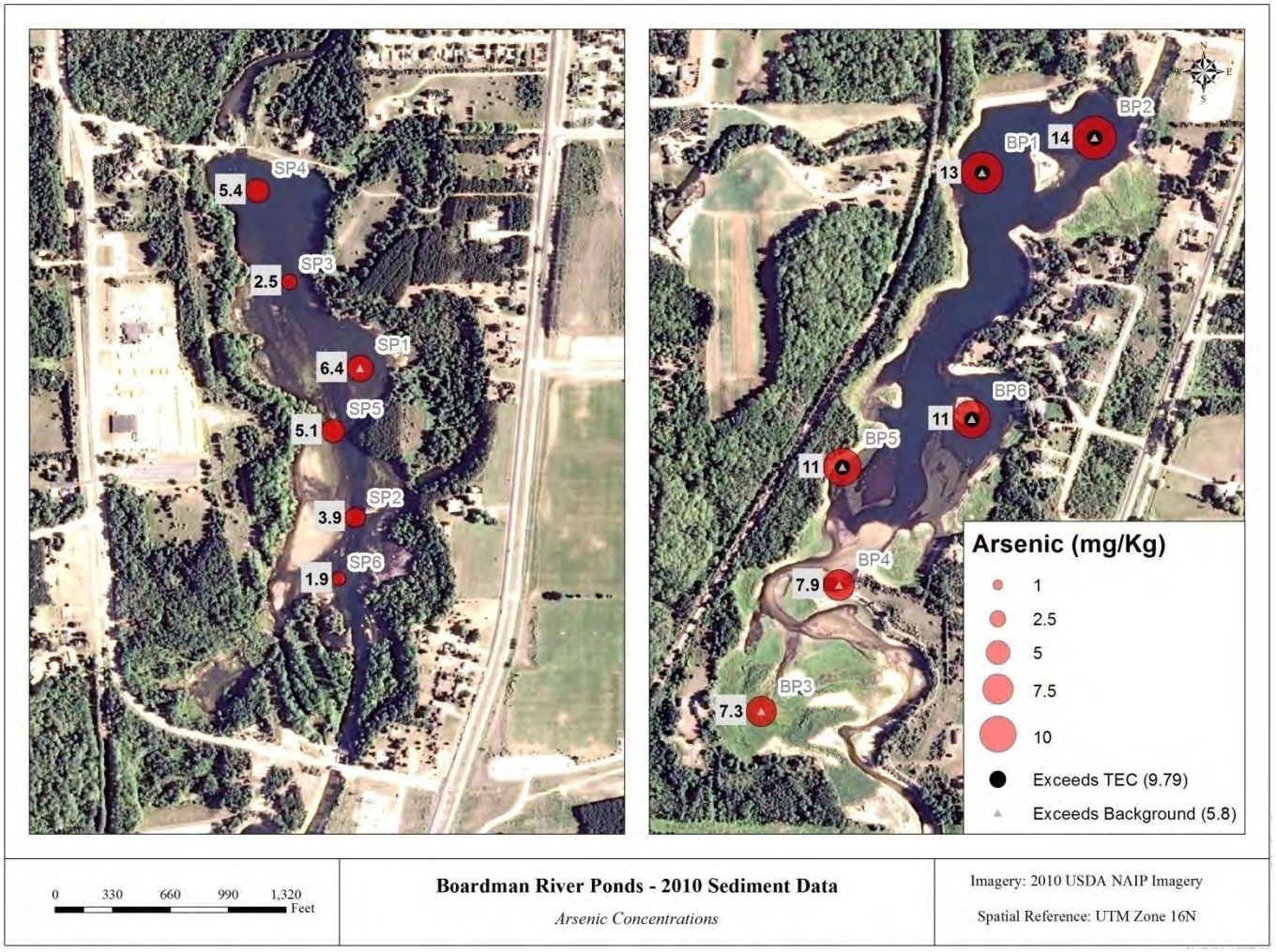

Figure 23: Results of 2010 sediment sampling for arsenic. Although four samples in the downstream portion of Boardman Pond exceeded TEC values, none in Sabin Pond exceeded this value. All samples exceeded statewide background levels in Boardman Pond and one sample in Sabin Pond exceeded background. (Adapted from GLEC 2011)

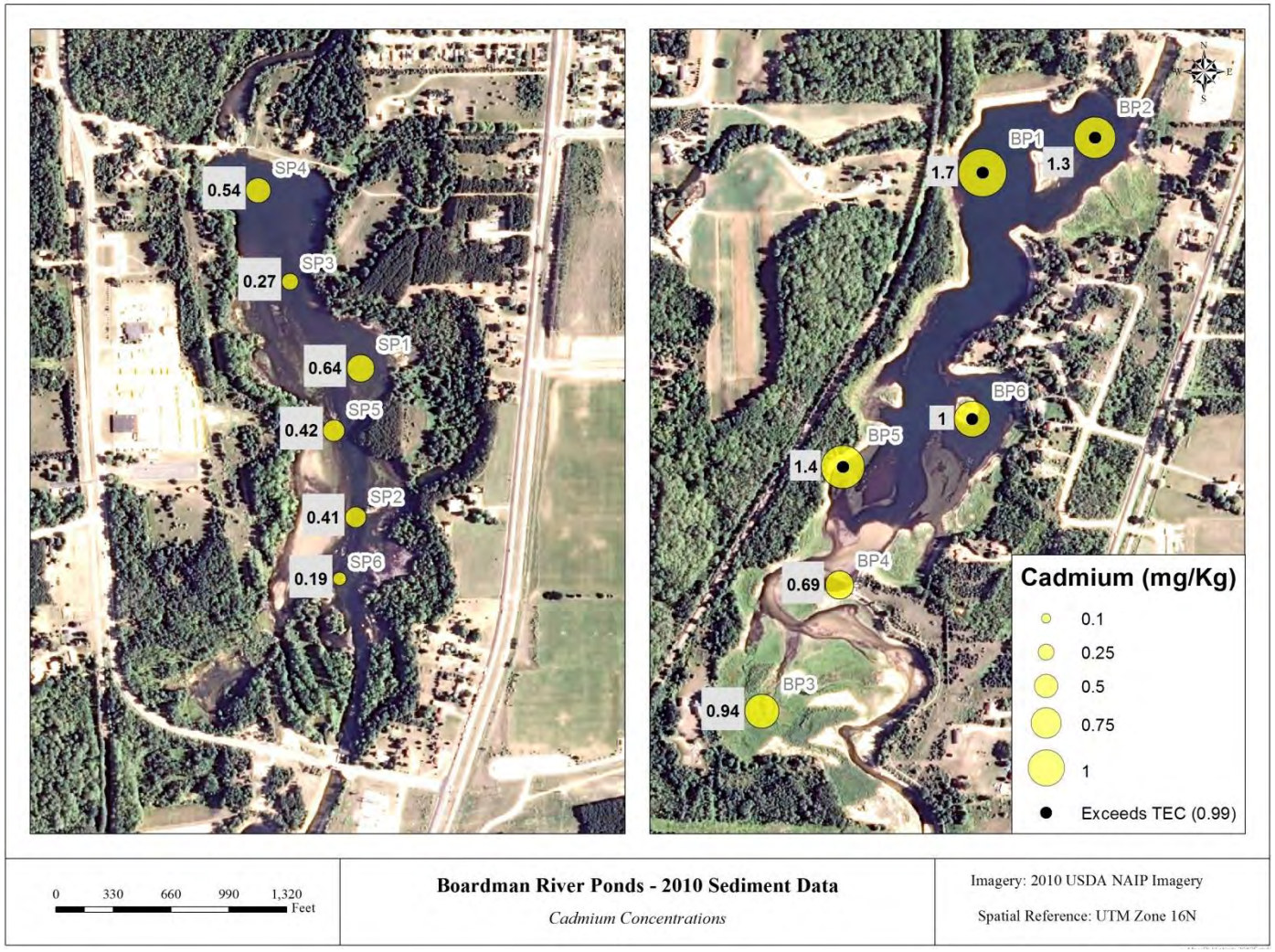

Figure 24: Results of 2010 sediment sampling for cadmium. Only samples in the downstream portion of Boardman Pond exceeded TEC levels. (Adapted from GLEC 2011)

4.1.5 Differences in Arsenic Concentrations from 2005 to 2010

Although results from the 2005 sampling are suspect based on sample handling, a comparison of arsenic concentrations between the 2005 and 2010 sampling in Boardman and Sabin Ponds is informative. The results of the comparison are shown in Figure 25. Sabin Pond showed minimal difference. In Boardman Pond, the 2010 arsenic levels were lower for the upstream sites (BP3 and BP4), and higher for the downstream sites (BP1 and BP2). While this may appear to indicate either consolidation of sediments through drawdown impacting metals composition, or mobility of metals in the reservoir through drawdown, the relatively low values and suspect sampling results for 2005 data preclude drawing any meaningful conclusions observed in differences between the 2005 and 2010 results. The consistent result is that arsenic levels in sediments were all found to be less than the PEC, generally less than the TEC (8 of 12 locations) and somewhat above the state background level (7 of 12 locations). These values are below any actionable thresholds that would require special handling or treatment in the current condition.

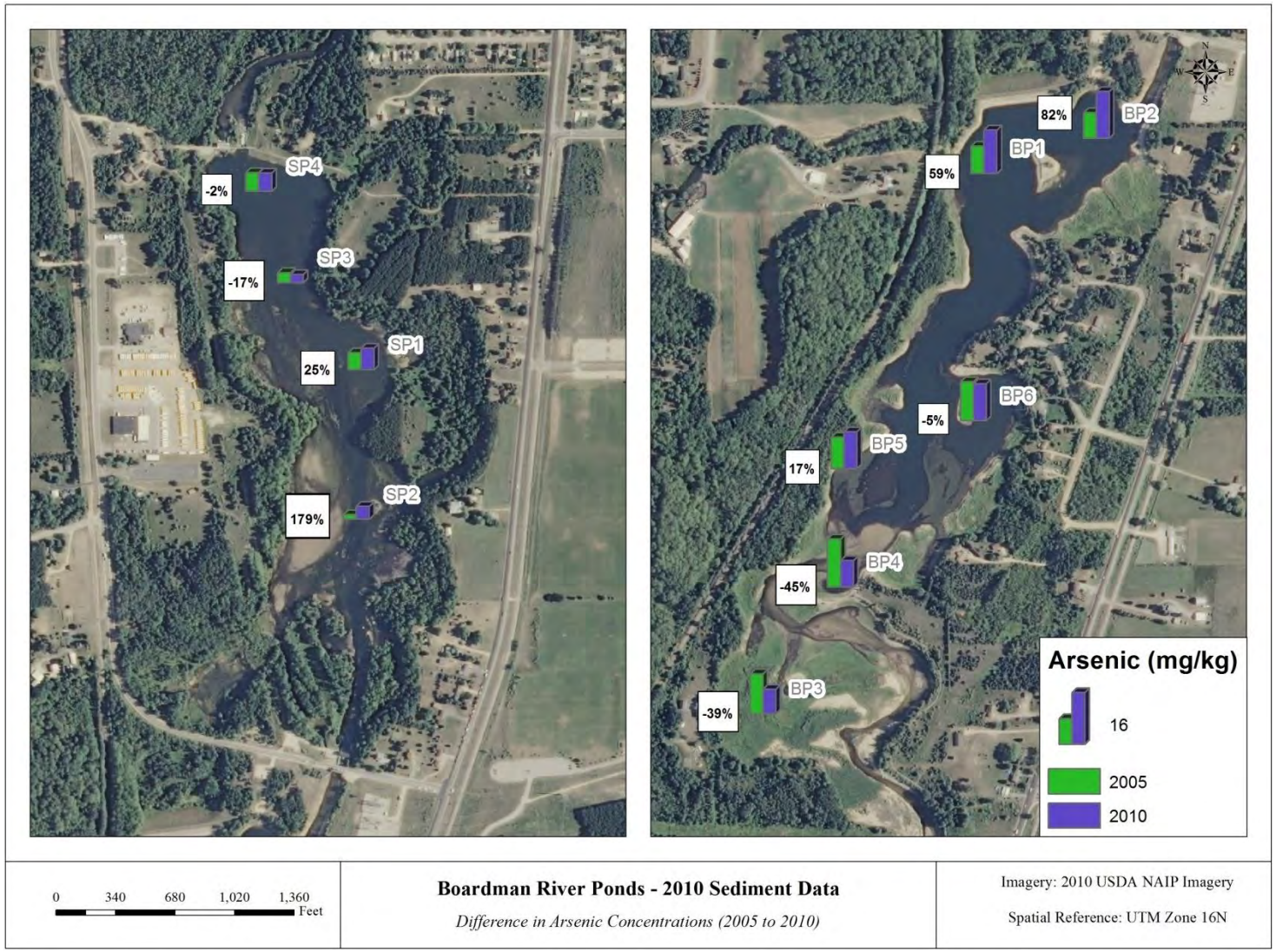

Figure 25: Differences in arsenic concentration of sediments from 2005 to 2010 (Adapted from GLEC 2011)

4.1.6 2012 Sampling

These paragraphs summarize data collected in 2012 for GLEC by RTI Laboratories (GLEC 2012). The most recent sediment sampling study on the Boardman River ponds was conducted by RIT Laboratories for GLEC (2012). A total of 37 samples were analyzed for arsenic concentrations and moisture percentages. Sediment samples were collected from 16 sites on Sabin Pond and 19 sites on Boardman Pond. The sample sites were chosen to represent soil samples at exposed deltas and on the earthen dam. Samples were collected using the same methods used in 2010.

Similar to 2010, the concentration levels were compared to several standards including the USEPA's TEC, the PEC, and statewide background levels from the MDEQ. Sample results, shown in Table 5 and Figure 26, demonstrate that the sediments in Boardman Pond contained a much higher concentration of arsenic than those in Sabin Pond, as none of the samples from Sabin Pond exceeded any of the above thresholds. On the other hand, the MDEQ's statewide default background level for arsenic was exceeded in eight of the sixteen samples in Boardman Pond. Additionally, six of those samples also exceeded USEPA's TEC level of 9.79 milligrams per kilogram. No samples were above the PEC. Arsenic was the only metal analyzed in this sampling as it was the only contaminant that significant exceeded the TEC in 2010.

Part 201 program of the MDEQ is responsible for the regulations for remediation and redevelopment. No risk criteria have been developed for recreational lands; however, nonresidential and residential landuse criteria are available. The standards for direct metal contact can be found at the following Web site: http://www.michigan.gov/deq/0,1607,7-135-3311_4109_9846_30022-101581--,00.html.

Additionally there are regulations for exposed sediments. Unlike 2010, the exposed sediments at Boardman Pond did exceed the residential direct contact levels of 7.6 ppm or milligrams per kilogram, but did not exceed the nonresidential criteria of 36 ppm. No special remediation or treatment is expected to be required because all soil samples were below the nonresidential criteria. As the locations of the sediment samples in the 2012 sampling were significantly different than the 2010 sampling no comparison between the 2 years was drawn.

Table 5: Results of the 2012 Arsenic Aampling in Boardman and Sabin Ponds

	Sample ID	Arsenic (mg/Kg)
Standards	Threshold Screening Level (TEC)[1]	9.79
	Probable Effect Level (PEC)[2]	33
	MDEQ Statewide Default Background[3]	5.8
	DEQ Nonresidential Soil Criteria	36
Sabin Pond	SP-1	1.9
	SP-2	1.9
	SP-3	1.7
	SP-4	1.4
	SP-5	2.1
	SP-6	0.92
	SP-7	1.1
	SP-8	4.2
	SP-9	1.1
	SP-10	1.1
	SP-11	0.73
	SP-12	0.49
	SP-13	0.37
	SP-14	0.37
	SP-15	1.3
	SP-16	0.54
Baordman Pond	BP-1	0.78
	BP-2	1
	BP-3	1.1
	BP-4	***10***
	BP-5	***12***
	BP-6	***16***
	BP-7	***12***
	BP-8	***13***
	BP-9	1.4
	BP-11	0.6
	BP-12	0.61
	BP-13	0.34
	BP-14	0.74
	BP-15	0.77
	BP-16	0.57
	BP-17	***11***
	BP-18	***7.5***
	BP-19	***8.8***
	BP-20	1.4
	BP-FD	***9.8***

[1] Threshold effect concentration
[2] Probable effect concentration from USEPA, *A Guidance Manual to Support the Assessment of Contaminated Sediments in Freshwater Ecosystems, Volume III, Dec. 2002.*
[3] Statewide default background, *Review Criteria and Detection Limits for Metals* (MDEQ 2010).

Note: Red highlighted cells indicate values exceeding the TEC. Bold red text indicates values that exceeded the MDEQ background level. No results exceeded the PEC. (Adapted from GLEC 2012)

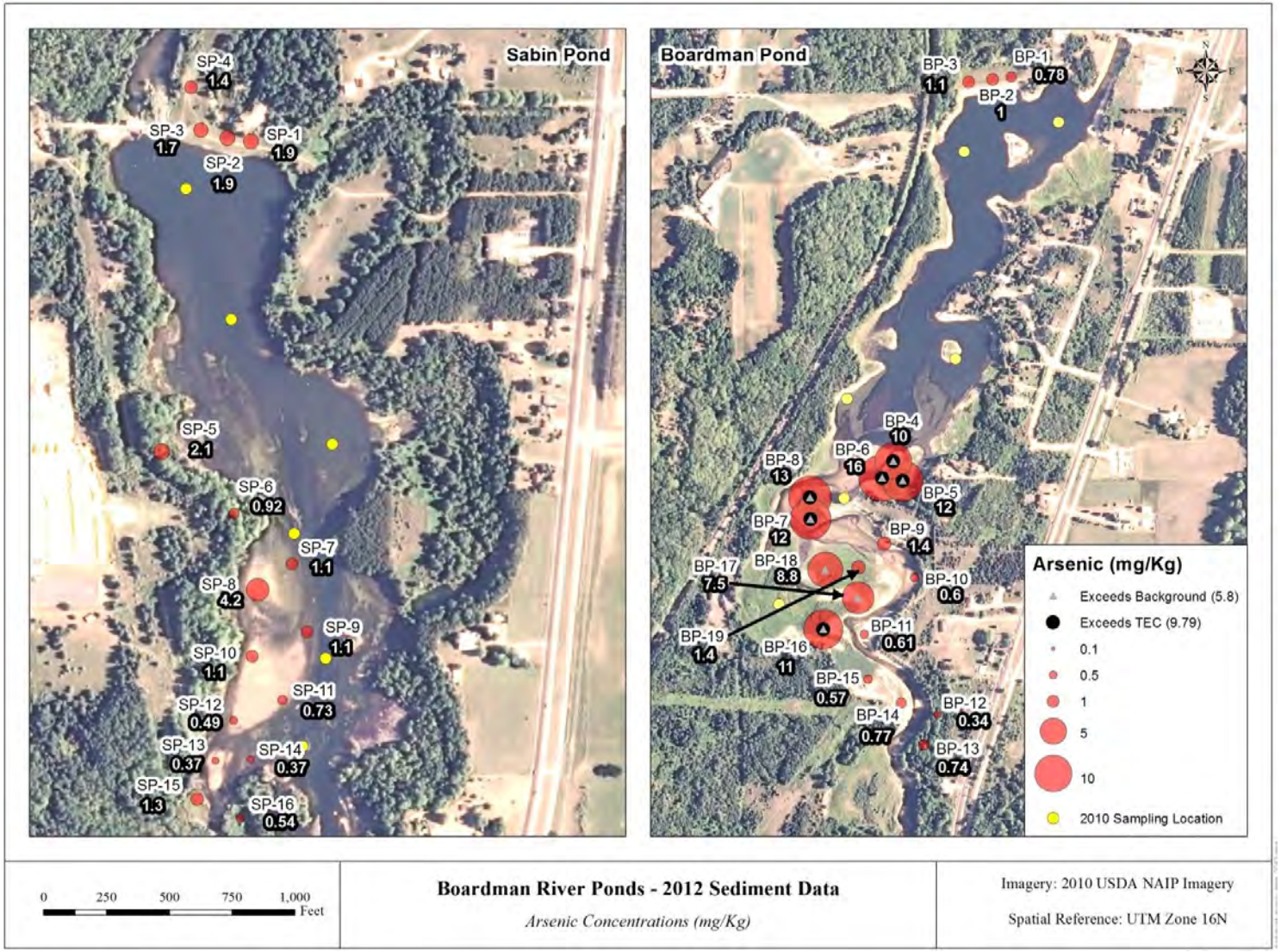

Figure 26: Results of 2012 sediment sampling for arsenic. Although six of the samples in Boardman Pond exceeded TEC values, none in Sabin Pond exceeded the standard. Eight Boardman Pond samples exceeded the MDEQ Background levels, while none of the samples in Sabin Pond exceeded the background level. (Adapted from GLEC 2012)

4.1.7 Future Sediment Management and Sampling Requirements

Communications were held with the MDEQ (email January 31, 2012, and phone meeting, February 6 2012) to obtain guidance on how to proceed with any issues relating to sediment sampling and management for sediments in Boardman and Sabin Ponds. MDEQ determined that based on the limited availability of quality sediment sample data and the fact that the sediments would undergo significant changes following removal, including relocation of dredged sediments and soil consolidation, sampling would be postponed until after dams are removed if there is any evidence that the soil exceeds the applicable criteria and sediments settle and dewater sufficiently to meet soil sampling criteria. At that time, soil sampling would be assessed and required to determine if there is any exposure risk. In the interim, additional samples would be gathered from soils on the bottom land and deltas exposed by the temporary draw down of Boardman and Sabin Ponds.

In addition, it is expected that construction activities associated with the channel restoration and dam breaching would result in fine silts and clays to be transported downstream to Boardman Lake. This material would be managed via a slow drawdown of the impoundment which would limit, but not eliminate movement of fine grained material. The magnitude and duration of fine sediment that is released downstream during construction should be monitored. During PED water quality based expectations related to turbidity and fine material levels should be developed with the regulatory agencies. This approach to managing the short and long term impacts of mobilized material would reflect a level of control commensurate with the environmental risk they pose during transport and settlement in Boardman Lake. Sediment quality sampling reported that all contaminants sampled were below the PEC and only arsenic and cadmium were above the TEC which indicates there should be limited to no toxicity from the mobilized sediments. This conclusion is further supported by the lack of sediment quality related water quality or aquatic toxicity issues in either Boardman or Sabin ponds.

4.2 Quantify Sediment Input

Since the dams were built on the Boardman River, sediment has built up behind them over time. Upon removal of the dams along the Boardman River, the sediment that has built up would be moved downstream. Additional sediment removal may be required depending on proposed channel alignment relative to engineered earthen embankments. Details of the sediment management framework are provided in the Detailed Project Report.

Anticipated future alignments through the impoundments following complete drawdown were based on a number of factors. New locations of the river channel through the existing dams were based on historic channel alignments, topographic characteristics of the area, and road crossing needs. For historical alignment comparisons, a historical image of Sabin Pond and Sabin Pond from 1916, shown in Figure 27, was referenced. Estimated channel locations were drafted consulting bathymetric data, aerial imagery, recent field observations, and historic drawings.

It is important to note that these alignments are estimates of the anticipated new river channel through the existing impoundments. Channel cross-sectional profiles were developed based on observations of natural channel areas upstream, and anticipated alignments were developed based on available data for feasibility level planning purposes only. During the final design phase, the floodplain design would be optimized to reproduce natural hydraulics and sediment transport similar to unimpounded areas of the river. This includes detailed modeling and geomorphic analysis to optimize design of natural riffle-pool structures, optimize bed/bank shears and velocities to reflect natural conditions, and restore natural erosion, deposition, and bed transport and sediment loads.

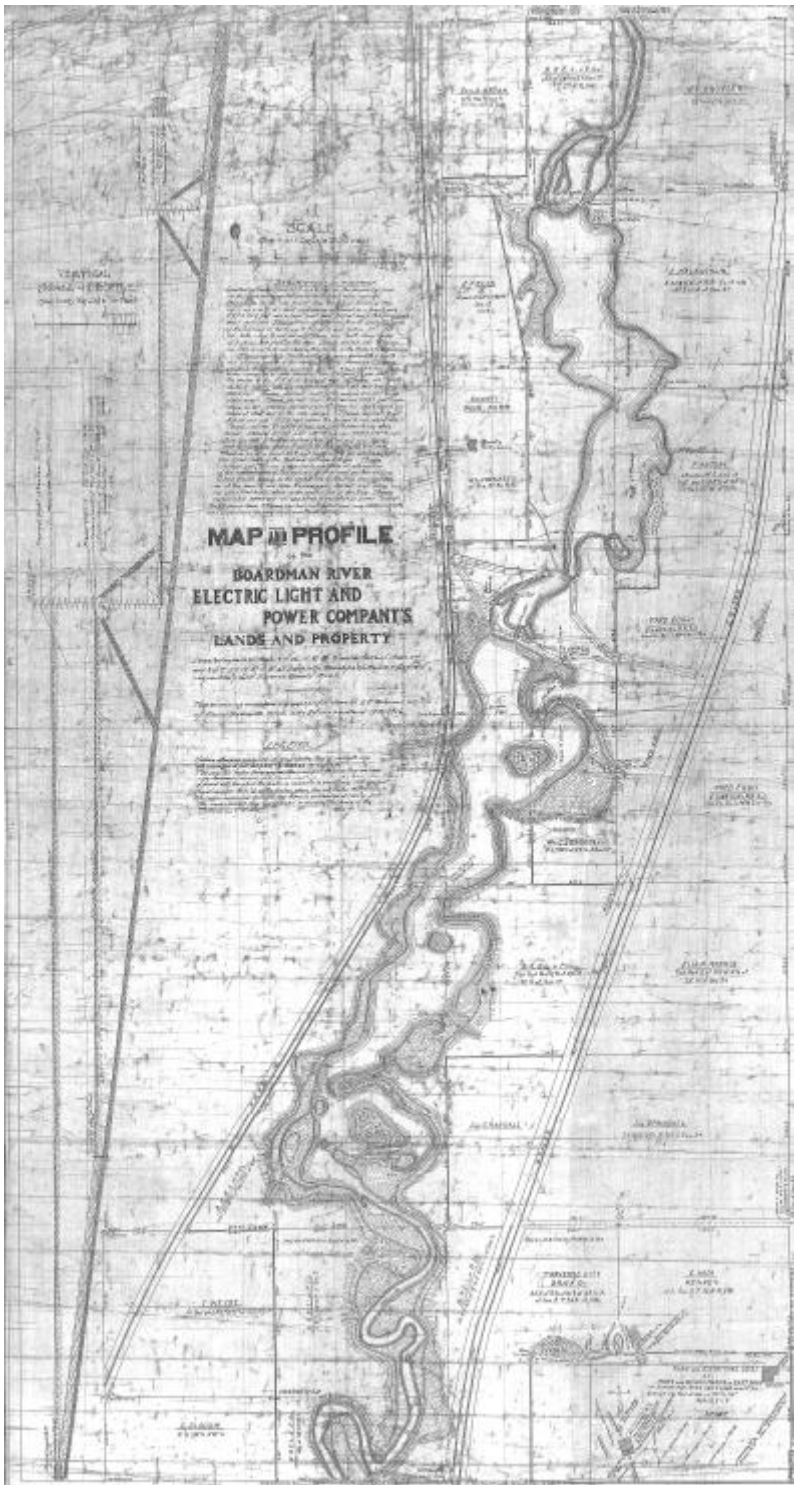

Figure 27: 1916 map of Boardman Pond and Sabin Pond area (Source: Boardman River Electric Light and Power Company 1916)

4.2.1 Boardman Dam

Sediment removal requirements for Boardman Pond were based on bathymetric data gathered in 2007 prior to the current drawdown. An anticipated alignment of the river channel for the removal alternative was developed based on a variety of data sources. The estimated volumes of sediment removal required for each alignment are shown in Table 6. A brief summary of sediment management and alignments is presented here; details regarding management of excess sediments are discussed in more detail in the Detailed Project Report.

Table 6: Estimated Sediment Removal Requirements through the Boardman Dam Area

Location	Anticipated Alignment
Boardman Dam	58,400 cubic yards
Boardman Impoundment	128,000 cubic yards

A conceptual channel cross-section (Figure 29) including a 60-foot-wide bankfull channel and 30-foot-wide floodplain on either side of the channel was applied through proposed channel alignments through the impoundments. The initial selection of an average of two times bankfull width for the floodplain bench originated from an analysis of floodplain widths in upstream sections. Figure 28 shows samples of typical floodplain widths upstream of the study area; two times bankfull width was a typical value observed. The range of bankfull widths observed was from very limited to four times bankfull with of floodplain. Thus, two times bankfull width was used as a starting point to assess the feasibility of restoring the channel through the impoundment. Through the VE process, the proposed floodplain width was finalized to 30 feet on either side of the bankfull channel. It is expected that during the design phase the floodplain bench would be optimized based on the H&H and sediment transport modeling and detailed geomorphologic analysis. The proposed channel alignment for the Boardman Dam and impoundment is shown in Figure 30. Red colors on these alignment figures indicate areas where the floodplain of the conceptual cross-section in Figure 29 cuts into the existing terrain or bathymetry requiring additional sediment removal.

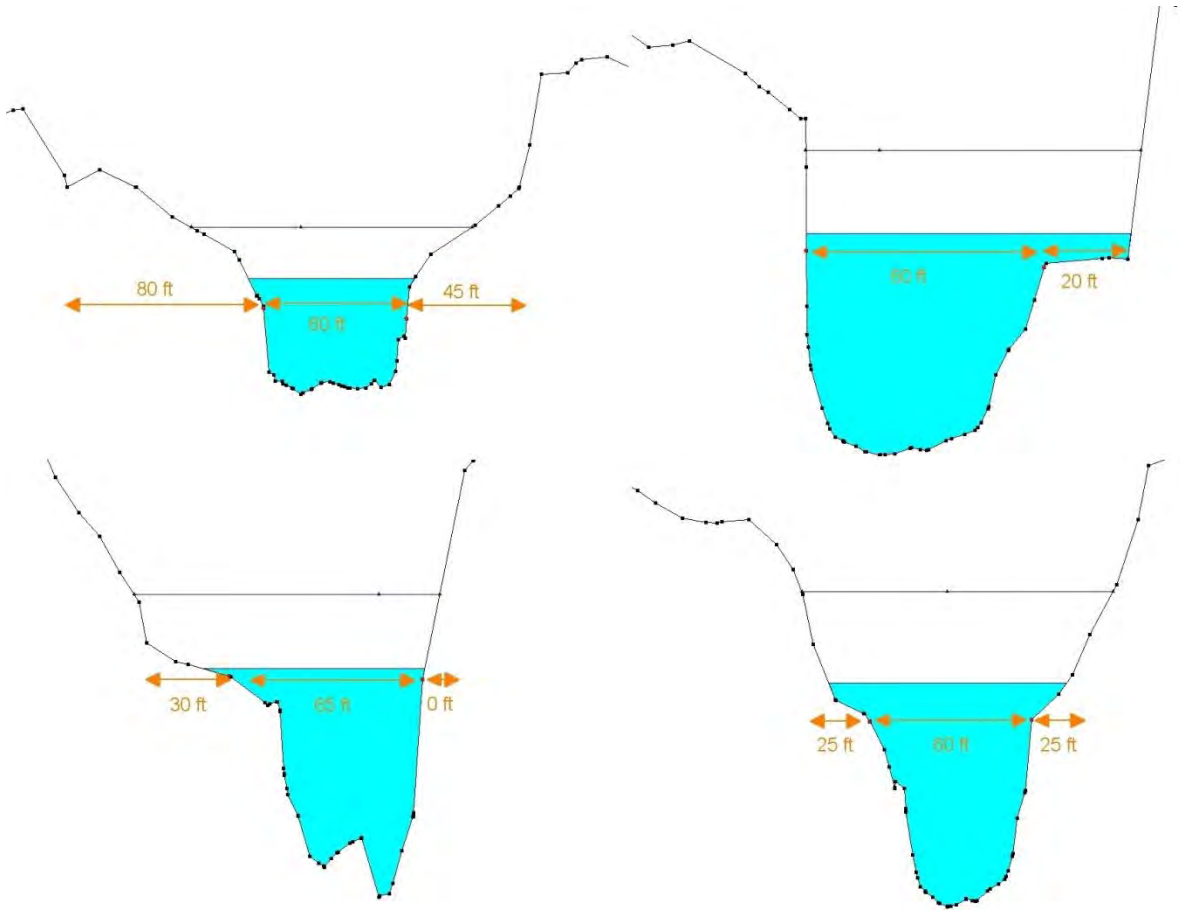

Figure 28: Sample floodplain widths from upstream of the study area. Cross sections from HEC-RAS model (graphics not to scale).

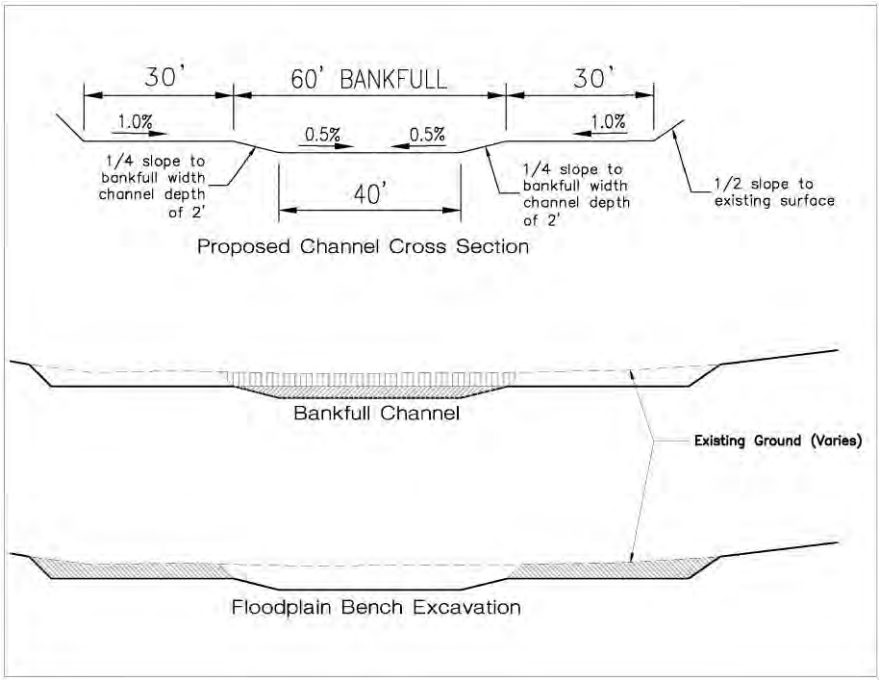

Figure 29: Conceptual cross-section illustrating typical channel through proposed alignment; includes 30-foot floodplain on either side of the bankfull channel

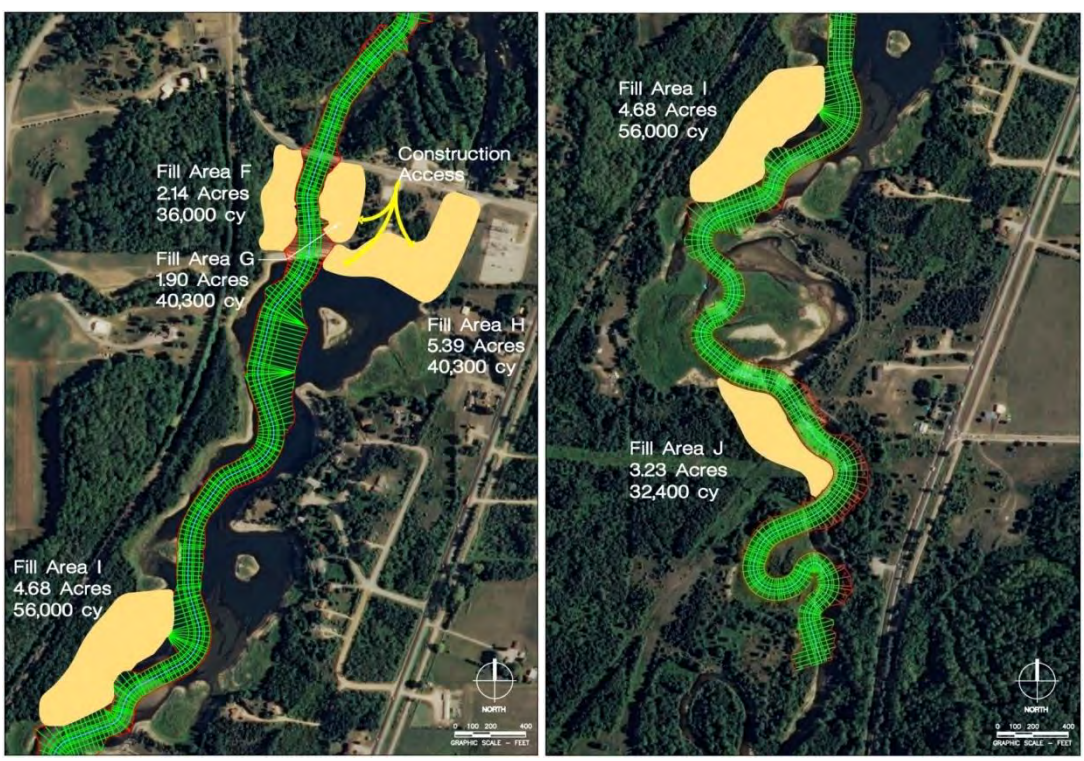

Figure 30: Proposed alignment through the existing Boardman Pond. The left side of the figure is the area near the dam; the right side is the area further upstream. Red areas indicate locations where high amounts of sediment removal may be required based on proposed conceptual alignments requirements for floodplain width.

4.2.2 Sabin Dam

Sediment removal requirements for Sabin Pond were based on bathymetric data gathered in 2007. Estimated removal volumes are shown in Table 7. Further details of sediment management for the Sabin Dam and Pond are included in the Detailed Project Report. The new anticipated channel, shown in Figure 31, is based on a number of information sources. The alignment through the channel was formed by existing bathymetry, historic maps, and recently collected data regarding tree stumps and depth or refusal. The proposed channel through the existing earthen berm to the river-right of the existing dam is through a historic channel, determined by historic maps, LIDAR data, and field observations of remains of a dam spillway structure. This alignment is preliminary for feasibility purposes and should be optimized through the detailed design phase of this project.

Table 7: Estimated Sediment Removal Requirements through the Sabin Dam Area

Location	Proposed Alignment
Sabin Dam	20,000 cubic yards
Sabin Pond	74,600 cubic yards

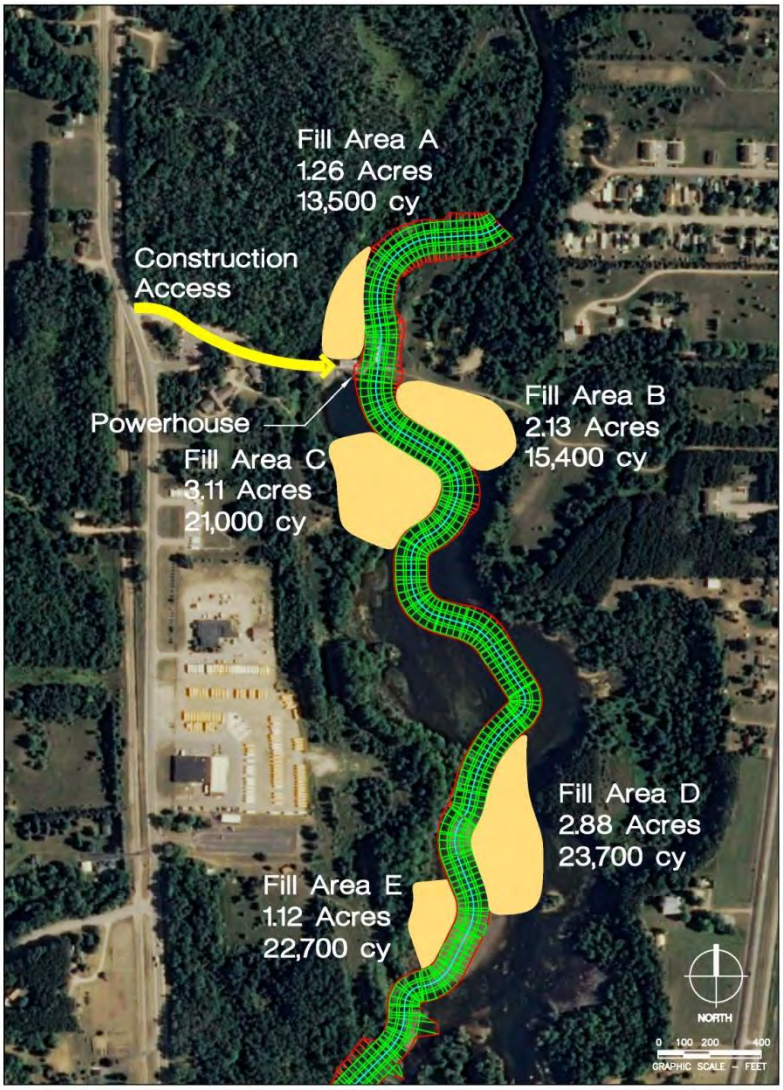

Figure 31: Proposed alignment through existing Sabin Dam impoundment

4.2.3 Union Street Dam

As the Union Street Dam is a low-head dam and has limited backwater before it reaches Boardman Lake, any proposed alternative is assumed to contribute little sediment movement to downstream reaches. Given the close proximity of the Union Street Dam downstream of Boardman Lake, a large sediment sink, minimal sediment accumulation behind the dam is assumed. Additionally, the Union Street Dam acts as a barrier to invasive species from Lake Michigan and Grand Traverse Bay to the Boardman River; and therefore full removal is not currently considered an alternative.

4.3 Sediment Transport, Deposition, and Scour

Sediment fate modeling of the existing conditions (before drawdowns of the Boardman Dam and the Brown Bridge Dam) was completed with the initial phase of work (USACE 2009a). This model was developed using existing hydraulic models for the study area to create a sediment

balance model and estimate the amount of sediment that had accumulated behind the dams since they were constructed. Recent field observations and examination of detailed engineering drawings of the dams in the study area allowed for detailed refinement of the model and definition of the existing conditions given recent drawdowns.

4.3.1 Baseline Conditions

The sediment budgets and characteristics of the existing impoundments were determined previously during the Baseline Conditions study (USACE 2009a). The original divided the river into sections that exhibited similar sediment gradations and channel slopes, shown in Figure 32. The results of this study indicated the river was largely in a graded state, with stable river channels and sediment transport through the river balanced with erosion and deposition. Within the impoundments, there was sediment surplus due to reduced transport capacity in the quiescent waters of the ponds. Downstream of the impoundments, there was a sediment shortage due to sediment trapping in the impoundments. Sediment trapping efficiency and average retention time of the dams were estimated to determine what fraction of incoming sediment would be trapped (Table 5). These results indicated the dams are effective sediment sinks retaining very fine sediments. A figure summarizing these results by sediment reach is shown in Figure 33. A comparison of sediment transport, between existing baseline conditions and proposed conditions, is provided in section 4.3.4.

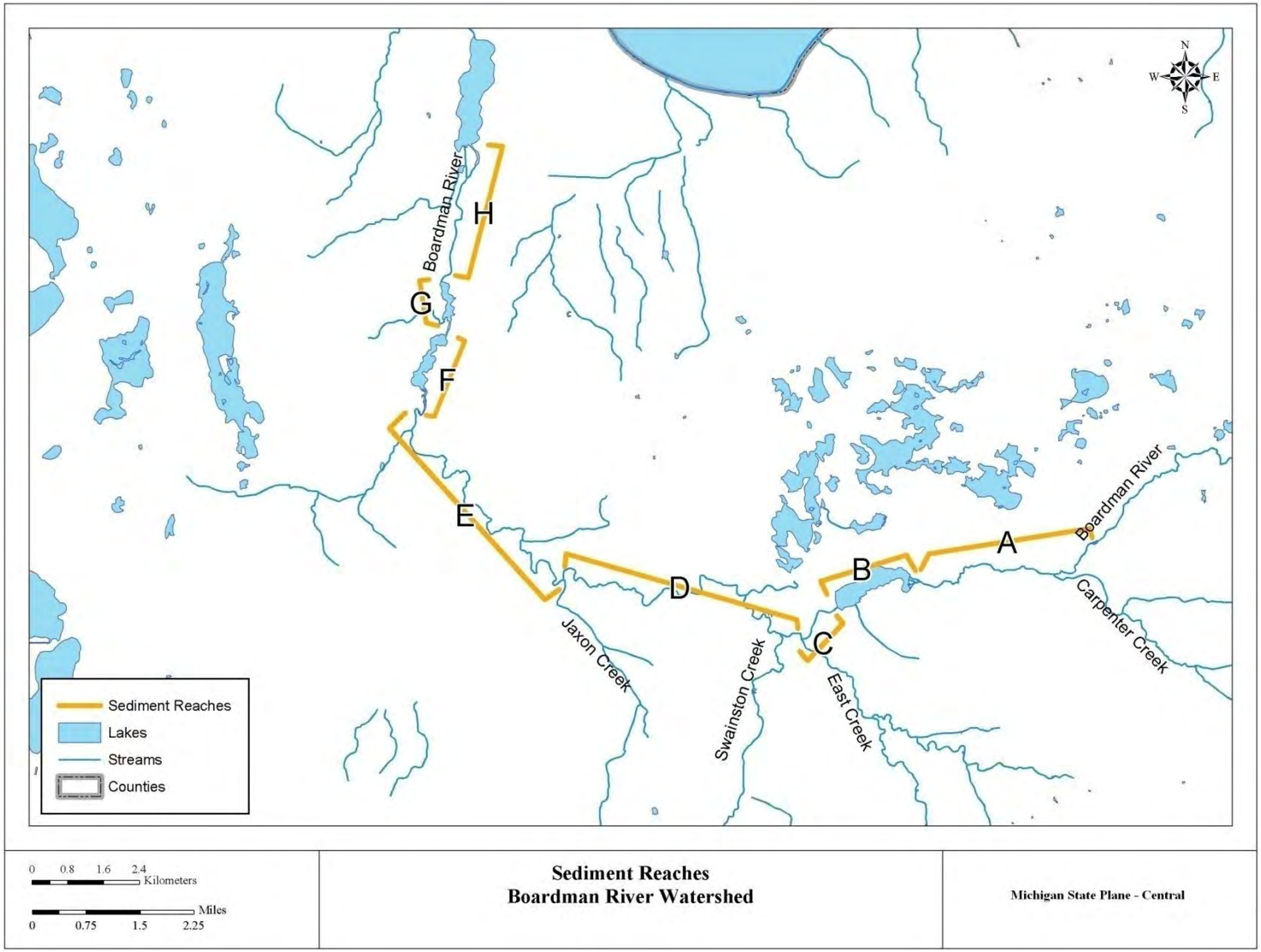

Figure 32: Major sediment reaches for sediment transport modeling of the Boardman River. Small reaches were also established to represent the deltas for Brown Bridge and Boardman Ponds, B and F, respectively. (USACE 2009a)

Table 8: Retention time and theoretical minimum particle size for sediment retention by the Boardman River dams under three flow scenarios

	Sabin		Boardman		Brown Bridge	
	Rt (days)	Dia (um)	Rt (days)	Dia (um)	Rt (days)	Dia (um)
Low Mean	5.7	0.3	18.8	0.2	66.1	0.1
High Mean	3.9	0.3	12.9	0.2	45.4	0.1
Peak	1.1	0.6	3.8	0.4	13.2	0.2

Note: Low Mean and High Mean represent average bounds from USGS flow data (scaled from Brown Bridge) and Peak is the largest event of record. Although Brown Bridge was part of the previous study; it is not included in this project.

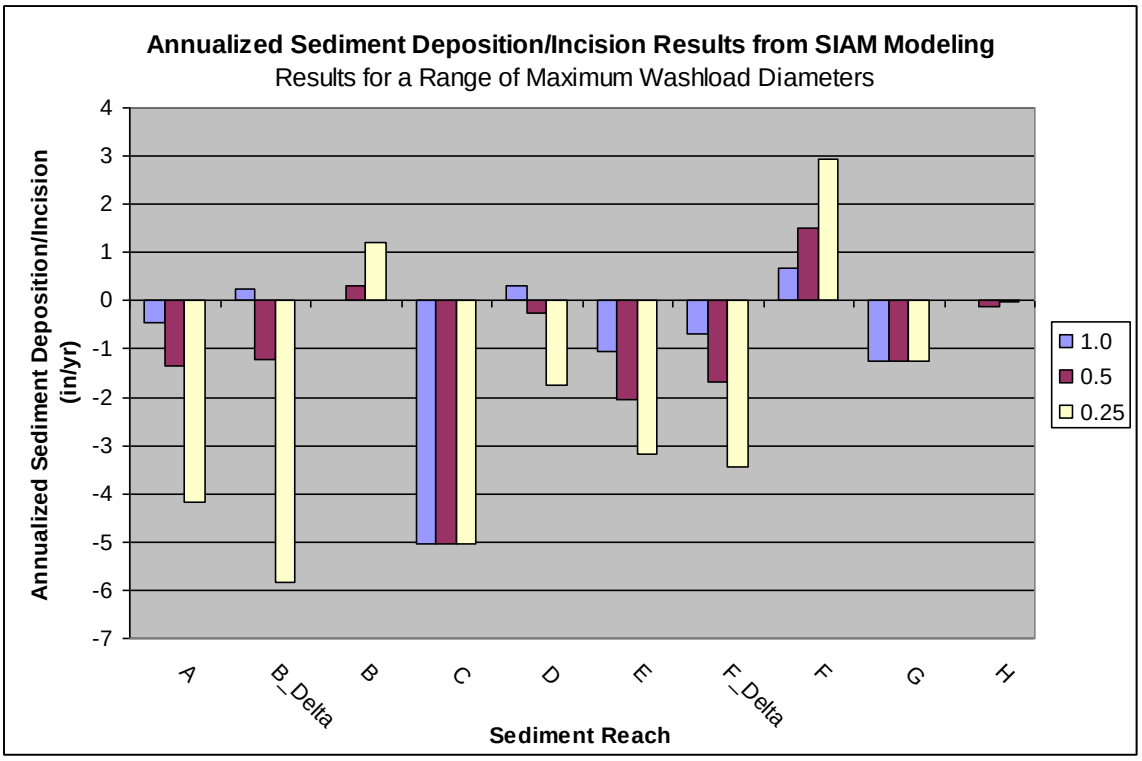

Figure 33: Summary of results from existing conditions SIAM modeling study

It is important to note that because SIAM is a sediment budget model, rather than a transport model, the results only indicate relative tendencies of surplus or deficit of material in each sediment reach and should be used only as a screening tool. Full details of the model and the results can be found in the report (USACE 2009a).

4.3.2 Sediment Movement Following Drawdowns

Since bathymetric surveys were completed in 2007, Boardman Pond and Brown Bridge Pond have been drawn down. As of June 2011, Sabin Pond is also in the beginning stages of drawdown mode; a succession of recent aerial photographs. No data are yet available for the Sabin Pond drawdown, but would be incorporated into the alternatives analysis, modeling effort,

and report as it becomes available. As a result, the sediment that had accumulated in the upstream deltas of each of the ponds appears to have prograded downstream. While this would not impact total sediment volumes in the impoundments for this phase of work, future more detailed sediment transport modeling for the final design phase of the project must take this change in bathymetry into account, potentially requiring further survey data.

Sediment movement in the two impoundments can be seen in time-lapse aerial photography in Figure 34 and Figure 35. Since the drawdown, the sediment has appeared to prograde downstream in Brown Bridge Pond approximately 2,000 feet; sediment in Boardman Pond has prograded approximately 2,700 feet downstream.

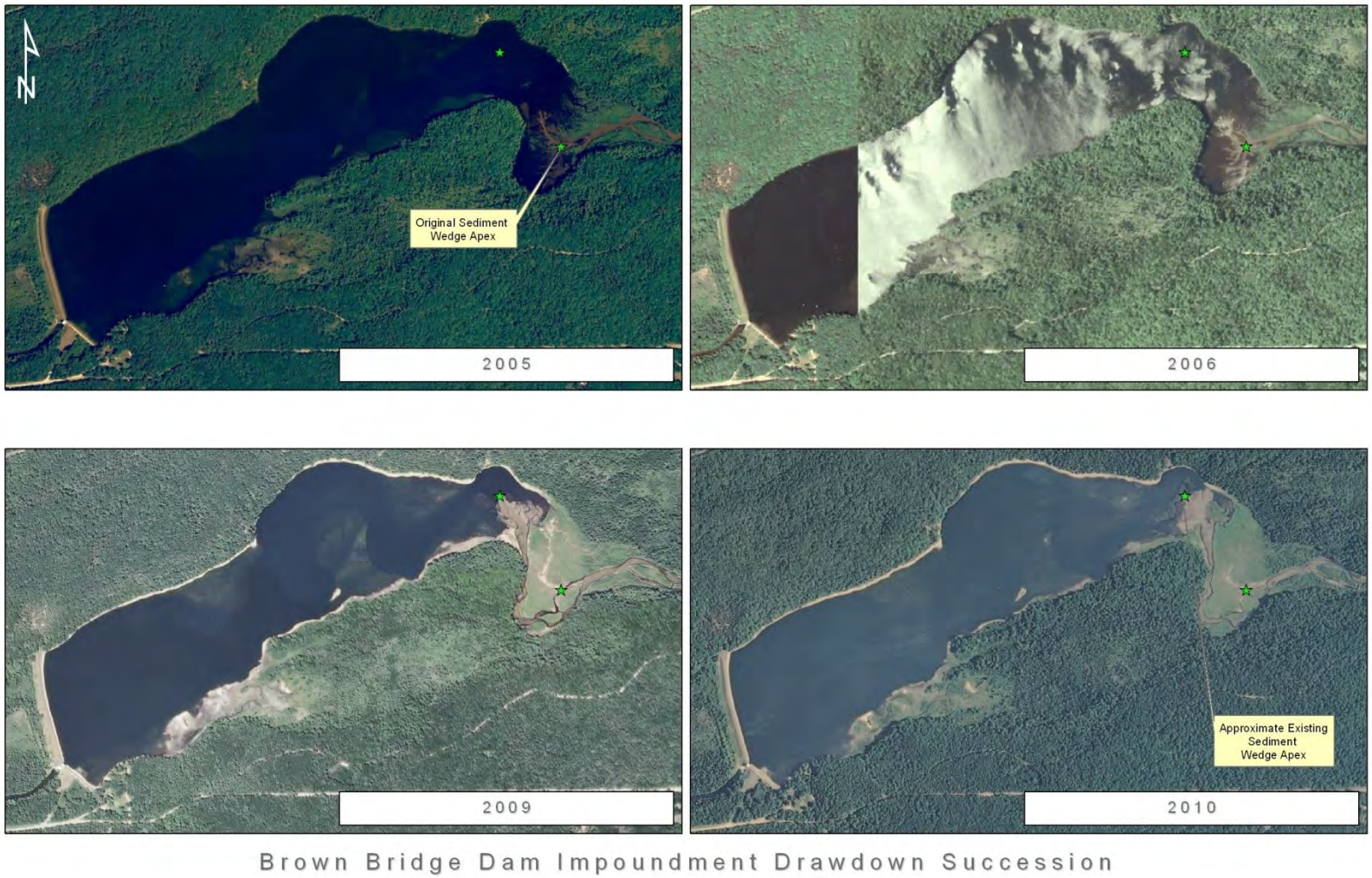

Figure 34: Sediment movement in Brown Bridge Pond following drawdown based on aerial imagery comparison

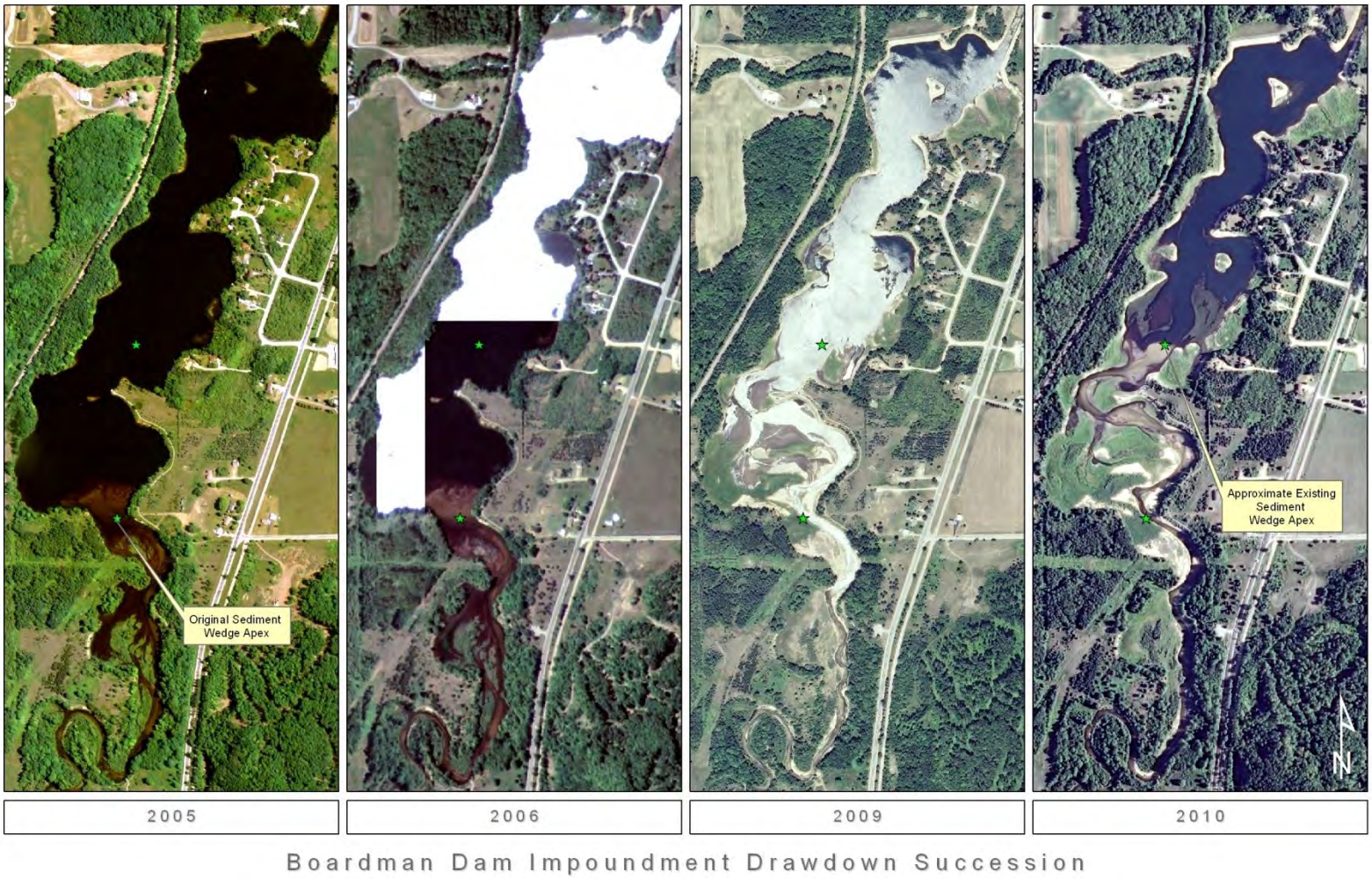

Figure 35: Sediment movement in Boardman Pond following drawdown based on aerial imagery comparison

Figure 36: Sediment movement in Sabin Pond following drawdown based on aerial imagery comparison

4.3.3 Sediment Gradation and Composition

As part of the sediment sampling efforts conducted in 2010 (GLEC 2011), sediment gradation measurements were completed using sieve analysis. These sediment samples were collected using a hand held Ponar dredge of surface sediments. Grain size data within the impoundment was collected by USACE during 2007. Sampling results were divided into fines (<0.125 millimeters [mm]) and coarse (>0.125 mm). Samples from 2010 were not burned for estimates of Total Carbon by loss on ignition (LOI) prior to mechanical sieving; therefore fines may include an unknown amount of organic content. Whether the 2007 samples were burned prior to sieving is unknown. Results are shown in Table 9.

Table 9: Summary of Coarse and Fine Grain Size Distribution Results within Boardman and Sabin Ponds

	2010 Sampling[1]			2007 Sampling[2]	
Site[3]	Coarse Material >0.125mm	Fine Material < 0.125mm	TOC[3]	Coarse Material >0.125mm	Fine Material < 0.125mm
BP1	70%	30%	15%	34%	66%
BP2	67%	33%	16%	81%	19%
BP3	73%	27%	9%	69%	31%
BP4	88%	12%	8%	56%	44%
BP5	65%	35%	13%	76%	24%
BP6	77%	23%	10%	76%	24%
SP1	56%	44%	9%	79%	21%
SP2	93%	7%	4%	77%	23%
SP3	82%	18%	0%	89%	11%
SP4	43%	57%	5%	79%	21%
SP5	92%	8%	1%	--	--
SP6	89%	11%	2%	--	--

[1]GLEC, 2011
[2]USACE, 2007, unpublished data
[3]Total Organic Carbon

The difference in coarse and fine materials during the sampling range is shown in Figure 37 and Figure 38. Changes in both coarse and fine sediments are evident at all sites during this period.

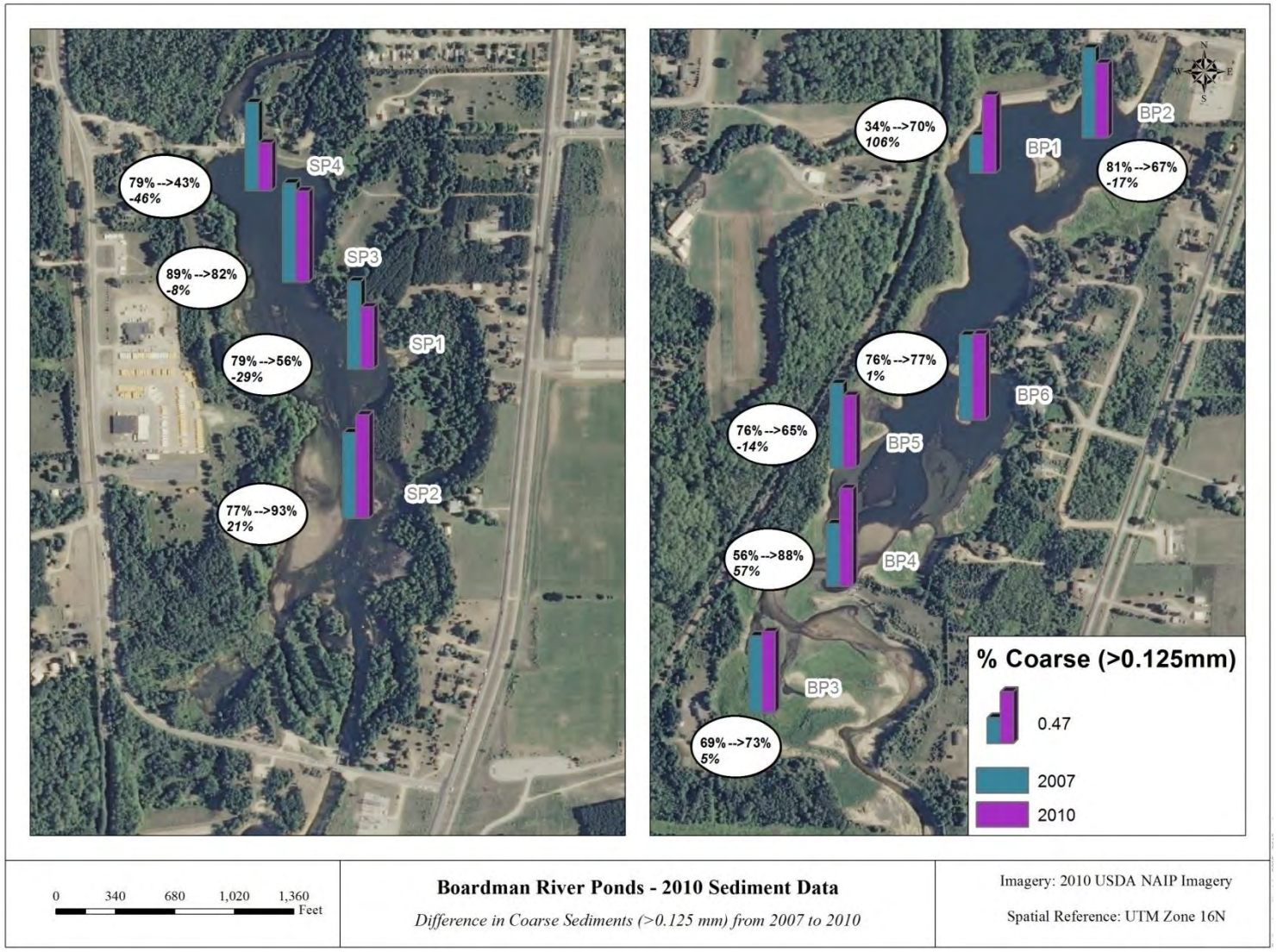

Figure 37: Difference in coarse sediments in Sabin and Boardman Ponds from 2007 to 2010

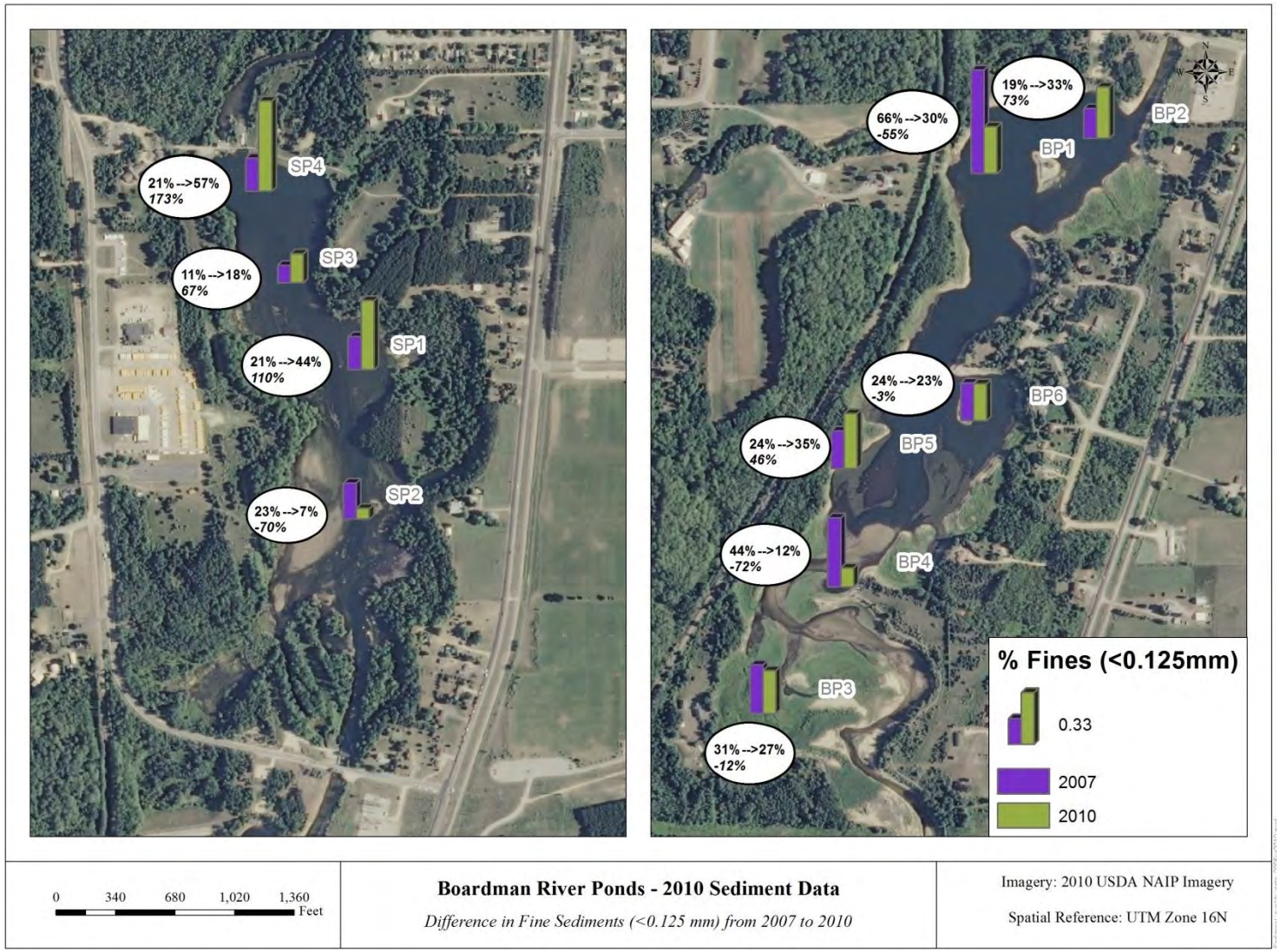

Figure 38: Difference in fine sediments in Sabin and Boardman Ponds from 2007 to 2010

4.3.4 Sediment Transport Analyses for Proposed Alternative Conditions

Sediment transport analyses were completed for the existing conditions and the proposed alternative alignment to examine what impact dam removals and channel modifications would potentially have on the existing sediment transport conditions and restoration of natural sediment transport. These results were used to inform areas of potential sediment management needs within the restored channel section. These modeling results are for feasibility planning purposes and not for detailed design. Model results are uncalibrated because of limited data. During the detailed design phase, additional modeling would be required to account for and inform further design decisions and sediment management. Further data would be required for sediment transport modeling during detailed design to better understand the nature of the sediments impounded behind the Sabin and Boardman Dams. This may include core samples of sediments, pre- and post- burned weight of cores to quantify organic matter, sediment gradations, and depth of refusal to accurately determine depth of historic channel.

Sediment transport analysis of the existing conditions and the proposed alternative was completed using the sediment transport model in HEC-RAS. The hydraulic models used to complete the flooding analysis were used for the baseline hydraulics for the sediment transport modeling. Sediment transport requires quasi-unsteady flow data to simulate sediment transport. Quasi-unsteady is a method between steady and unsteady flow where a time series of flow is broken into a series of steady flows to present a simplified flow hydrograph to represent flow conditions. Flow data from the USGS gauge were only available from 1997 to present; the maximum flow observed during that period is approximately equivalent to the 2-year flow according the MDEQ (USACE 2008a). This record was converted to a quasi-steady simplified dataset for modeling a comparison of the existing and alternative condition.

Sediment input data were used from the SIAM base case scenario study (USACE 2009a). Sediment gradation data were divided into similar sediment reaches, as presented in the SIAM study. These areas were determined by similar sediment characteristics including bed gradation and channel slopes. A summary of these sediment reaches is shown previously in Figure 32. Representative particle sizes for these reaches are shown in Figure 39.

Because no data were available for calibration of the sediment transport model, parameters from the base case SIAM study (USACE 2009a) were applied to the model. It is important to note that the results of the sediment transport model are uncalibrated and for feasibility level planning purposes only. Additional modeling with more detailed data collection of sediment characteristics and depth of refusal data from the existing impoundments may be conducted for detailed design analysis and sediment management practices.

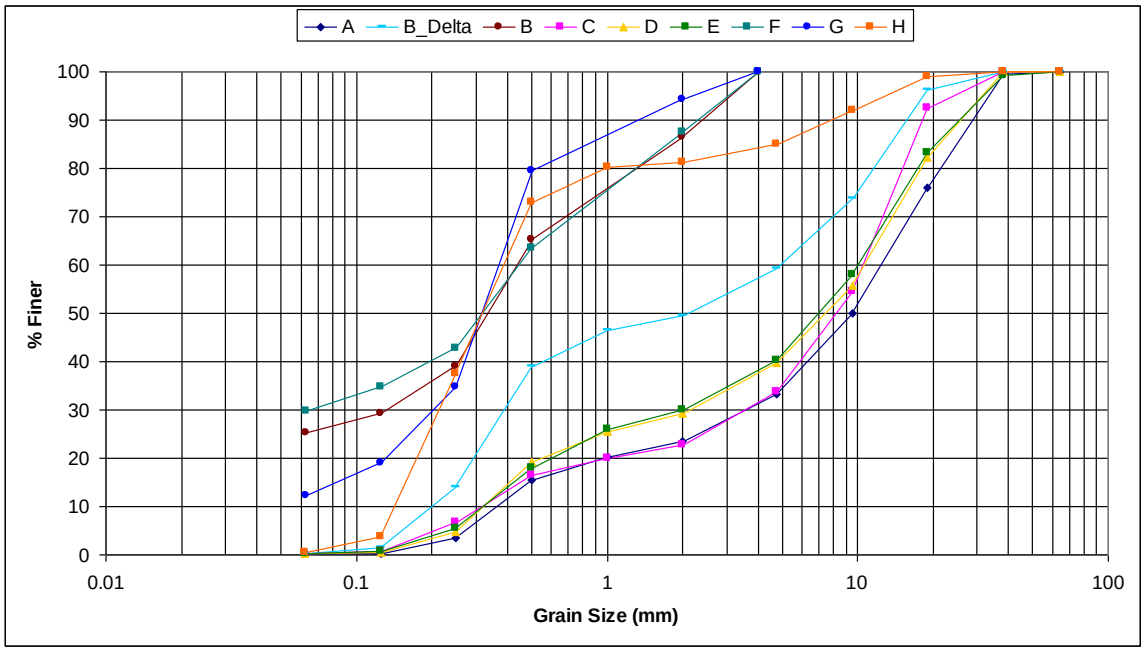

Figure 39: Representative particle size distributions for each sediment reach (USACE 2009a)

4.3.4.1 Sediment Transport Results

Channel incision and mass bed change under the existing and alternative conditions were compared by running15-year simulations of each condition in the sediment transport model. The results of the model runs are presented below.

Results of the existing conditions 15-year simulation are shown in Figure 40. These results illustrate the impact of the drawdown on the location of the sediment wedge within the impoundments; a large amount of sediment mobilization is evident in the model results under existing conditions in the deltas within Boardman Pond and Sabin Pond. This is a result of the impacts of the drawdowns at the dams mobilizing the accumulated sediment wedge on the upstream end of Boardman Pond, as bathymetry data pre-dates drawdowns on both impoundments. The pattern of sediment movement within the impoundments agrees with observations of drawdown progress previously presented in Figure 35 and Figure 36. The sediment deficit downstream of the Boardman Dam is evident in the channel invert change within the upstream reach of Sabin Pond. While active incision may not be that deep downstream of Boardman, the model indicates that this area is sediment starved and potential for transport from upstream sediment sources is minimal.

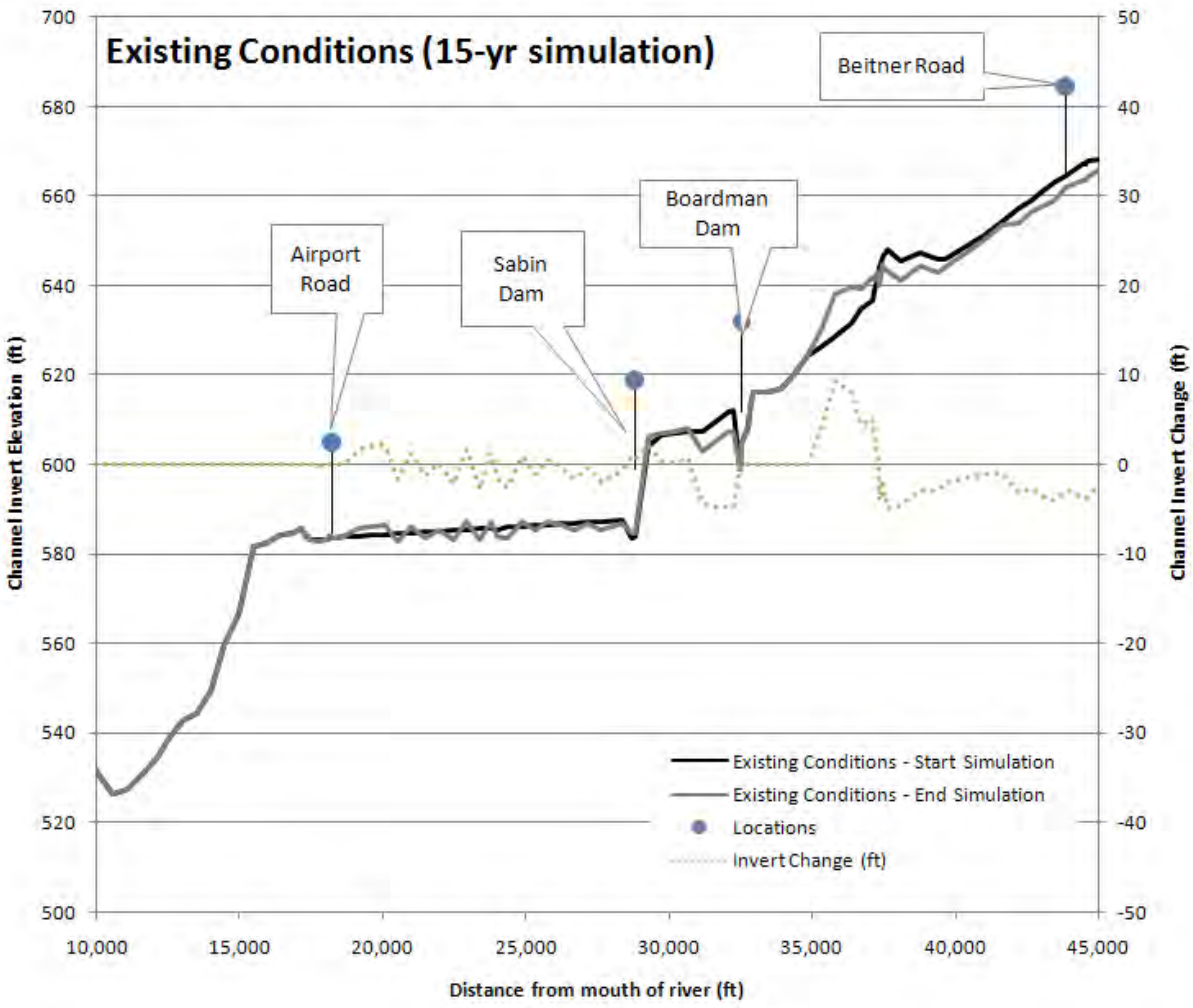

Figure 40: Channel invert change for the existing river configuration

Results of the anticipated alternative in Figure 41 illustrate sediment transport in impounded areas was predicted to be more uniform along the previously impounded reach. Areas from within the existing impoundments of Sabin and Boardman Dams go from being sediment traps to a connected, continuous area of sediment transport. While the areas that were previously impounded show incision within these reaches, actual incision within the impoundments following removal is dependent upon morphological adjustment of the existing impounded sediments. The depth of the native sediment layer under the accumulated sediments can also determine amount of incision possible under the alternative condition; this depth can be estimated through a depth of refusal measurement. Under the proposed alternative, the physical barriers (the Boardman and Sabin Dams) to sediment transport and more quiescent impounded waters that resulted in large amounts of deposition under existing conditions no longer exist in the proposed alternative. The area downstream of Sabin Dam has a scour hole and has been actively dredged (personal communication, Kaltenbach(TCLP)). The transition in the area from Sabin Dam to downstream goes from a steeper longitudinal profile to a flatter section of river, partly due to the presence of the scour and dredging at this location; this steep transition may also be a natural feature of the channel in this area. Because of this rapid profile change, this area

is expected to be a depositional section of river as the river works to restore connected sediment transport and a more continuous, gradual slope, shown by the gray line in the figure below. This depositional area in the results continues to approximately halfway between Sabin Dam and Airport Road, or about one river mile downstream of the Sabin Dam location.

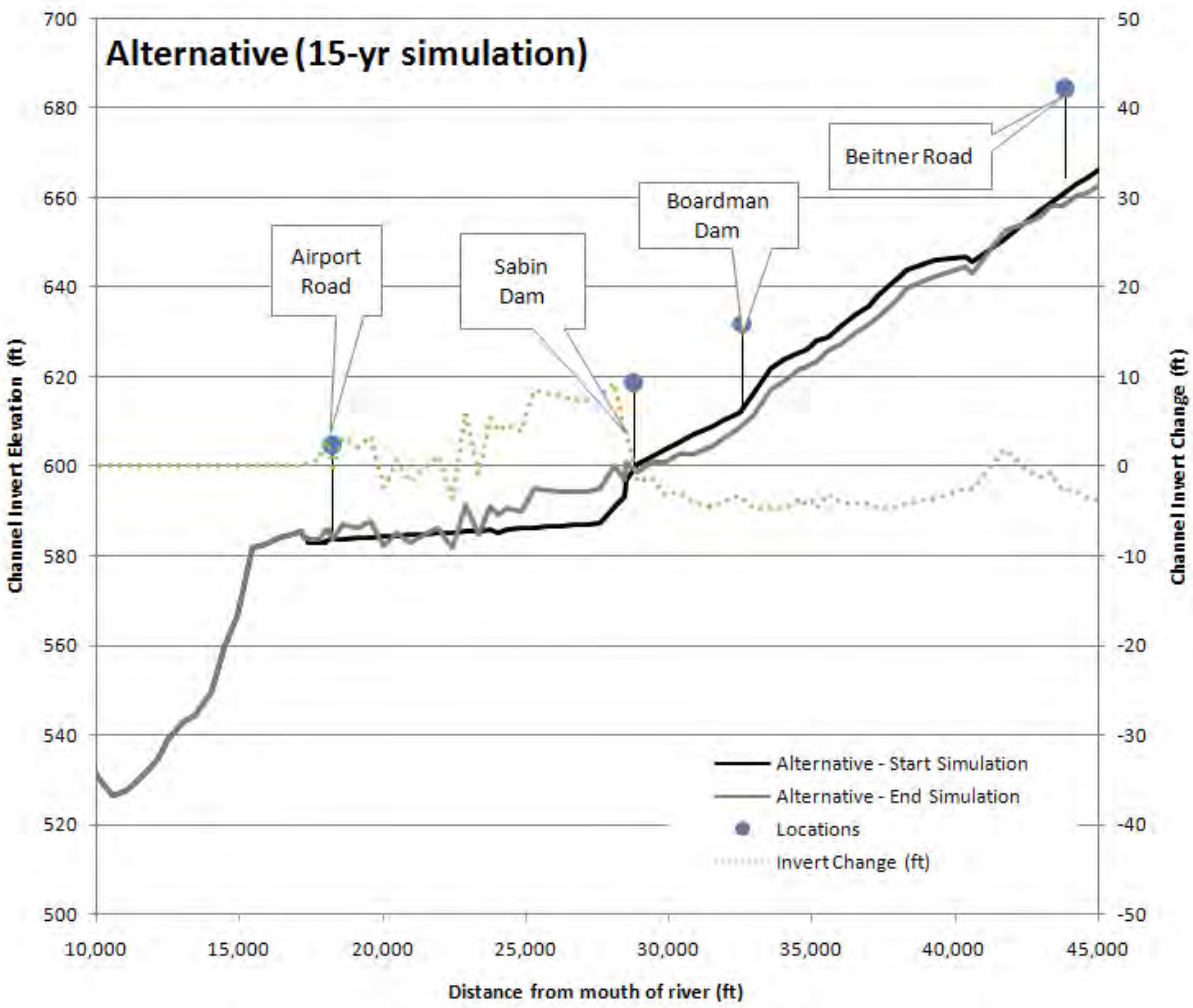

Figure 41: Channel invert changes for the anticipated alternative configuration

Figure 42 compares the final inverts and invert changes of the 15-year simulation of the existing and alternative models. Under existing conditions, Boardman Pond has a large wedge of sediment that has moved downstream as a result of the drawdown conditions and is starved for sediment downstream of the Boardman Dam within Sabin Pond. Under the alternative condition, the large wedge of sediment no longer exists within Boardman Pond. Additionally, under the alternative conditions, the area just downstream of the Sabin Dam becomes a net deposition site because of the relatively flat nature of the channel and the abrupt shift in longitudinal profile due to scour and previous dredging activities.

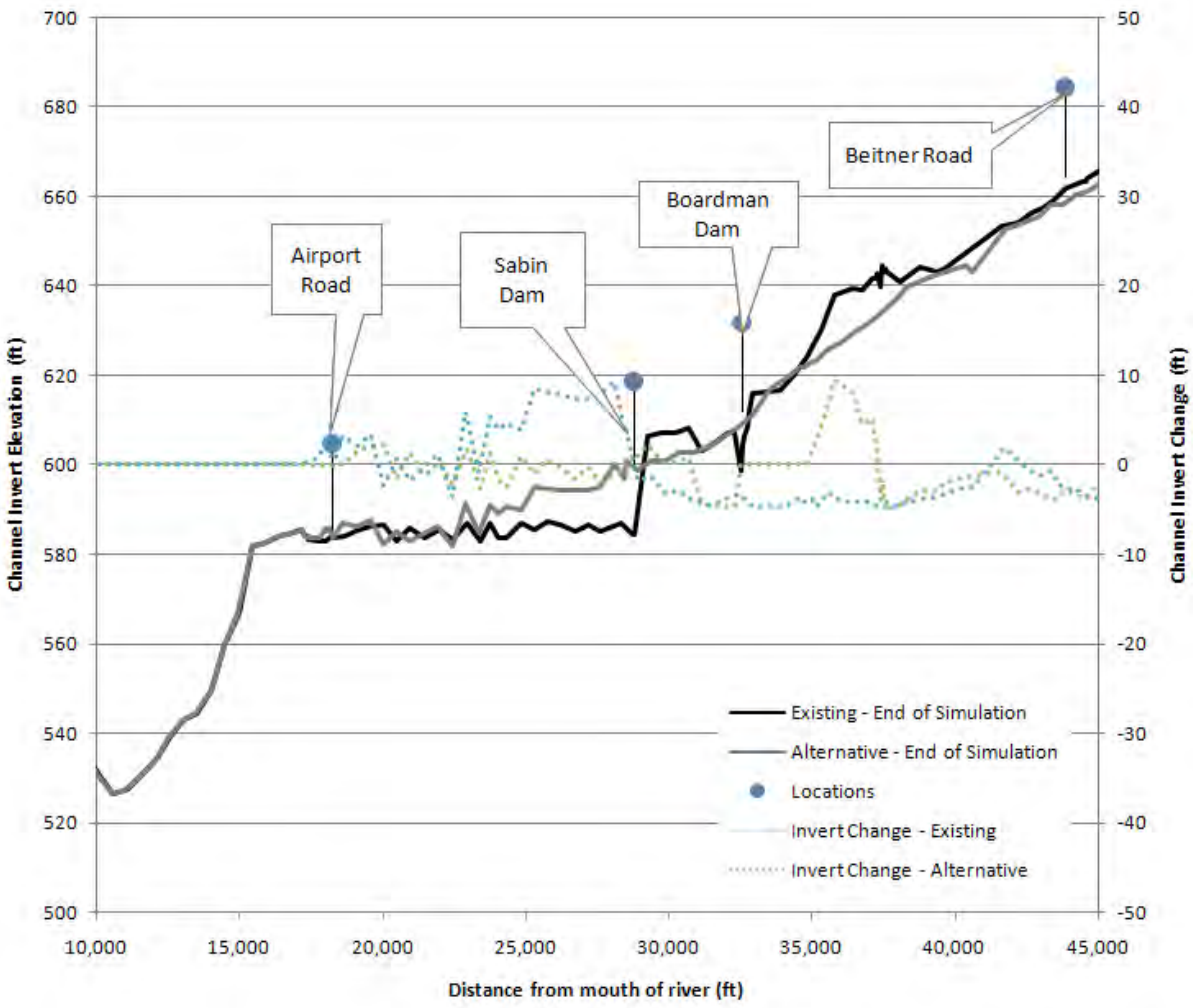

Figure 42: Comparison of channel inverts and invert changes for existing and alternative conditions

These results illustrate the differences in sediment transport within the study area for the existing conditions and the proposed alternative. Removal of the dams allows for throughput of sediment through previously impounded reaches in the Boardman River as compared to the existing ponds that allow for buildup of alluvial sediments and block natural passage of sediments to downstream reaches.

Sediment gradation data for the Sabin and Boardman Ponds was taken from grab samples rather than cores through the impounded sediments for this area, therefore sediment gradations in the model through these reaches is a more sandy material than other reaches in the model. This may result in some uncertainty in the results through this reach; however trends through the study area were reasonable.

No data were available for calibration or validation of the sediment transport simulation, so the model predictions should only be used to assess general trends rather than absolute values of transport potential by reach within the study area. The pattern of the results and relative changes

of future sediment transport conditions should be used to understand the future conditions of the system.

Results of this one-dimensional model of sediment transport should be used to interpret general patterns of future deposition or incision. Actual rates of deposition and incision are dependent upon a number of factors that cannot be simulated through this modeling, including appropriate planform geometry and the impact of vegetation on stability of the newly defined channel. Additionally, the only available sediment gradation data within the impoundments was from grab samples rather than depth of refusal core samples, so sediment data within these reaches of the model were more sand than other reaches of the model. During final design, depth of refusal and sediment core gradation data should be collected to better understand the nature of the impounded sediments. This model also does not simulate the presence or any subsequent maintenance of sediment traps that might be used during the drawdown process.

5 Conclusions and Recommendations

5.1 Data and Knowledge Gaps

These analyses were conducted using only previously collected data or data collected from others. These data gaps should be acknowledged when interpreting the results of the hydraulic and sediment transport studies.

5.1.1 Sediment Gradation and Chemistry Data

Sediment gradation and chemistry data were collected during several time periods by several different groups, as summarized in this report. These analyses were completed on aqueous samples within the existing impoundments. Through the drawdown process, sediments may move and condense, impacting the accuracy of the sediment samples. Additionally, most samples were grab samples only and not core samples, which leave uncertainty in composition of impounded sediments below surface sediments.

Sediment gradation data from within the impoundments were computed on grab samples of sediments rather than core samples; therefore, we do not know the true grain size composition of the sediments in the deltas behind the dams. Additionally, results were not reported as burned for Total Carbon LOI, so there is uncertainty in how much of the fine sediments were organic matter as opposed to fine silts and clays. Because of these gaps in the data, there is a large amount of uncertainty in the nature of the sediments contained within the existing impoundments. The models used these existing datasets to simulate sediment transport within the impoundments as it was the best data available.

5.1.2 Water Level Data for Calibration

The original model developed by USACE (2008a) examined flooding conditions on the river and was not calibrated. Additional calibration data were not available for this study, therefore the hydraulics of the model are based on the 2008 model developed by USACE as the best available source. This is especially important to note that the hydraulic model is uncalibrated in modeling of lower flow situations on the river.

5.1.3 Sediment Transport Modeling

Both the previous SIAM base-case scenario modeling study (USACE 2009a) and this study are uncalibrated. However, results have been compared to reference reaches or observations in the field as a reference guide for model results; results in this study examine relative changes in sediment transport from existing conditions to the proposed alternative rather than absolute values. Also, the results of these modeling studies should be considered for feasibility level planning purposes only. Because the sediment transport model is one-dimensional, it can be used to understand potential incision and deposition trends, however three-dimensional geomorphic responses of the river following removal cannot be discerned from this model. Sediment response of the system following removal is also partly dependent upon sequencing of flood events which is an uncertainty. For final design, a more detailed geomorphic assessment should

be conducted to understand river response. As this study relied on previously collected data, additional data should be collected with regards to sediment composition, depth of refusal, and existing bathymetry for final design purposes in the future.

Because input and calibration data were limited, results for these analyses are uncalibrated and used for feasibility level planning purposes only. During detailed design, additional data would be required.

5.2 Suggestions for Sediment Monitoring

These results illustrate the differences in sediment transport within the study area for the existing conditions and the proposed alternative. Removal of the dams restores natural sediment transport in the Boardman River as compared to the existing ponds that allow for buildup of alluvial sediments and block natural passage of sediments to downstream reaches. However, given the large amount of sediment buildup within Boardman Pond, the relatively flat nature of the section of river directly downstream of Sabin Dam, and the constrictions posed by the Airport Road culverts, sediment transport may be monitored in this section of river. A more detailed plan for sediment requirements for this section of river is provided in the monitoring plan.

Because sediment samples within the impoundments were not tested for carbon content (LOI), the nature of the impounded fines is unknown. Based on retention time estimates of the reservoirs presented, the dams are effective sinks of fine sediments (Table 8).Therefore, during the final detailed design and removal process, fines should be managed and monitored during removal and excavation.

5.3 Detailed Design Planning

The results presented in this analysis are for feasibility-level planning. Model results are largely uncalibrated because of data gaps. During the final design phase, the floodplain design would be optimized to reproduce natural hydraulics and sediment transport similar to unimpounded areas of the river. This includes detailed modeling and geomorphic analysis to optimize design of natural riffle-pool structures, optimize bed/bank shears and velocities to reflect natural conditions, and restore natural erosion, deposition, and bed transport and sediment loads. Additionally, during channel restoration design, impact of vegetation of bank stability in the restored section of channel should be taken into account.

While the HEC-RAS model has been used to understand the potential patterns of sediment transport in the river under existing and proposed conditions, this does not represent a sufficient level of detail to undertake detailed design of the remedial activities, and the model results should not be used in support of detailed design. Moreover, the morphological response of the remedial design should be evaluated by a suitably qualified professional as part of the detailed design phase of this study. Baird makes no warranty as to the suitability of the model results presented in this report for such a purpose and accepts no liability for third-party use of these results.

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8 Hydraulic model results

Table 10: Hydraulic model results from existing conditions model

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	43013.5	25yr	1300	665.72	4.75	0.72
5	Boardman	43013.5	50yr	1400	665.87	4.86	0.75
5	Boardman	43013.5	100yr	1500	666	4.98	0.77
5	Boardman	43013.5	200yr	1700	666.28	5.19	0.81
5	Boardman	43013.5	500yr	1900	666.53	5.38	0.85
5	Boardman	42618.39	2yr	750	662.68	5.15	0.86
5	Boardman	42618.39	5yr	950	662.98	5.77	1.04
5	Boardman	42618.39	10yr	1100	663.19	6.16	1.16
5	Boardman	42618.39	25yr	1300	663.4	6.74	1.36
5	Boardman	42618.39	50yr	1400	663.52	6.97	1.44
5	Boardman	42618.39	100yr	1500	663.64	7.17	1.5
5	Boardman	42618.39	200yr	1700	663.83	7.64	1.68
5	Boardman	42618.39	500yr	1900	664	8.1	1.86
5	Boardman	42196.73	2yr	750	660.96	4.24	0.6
5	Boardman	42196.73	5yr	950	661.27	4.48	0.64
5	Boardman	42196.73	10yr	1100	661.46	4.7	0.69
5	Boardman	42196.73	25yr	1300	661.79	4.76	0.69
5	Boardman	42196.73	50yr	1400	661.92	4.86	0.71
5	Boardman	42196.73	100yr	1500	662.06	4.97	0.73
5	Boardman	42196.73	200yr	1700	662.3	5.09	0.75
5	Boardman	42196.73	500yr	1900	662.52	5.19	0.76
5	Boardman	41597.69	2yr	750	657.79	5.11	0.93
5	Boardman	41597.69	5yr	950	658.17	5.45	1.02
5	Boardman	41597.69	10yr	1100	658.46	5.6	1.04
5	Boardman	41597.69	25yr	1300	658.53	6.43	1.36
5	Boardman	41597.69	50yr	1400	658.64	6.65	1.43
5	Boardman	41597.69	100yr	1500	658.74	6.86	1.51
5	Boardman	41597.69	200yr	1700	658.93	7.28	1.66
5	Boardman	41597.69	500yr	1900	659.11	7.67	1.81
5	Boardman	40929.91	2yr	750	655.58	3.38	0.37

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	40929.91	5yr	950	656.28	3.41	0.35
5	Boardman	40929.91	10yr	1100	656.57	3.61	0.39
5	Boardman	40929.91	25yr	1300	656.78	3.51	0.37
5	Boardman	40929.91	50yr	1400	656.92	3.57	0.37
5	Boardman	40929.91	100yr	1500	657.06	3.61	0.38
5	Boardman	40929.91	200yr	1700	657.31	3.7	0.39
5	Boardman	40929.91	500yr	1900	657.55	3.77	0.4
5	Boardman	39591.78	2yr	750	653.66	2.8	0.2
5	Boardman	39591.78	5yr	950	654.25	2.65	0.17
5	Boardman	39591.78	10yr	1100	654.53	2.67	0.19
5	Boardman	39591.78	25yr	1300	654.88	2.73	0.21
5	Boardman	39591.78	50yr	1400	655.03	2.77	0.22
5	Boardman	39591.78	100yr	1500	655.18	2.82	0.23
5	Boardman	39591.78	200yr	1700	655.44	2.91	0.25
5	Boardman	39591.78	500yr	1900	655.7	3.01	0.27
5	Boardman	39356.53	2yr	750	653.32	3.05	0.3
5	Boardman	39356.53	5yr	950	653.83	3.17	0.21
5	Boardman	39356.53	10yr	1100	654.14	3.05	0.18
5	Boardman	39356.53	25yr	1300	654.52	2.97	0.2
5	Boardman	39356.53	50yr	1400	654.68	2.98	0.21
5	Boardman	39356.53	100yr	1500	654.83	2.99	0.22
5	Boardman	39356.53	200yr	1700	655.1	3.04	0.24
5	Boardman	39356.53	500yr	1900	655.36	3.1	0.26
5	Boardman	38762.36	2yr	750	652.41	2.83	0.26
5	Boardman	38762.36	5yr	950	652.85	3.1	0.3
5	Boardman	38762.36	10yr	1100	653.16	3.27	0.32
5	Boardman	38762.36	25yr	1300	653.52	3.48	0.34
5	Boardman	38762.36	50yr	1400	653.69	3.53	0.23
5	Boardman	38762.36	100yr	1500	653.86	3.49	0.2
5	Boardman	38762.36	200yr	1700	654.17	3.4	0.2
5	Boardman	38762.36	500yr	1900	654.47	3.23	0.13
5	Boardman	38041.11	2yr	750	651.44	2.73	0.23
5	Boardman	38041.11	5yr	950	651.79	3.1	0.29

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	38041.11	10yr	1100	652.01	3.36	0.34
5	Boardman	38041.11	25yr	1300	652.3	3.68	0.4
5	Boardman	38041.11	50yr	1400	652.43	3.83	0.42
5	Boardman	38041.11	100yr	1500	652.56	3.97	0.45
5	Boardman	38041.11	200yr	1700	652.8	4.24	0.51
5	Boardman	38041.11	500yr	1900	653.02	4.5	0.56
5	Boardman	37603.96	2yr	750	649.81	4.59	1.21
5	Boardman	37603.96	5yr	950	649.98	4.98	1.36
5	Boardman	37603.96	10yr	1100	650.1	5.22	1.45
5	Boardman	37603.96	25yr	1300	650.24	5.54	1.58
5	Boardman	37603.96	50yr	1400	650.3	5.68	1.65
5	Boardman	37603.96	100yr	1500	650.37	5.83	1.71
5	Boardman	37603.96	200yr	1700	650.49	6.1	1.83
5	Boardman	37603.96	500yr	1900	650.6	6.35	1.95
5	Boardman	37543.4*	2yr	750	648.87	4.09	0.94
5	Boardman	37543.4*	5yr	950	649.04	4.46	1.07
5	Boardman	37543.4*	10yr	1100	649.15	4.73	1.18
5	Boardman	37543.4*	25yr	1300	649.29	5.02	1.29
5	Boardman	37543.4*	50yr	1400	649.36	5.13	1.34
5	Boardman	37543.4*	100yr	1500	649.43	5.26	1.38
5	Boardman	37543.4*	200yr	1700	649.56	5.47	1.47
5	Boardman	37543.4*	500yr	1900	649.68	5.68	1.56
5	Boardman	37482.9*	2yr	750	648.04	3.94	0.74
5	Boardman	37482.9*	5yr	950	648.15	4.4	0.89
5	Boardman	37482.9*	10yr	1100	648.23	4.71	0.99
5	Boardman	37482.9*	25yr	1300	648.33	5.08	1.14
5	Boardman	37482.9*	50yr	1400	648.36	5.3	1.22
5	Boardman	37482.9*	100yr	1500	648.4	5.47	1.29
5	Boardman	37482.9*	200yr	1700	648.48	5.82	1.44
5	Boardman	37482.9*	500yr	1900	648.56	6.12	1.57
5	Boardman	37422.46	2yr	750	647.08	4.51	0.61
5	Boardman	37422.46	5yr	950	647.19	4.84	0.67
5	Boardman	37422.46	10yr	1100	647.26	5.08	0.71

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	37422.46	25yr	1300	647.36	5.35	0.76
5	Boardman	37422.46	50yr	1400	647.41	5.45	0.78
5	Boardman	37422.46	100yr	1500	647.45	5.58	0.8
5	Boardman	37422.46	200yr	1700	647.54	5.78	0.84
5	Boardman	37422.46	500yr	1900	647.62	6	0.89
5	Boardman	37338.9*	2yr	750	645.07	4.36	0.58
5	Boardman	37338.9*	5yr	950	645.18	4.69	0.64
5	Boardman	37338.9*	10yr	1100	645.25	4.9	0.68
5	Boardman	37338.9*	25yr	1300	645.34	5.13	0.72
5	Boardman	37338.9*	50yr	1400	645.38	5.26	0.75
5	Boardman	37338.9*	100yr	1500	645.42	5.38	0.77
5	Boardman	37338.9*	200yr	1700	645.82	4.14	0.41
5	Boardman	37338.9*	500yr	1900	646.39	3.1	0.21
5	Boardman	37255.4*	2yr	750	643.08	3.76	0.39
5	Boardman	37255.4*	5yr	950	643.83	2.17	0.11
5	Boardman	37255.4*	10yr	1100	644.31	1.76	0.07
5	Boardman	37255.4*	25yr	1300	644.89	1.46	0.05
5	Boardman	37255.4*	50yr	1400	645.16	1.35	0.04
5	Boardman	37255.4*	100yr	1500	645.44	1.25	0.03
5	Boardman	37255.4*	200yr	1700	645.95	1.12	0.02
5	Boardman	37255.4*	500yr	1900	646.45	1.03	0.02
5	Boardman	37171.8*	2yr	750	643.2	0.66	0.01
5	Boardman	37171.8*	5yr	950	643.86	0.6	0.01
5	Boardman	37171.8*	10yr	1100	644.33	0.57	0.01
5	Boardman	37171.8*	25yr	1300	644.9	0.55	0.01
5	Boardman	37171.8*	50yr	1400	645.17	0.54	0.01
5	Boardman	37171.8*	100yr	1500	645.45	0.54	0
5	Boardman	37171.8*	200yr	1700	645.96	0.54	0
5	Boardman	37171.8*	500yr	1900	646.46	0.53	0
5	Boardman	37088.37	2yr	750	643.21	0.27	0
5	Boardman	37088.37	5yr	950	643.87	0.29	0
5	Boardman	37088.37	10yr	1100	644.33	0.3	0
5	Boardman	37088.37	25yr	1300	644.9	0.31	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	37088.37	50yr	1400	645.18	0.32	0
5	Boardman	37088.37	100yr	1500	645.45	0.32	0
5	Boardman	37088.37	200yr	1700	645.96	0.33	0
5	Boardman	37088.37	500yr	1900	646.46	0.34	0
5	Boardman	36705.14	2yr	750	643.2	0.2	0
5	Boardman	36705.14	5yr	950	643.87	0.23	0
5	Boardman	36705.14	10yr	1100	644.33	0.25	0
5	Boardman	36705.14	25yr	1300	644.9	0.27	0
5	Boardman	36705.14	50yr	1400	645.18	0.28	0
5	Boardman	36705.14	100yr	1500	645.45	0.29	0
5	Boardman	36705.14	200yr	1700	645.96	0.3	0
5	Boardman	36705.14	500yr	1900	646.46	0.32	0
5	Boardman	36364.25	2yr	750	643.2	0.42	0
5	Boardman	36364.25	5yr	950	643.86	0.49	0
5	Boardman	36364.25	10yr	1100	644.32	0.54	0
5	Boardman	36364.25	25yr	1300	644.9	0.59	0
5	Boardman	36364.25	50yr	1400	645.17	0.62	0
5	Boardman	36364.25	100yr	1500	645.45	0.64	0.01
5	Boardman	36364.25	200yr	1700	645.95	0.69	0.01
5	Boardman	36364.25	500yr	1900	646.45	0.73	0.01
5	Boardman	35760.29	2yr	750	643.2	0.19	0
5	Boardman	35760.29	5yr	950	643.86	0.22	0
5	Boardman	35760.29	10yr	1100	644.32	0.24	0
5	Boardman	35760.29	25yr	1300	644.9	0.26	0
5	Boardman	35760.29	50yr	1400	645.17	0.27	0
5	Boardman	35760.29	100yr	1500	645.45	0.28	0
5	Boardman	35760.29	200yr	1700	645.95	0.3	0
5	Boardman	35760.29	500yr	1900	646.45	0.32	0
5	Boardman	35298.84	2yr	750	643.2	0.12	0
5	Boardman	35298.84	5yr	950	643.86	0.15	0
5	Boardman	35298.84	10yr	1100	644.32	0.16	0
5	Boardman	35298.84	25yr	1300	644.9	0.18	0
5	Boardman	35298.84	50yr	1400	645.17	0.19	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	35298.84	100yr	1500	645.45	0.2	0
5	Boardman	35298.84	200yr	1700	645.95	0.21	0
5	Boardman	35298.84	500yr	1900	646.45	0.23	0
5	Boardman	34793.18	2yr	750	643.2	0.26	0
5	Boardman	34793.18	5yr	950	643.86	0.3	0
5	Boardman	34793.18	10yr	1100	644.32	0.34	0
5	Boardman	34793.18	25yr	1300	644.9	0.38	0
5	Boardman	34793.18	50yr	1400	645.17	0.39	0
5	Boardman	34793.18	100yr	1500	645.45	0.41	0
5	Boardman	34793.18	200yr	1700	645.95	0.45	0
5	Boardman	34793.18	500yr	1900	646.45	0.48	0
5	Boardman	34335.17	2yr	750	643.2	0.12	0
5	Boardman	34335.17	5yr	950	643.86	0.15	0
5	Boardman	34335.17	10yr	1100	644.32	0.16	0
5	Boardman	34335.17	25yr	1300	644.9	0.19	0
5	Boardman	34335.17	50yr	1400	645.17	0.2	0
5	Boardman	34335.17	100yr	1500	645.45	0.21	0
5	Boardman	34335.17	200yr	1700	645.95	0.23	0
5	Boardman	34335.17	500yr	1900	646.45	0.25	0
5	Boardman	33861.08	2yr	750	643.2	0.07	0
5	Boardman	33861.08	5yr	950	643.86	0.08	0
5	Boardman	33861.08	10yr	1100	644.32	0.09	0
5	Boardman	33861.08	25yr	1300	644.9	0.11	0
5	Boardman	33861.08	50yr	1400	645.17	0.11	0
5	Boardman	33861.08	100yr	1500	645.45	0.12	0
5	Boardman	33861.08	200yr	1700	645.95	0.13	0
5	Boardman	33861.08	500yr	1900	646.45	0.14	0
5	Boardman	33346.62	2yr	750	643.2	0.1	0
5	Boardman	33346.62	5yr	950	643.86	0.12	0
5	Boardman	33346.62	10yr	1100	644.32	0.14	0
5	Boardman	33346.62	25yr	1300	644.9	0.15	0
5	Boardman	33346.62	50yr	1400	645.17	0.16	0
5	Boardman	33346.62	100yr	1500	645.45	0.17	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	33346.62	200yr	1700	645.95	0.18	0
5	Boardman	33346.62	500yr	1900	646.45	0.2	0
5	Boardman	32883.33	2yr	750	643.2	0.31	0
5	Boardman	32883.33	5yr	950	643.86	0.39	0
5	Boardman	32883.33	10yr	1100	644.32	0.44	0
5	Boardman	32883.33	25yr	1300	644.89	0.5	0.01
5	Boardman	32883.33	50yr	1400	645.16	0.54	0.01
5	Boardman	32883.33	100yr	1500	645.44	0.57	0.01
5	Boardman	32883.33	200yr	1700	645.94	0.63	0.01
5	Boardman	32883.33	500yr	1900	646.44	0.69	0.01
5	Boardman	32796.0*	2yr	750	643.2	0.3	0
5	Boardman	32796.0*	5yr	950	643.86	0.37	0
5	Boardman	32796.0*	10yr	1100	644.32	0.42	0
5	Boardman	32796.0*	25yr	1300	644.89	0.49	0.01
5	Boardman	32796.0*	50yr	1400	645.16	0.52	0.01
5	Boardman	32796.0*	100yr	1500	645.44	0.55	0.01
5	Boardman	32796.0*	200yr	1700	645.94	0.61	0.01
5	Boardman	32796.0*	500yr	1900	646.44	0.67	0.01
5	Boardman	32708.8*	2yr	750	643.2	0.28	0
5	Boardman	32708.8*	5yr	950	643.86	0.35	0
5	Boardman	32708.8*	10yr	1100	644.32	0.4	0
5	Boardman	32708.8*	25yr	1300	644.89	0.45	0
5	Boardman	32708.8*	50yr	1400	645.16	0.48	0
5	Boardman	32708.8*	100yr	1500	645.44	0.51	0
5	Boardman	32708.8*	200yr	1700	645.94	0.57	0.01
5	Boardman	32708.8*	500yr	1900	646.44	0.62	0.01
5	Boardman	32621.6*	2yr	750	643.2	0.26	0
5	Boardman	32621.6*	5yr	950	643.86	0.32	0
5	Boardman	32621.6*	10yr	1100	644.32	0.37	0
5	Boardman	32621.6*	25yr	1300	644.89	0.42	0
5	Boardman	32621.6*	50yr	1400	645.16	0.45	0
5	Boardman	32621.6*	100yr	1500	645.44	0.48	0
5	Boardman	32621.6*	200yr	1700	645.94	0.53	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
5	Boardman	32621.6*	500yr	1900	646.44	0.58	0
5	Boardman	32534.37	2yr	750	643.2	0.26	0
5	Boardman	32534.37	5yr	950	643.86	0.32	0
5	Boardman	32534.37	10yr	1100	644.32	0.36	0
5	Boardman	32534.37	25yr	1300	644.89	0.42	0
5	Boardman	32534.37	50yr	1400	645.16	0.45	0
5	Boardman	32534.37	100yr	1500	645.44	0.47	0
5	Boardman	32534.37	200yr	1700	645.94	0.53	0
5	Boardman	32534.37	500yr	1900	646.44	0.58	0
	Boardman	32500.95		Inl Struct			
4	Boardman	32471.9	2yr	800	616.15	1	0.02
4	Boardman	32471.9	5yr	1000	616.56	1.19	0.03
4	Boardman	32471.9	10yr	1200	616.92	1.37	0.04
4	Boardman	32471.9	25yr	1400	617.24	1.54	0.05
4	Boardman	32471.9	50yr	1500	617.4	1.62	0.06
4	Boardman	32471.9	100yr	1700	617.69	1.77	0.07
4	Boardman	32471.9	200yr	1900	617.95	1.93	0.08
4	Boardman	32471.9	500yr	2200	618.32	2.15	0.1
4	Boardman	32247.59	2yr	800	615.72	4.56	0.74
4	Boardman	32247.59	5yr	1000	616.05	4.9	0.83
4	Boardman	32247.59	10yr	1200	616.35	5.19	0.91
4	Boardman	32247.59	25yr	1400	616.62	5.44	0.98
4	Boardman	32247.59	50yr	1500	616.75	5.56	1.01
4	Boardman	32247.59	100yr	1700	616.98	5.79	1.08
4	Boardman	32247.59	200yr	1900	617.2	6	1.14
4	Boardman	32247.59	500yr	2200	617.49	6.32	1.24
4	Boardman	32038.22	2yr	800	614.73	3.71	0.61
4	Boardman	32038.22	5yr	1000	615.04	4.07	0.71
4	Boardman	32038.22	10yr	1200	615.35	4.32	0.77
4	Boardman	32038.22	25yr	1400	615.6	4.63	0.86
4	Boardman	32038.22	50yr	1500	615.7	4.79	0.91

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
4	Boardman	32038.22	100yr	1700	615.88	5.12	1.02
4	Boardman	32038.22	200yr	1900	616.04	5.45	1.14
4	Boardman	32038.22	500yr	2200	616.13	6.15	1.44
4	Boardman	31580.99	2yr	800	612.75	3.23	0.41
4	Boardman	31580.99	5yr	1000	612.97	3.54	0.48
4	Boardman	31580.99	10yr	1200	613.05	4.03	0.61
4	Boardman	31580.99	25yr	1400	613.22	4.28	0.68
4	Boardman	31580.99	50yr	1500	613.34	4.29	0.68
4	Boardman	31580.99	100yr	1700	613.6	4.18	0.64
4	Boardman	31580.99	200yr	1900	613.88	3.97	0.57
4	Boardman	31580.99	500yr	2200	614.3	3.62	0.46
4	Boardman	31124.5	2yr	800	610.98	3.92	0.33
4	Boardman	31124.5	5yr	1000	611.49	3.54	0.26
4	Boardman	31124.5	10yr	1200	611.99	3.16	0.19
4	Boardman	31124.5	25yr	1400	612.47	2.92	0.16
4	Boardman	31124.5	50yr	1500	612.68	2.87	0.15
4	Boardman	31124.5	100yr	1700	613.06	2.8	0.13
4	Boardman	31124.5	200yr	1900	613.4	2.79	0.13
4	Boardman	31124.5	500yr	2200	613.9	2.77	0.12
4	Boardman	30629.18	2yr	800	610.78	1.42	0.04
4	Boardman	30629.18	5yr	1000	611.34	1.39	0.04
4	Boardman	30629.18	10yr	1200	611.89	1.38	0.03
4	Boardman	30629.18	25yr	1400	612.39	1.38	0.03
4	Boardman	30629.18	50yr	1500	612.6	1.39	0.03
4	Boardman	30629.18	100yr	1700	613	1.43	0.03
4	Boardman	30629.18	200yr	1900	613.34	1.48	0.03
4	Boardman	30629.18	500yr	2200	613.85	1.54	0.04
4	Boardman	30166.93	2yr	800	610.72	0.75	0.01
4	Boardman	30166.93	5yr	1000	611.31	0.71	0.01
4	Boardman	30166.93	10yr	1200	611.87	0.69	0.01
4	Boardman	30166.93	25yr	1400	612.38	0.68	0.01
4	Boardman	30166.93	50yr	1500	612.59	0.68	0.01
4	Boardman	30166.93	100yr	1700	612.98	0.69	0.01

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
4	Boardman	30166.93	200yr	1900	613.33	0.7	0.01
4	Boardman	30166.93	500yr	2200	613.84	0.72	0.01
4	Boardman	29697.73	2yr	800	610.68	0.78	0.01
4	Boardman	29697.73	5yr	1000	611.28	0.82	0.01
4	Boardman	29697.73	10yr	1200	611.84	0.82	0.01
4	Boardman	29697.73	25yr	1400	612.35	0.82	0.01
4	Boardman	29697.73	50yr	1500	612.56	0.83	0.01
4	Boardman	29697.73	100yr	1700	612.96	0.85	0.01
4	Boardman	29697.73	200yr	1900	613.31	0.88	0.01
4	Boardman	29697.73	500yr	2200	613.82	0.91	0.01
4	Boardman	29245.07	2yr	800	610.68	0.44	0
4	Boardman	29245.07	5yr	1000	611.27	0.49	0
4	Boardman	29245.07	10yr	1200	611.83	0.53	0
4	Boardman	29245.07	25yr	1400	612.35	0.57	0
4	Boardman	29245.07	50yr	1500	612.56	0.59	0
4	Boardman	29245.07	100yr	1700	612.96	0.62	0.01
4	Boardman	29245.07	200yr	1900	613.3	0.66	0.01
4	Boardman	29245.07	500yr	2200	613.81	0.71	0.01
4	Boardman	28776.65	2yr	800	610.68	0.24	0
4	Boardman	28776.65	5yr	1000	611.27	0.29	0
4	Boardman	28776.65	10yr	1200	611.83	0.33	0
4	Boardman	28776.65	25yr	1400	612.35	0.37	0
4	Boardman	28776.65	50yr	1500	612.56	0.4	0
4	Boardman	28776.65	100yr	1700	612.96	0.44	0
4	Boardman	28776.65	200yr	1900	613.3	0.48	0
4	Boardman	28776.65	500yr	2200	613.81	0.54	0
	Boardman	28746		Inl Struct			
3	Boardman	28696.38	2yr	800	593.95	0.71	0.01
3	Boardman	28696.38	5yr	1000	594.67	0.81	0.01
3	Boardman	28696.38	10yr	1200	595.31	0.9	0.02
3	Boardman	28696.38	25yr	1400	595.9	0.98	0.02

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	28696.38	50yr	1600	596.43	1.06	0.02
3	Boardman	28696.38	100yr	1700	596.71	1.09	0.03
3	Boardman	28696.38	200yr	1900	597.23	1.16	0.03
3	Boardman	28696.38	500yr	2000	597.53	1.19	0.03
3	Boardman	28308.14	2yr	800	593.88	1.76	0.08
3	Boardman	28308.14	5yr	1000	594.59	1.91	0.09
3	Boardman	28308.14	10yr	1200	595.23	2.05	0.11
3	Boardman	28308.14	25yr	1400	595.8	2.19	0.12
3	Boardman	28308.14	50yr	1600	596.32	2.31	0.13
3	Boardman	28308.14	100yr	1700	596.6	2.36	0.13
3	Boardman	28308.14	200yr	1900	597.11	2.46	0.14
3	Boardman	28308.14	500yr	2000	597.41	2.49	0.14
3	Boardman	27560.91	2yr	800	593.67	1.73	0.08
3	Boardman	27560.91	5yr	1000	594.38	1.88	0.09
3	Boardman	27560.91	10yr	1200	595.01	2.03	0.1
3	Boardman	27560.91	25yr	1400	595.58	2.16	0.11
3	Boardman	27560.91	50yr	1600	596.1	2.29	0.13
3	Boardman	27560.91	100yr	1700	596.38	2.34	0.13
3	Boardman	27560.91	200yr	1900	596.89	2.45	0.14
3	Boardman	27560.91	500yr	2000	597.19	2.48	0.14
3	Boardman	27141.14	2yr	800	593.56	1.71	0.08
3	Boardman	27141.14	5yr	1000	594.27	1.87	0.09
3	Boardman	27141.14	10yr	1200	594.9	2.01	0.1
3	Boardman	27141.14	25yr	1400	595.46	2.15	0.11
3	Boardman	27141.14	50yr	1600	595.98	2.28	0.12
3	Boardman	27141.14	100yr	1700	596.26	2.33	0.13
3	Boardman	27141.14	200yr	1900	596.76	2.44	0.14
3	Boardman	27141.14	500yr	2000	597.07	2.47	0.14
3	Boardman	26677.17	2yr	800	593.45	1.69	0.08
3	Boardman	26677.17	5yr	1000	594.15	1.85	0.09
3	Boardman	26677.17	10yr	1200	594.77	2	0.1
3	Boardman	26677.17	25yr	1400	595.33	2.13	0.11
3	Boardman	26677.17	50yr	1600	595.85	2.27	0.12

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	26677.17	100yr	1700	596.13	2.32	0.13
3	Boardman	26677.17	200yr	1900	596.63	2.42	0.13
3	Boardman	26677.17	500yr	2000	596.94	2.45	0.14
3	Boardman	26194.53	2yr	800	593.33	1.66	0.07
3	Boardman	26194.53	5yr	1000	594.03	1.83	0.09
3	Boardman	26194.53	10yr	1200	594.65	1.98	0.1
3	Boardman	26194.53	25yr	1400	595.2	2.11	0.11
3	Boardman	26194.53	50yr	1600	595.71	2.25	0.12
3	Boardman	26194.53	100yr	1700	596	2.3	0.12
3	Boardman	26194.53	200yr	1900	596.5	2.4	0.13
3	Boardman	26194.53	500yr	2000	596.81	2.44	0.13
3	Boardman	25726.61	2yr	800	593.22	1.64	0.07
3	Boardman	25726.61	5yr	1000	593.91	1.81	0.08
3	Boardman	25726.61	10yr	1200	594.53	1.96	0.1
3	Boardman	25726.61	25yr	1400	595.08	2.1	0.11
3	Boardman	25726.61	50yr	1600	595.59	2.23	0.12
3	Boardman	25726.61	100yr	1700	595.87	2.28	0.12
3	Boardman	25726.61	200yr	1900	596.38	2.39	0.13
3	Boardman	25726.61	500yr	2000	596.69	2.42	0.13
3	Boardman	25272.98	2yr	800	593.12	1.62	0.07
3	Boardman	25272.98	5yr	1000	593.81	1.78	0.08
3	Boardman	25272.98	10yr	1200	594.41	1.94	0.09
3	Boardman	25272.98	25yr	1400	594.96	2.08	0.1
3	Boardman	25272.98	50yr	1600	595.46	2.21	0.12
3	Boardman	25272.98	100yr	1700	595.75	2.26	0.12
3	Boardman	25272.98	200yr	1900	596.25	2.36	0.13
3	Boardman	25272.98	500yr	2000	596.57	2.39	0.13
3	Boardman	24820.52	2yr	800	593.02	1.66	0.07
3	Boardman	24820.52	5yr	1000	593.7	1.85	0.09
3	Boardman	24820.52	10yr	1200	594.29	2.03	0.1
3	Boardman	24820.52	25yr	1400	594.83	2.19	0.12
3	Boardman	24820.52	50yr	1600	595.33	2.34	0.13
3	Boardman	24820.52	100yr	1700	595.61	2.4	0.13

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	24820.52	200yr	1900	596.11	2.52	0.15
3	Boardman	24820.52	500yr	2000	596.43	2.55	0.15
3	Boardman	24316.27	2yr	800	592.86	1.91	0.1
3	Boardman	24316.27	5yr	1000	593.53	2.08	0.12
3	Boardman	24316.27	10yr	1200	594.12	2.22	0.13
3	Boardman	24316.27	25yr	1400	594.66	2.35	0.14
3	Boardman	24316.27	50yr	1600	595.14	2.48	0.15
3	Boardman	24316.27	100yr	1700	595.43	2.52	0.16
3	Boardman	24316.27	200yr	1900	595.93	2.61	0.16
3	Boardman	24316.27	500yr	2000	596.26	2.63	0.16
3	Boardman	24002.28	2yr	800	592.74	2.02	0.11
3	Boardman	24002.28	5yr	1000	593.4	2.25	0.13
3	Boardman	24002.28	10yr	1200	593.98	2.46	0.15
3	Boardman	24002.28	25yr	1400	594.51	2.65	0.17
3	Boardman	24002.28	50yr	1600	594.99	2.82	0.19
3	Boardman	24002.28	100yr	1700	595.28	2.87	0.19
3	Boardman	24002.28	200yr	1900	595.78	2.96	0.2
3	Boardman	24002.28	500yr	2000	596.14	2.87	0.18
3	Boardman	23717.84	2yr	800	592.69	1.62	0.07
3	Boardman	23717.84	5yr	1000	593.34	1.8	0.08
3	Boardman	23717.84	10yr	1200	593.92	1.97	0.1
3	Boardman	23717.84	25yr	1400	594.44	2.13	0.11
3	Boardman	23717.84	50yr	1600	594.92	2.27	0.12
3	Boardman	23717.84	100yr	1700	595.21	2.32	0.13
3	Boardman	23717.84	200yr	1900	595.72	2.44	0.13
3	Boardman	23717.84	500yr	2000	596.07	2.45	0.14
3	Boardman	23364.7	2yr	800	592.57	2.03	0.11
3	Boardman	23364.7	5yr	1000	593.21	2.28	0.13
3	Boardman	23364.7	10yr	1200	593.77	2.51	0.15
3	Boardman	23364.7	25yr	1400	594.28	2.72	0.18
3	Boardman	23364.7	50yr	1600	594.74	2.92	0.2
3	Boardman	23364.7	100yr	1700	595.03	2.99	0.21
3	Boardman	23364.7	200yr	1900	595.53	3.14	0.22

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	23364.7	500yr	2000	595.88	3.17	0.22
3	Boardman	22888.98	2yr	800	592.45	1.72	0.08
3	Boardman	22888.98	5yr	1000	593.08	1.93	0.09
3	Boardman	22888.98	10yr	1200	593.64	2.13	0.11
3	Boardman	22888.98	25yr	1400	594.14	2.31	0.13
3	Boardman	22888.98	50yr	1600	594.6	2.46	0.14
3	Boardman	22888.98	100yr	1700	594.89	2.5	0.14
3	Boardman	22888.98	200yr	1900	595.4	2.58	0.15
3	Boardman	22888.98	500yr	2000	595.78	2.42	0.13
3	Boardman	22420.06	2yr	800	592.32	1.94	0.1
3	Boardman	22420.06	5yr	1000	592.93	2.17	0.12
3	Boardman	22420.06	10yr	1200	593.47	2.38	0.14
3	Boardman	22420.06	25yr	1400	593.96	2.58	0.16
3	Boardman	22420.06	50yr	1600	594.4	2.76	0.18
3	Boardman	22420.06	100yr	1700	594.7	2.81	0.19
3	Boardman	22420.06	200yr	1900	595.21	2.89	0.19
3	Boardman	22420.06	500yr	2000	595.61	2.79	0.18
3	Boardman	21921.43	2yr	800	592.15	2.05	0.11
3	Boardman	21921.43	5yr	1000	592.74	2.29	0.13
3	Boardman	21921.43	10yr	1200	593.26	2.51	0.16
3	Boardman	21921.43	25yr	1400	593.74	2.7	0.18
3	Boardman	21921.43	50yr	1600	594.18	2.87	0.2
3	Boardman	21921.43	100yr	1700	594.48	2.9	0.2
3	Boardman	21921.43	200yr	1900	595	2.94	0.2
3	Boardman	21921.43	500yr	2000	595.43	2.84	0.18
3	Boardman	21450.08	2yr	800	591.94	2.25	0.14
3	Boardman	21450.08	5yr	1000	592.52	2.51	0.16
3	Boardman	21450.08	10yr	1200	593.02	2.75	0.19
3	Boardman	21450.08	25yr	1400	593.48	2.97	0.22
3	Boardman	21450.08	50yr	1600	593.9	3.17	0.24
3	Boardman	21450.08	100yr	1700	594.21	3.21	0.24
3	Boardman	21450.08	200yr	1900	594.75	3.25	0.25
3	Boardman	21450.08	500yr	2000	595.22	3.1	0.22

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	20920.77	2yr	800	591.73	2.1	0.12
3	Boardman	20920.77	5yr	1000	592.29	2.37	0.14
3	Boardman	20920.77	10yr	1200	592.77	2.63	0.17
3	Boardman	20920.77	25yr	1400	593.21	2.86	0.2
3	Boardman	20920.77	50yr	1600	593.63	3.03	0.22
3	Boardman	20920.77	100yr	1700	593.96	3.01	0.21
3	Boardman	20920.77	200yr	1900	594.54	2.9	0.19
3	Boardman	20920.77	500yr	2000	595.06	2.66	0.16
3	Boardman	20460.01	2yr	800	591.46	2.66	0.19
3	Boardman	20460.01	5yr	1000	591.98	2.99	0.24
3	Boardman	20460.01	10yr	1200	592.47	3.06	0.24
3	Boardman	20460.01	25yr	1400	592.96	2.93	0.22
3	Boardman	20460.01	50yr	1600	593.43	2.72	0.18
3	Boardman	20460.01	100yr	1700	593.82	2.45	0.15
3	Boardman	20460.01	200yr	1900	594.46	2.07	0.1
3	Boardman	20460.01	500yr	2000	595.01	1.73	0.07
3	Boardman	19995.95	2yr	800	591.37	1.42	0.05
3	Boardman	19995.95	5yr	1000	591.88	1.59	0.07
3	Boardman	19995.95	10yr	1200	592.37	1.71	0.07
3	Boardman	19995.95	25yr	1400	592.86	1.76	0.08
3	Boardman	19995.95	50yr	1600	593.33	1.76	0.08
3	Boardman	19995.95	100yr	1700	593.73	1.67	0.07
3	Boardman	19995.95	200yr	1900	594.39	1.53	0.05
3	Boardman	19995.95	500yr	2000	594.96	1.36	0.04
3	Boardman	19532.95	2yr	800	591.3	1.37	0.05
3	Boardman	19532.95	5yr	1000	591.81	1.47	0.05
3	Boardman	19532.95	10yr	1200	592.3	1.51	0.06
3	Boardman	19532.95	25yr	1400	592.8	1.51	0.05
3	Boardman	19532.95	50yr	1600	593.28	1.48	0.05
3	Boardman	19532.95	100yr	1700	593.69	1.39	0.04
3	Boardman	19532.95	200yr	1900	594.36	1.28	0.04
3	Boardman	19532.95	500yr	2000	594.94	1.14	0.03

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
3	Boardman	19106.62	2yr	800	591.29	0.6	0.01
3	Boardman	19106.62	5yr	1000	591.8	0.6	0.01
3	Boardman	19106.62	10yr	1200	592.29	0.61	0.01
3	Boardman	19106.62	25yr	1400	592.79	0.62	0.01
3	Boardman	19106.62	50yr	1600	593.27	0.61	0.01
3	Boardman	19106.62	100yr	1700	593.68	0.59	0.01
3	Boardman	19106.62	200yr	1900	594.35	0.56	0.01
3	Boardman	19106.62	500yr	2000	594.94	0.52	0.01
3	Boardman	18601.62	2yr	800	591.27	0.46	0.01
3	Boardman	18601.62	5yr	1000	591.78	0.5	0.01
3	Boardman	18601.62	10yr	1200	592.27	0.53	0.01
3	Boardman	18601.62	25yr	1400	592.77	0.54	0.01
3	Boardman	18601.62	50yr	1600	593.26	0.56	0.01
3	Boardman	18601.62	100yr	1700	593.67	0.54	0.01
3	Boardman	18601.62	200yr	1900	594.34	0.53	0.01
3	Boardman	18601.62	500yr	2000	594.93	0.51	0.01
3	Boardman	18207.99	2yr	800	591.24	0.61	0.01
3	Boardman	18207.99	5yr	1000	591.76	0.67	0.01
3	Boardman	18207.99	10yr	1200	592.25	0.7	0.01
3	Boardman	18207.99	25yr	1400	592.75	0.73	0.02
3	Boardman	18207.99	50yr	1600	593.24	0.75	0.02
3	Boardman	18207.99	100yr	1700	593.65	0.73	0.01
3	Boardman	18207.99	200yr	1900	594.33	0.72	0.01
3	Boardman	18207.99	500yr	2000	594.92	0.69	0.01
	Boardman	18159.36		Culvert			
2	Boardman	18108.3	2yr	800	591.21	0.91	0.02
2	Boardman	18108.3	5yr	1000	591.73	0.98	0.03
2	Boardman	18108.3	10yr	1200	592.23	1.04	0.03
2	Boardman	18108.3	25yr	1400	592.73	1.07	0.03
2	Boardman	18108.3	50yr	1600	593.21	1.09	0.03
2	Boardman	18108.3	100yr	1700	593.61	1.05	0.03
2	Boardman	18108.3	200yr	1900	594.3	1.01	0.02
2	Boardman	18108.3	500yr	2000	594.89	0.95	0.02

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
	Boardman	18072.91		Culvert			
2	Boardman	18028.0*	2yr	800	590.81	1.23	0.04
2	Boardman	18028.0*	5yr	1000	591.15	1.36	0.05
2	Boardman	18028.0*	10yr	1200	591.44	1.48	0.06
2	Boardman	18028.0*	25yr	1400	591.7	1.59	0.07
2	Boardman	18028.0*	50yr	1600	591.89	1.72	0.08
2	Boardman	18028.0*	100yr	1700	592.13	1.72	0.08
2	Boardman	18028.0*	200yr	1900	592.45	1.77	0.08
2	Boardman	18028.0*	500yr	2000	593.08	1.6	0.06
2	Boardman	17997.4	2yr	800	590.81	1.19	0.04
2	Boardman	17997.4	5yr	1000	591.15	1.32	0.05
2	Boardman	17997.4	10yr	1200	591.43	1.44	0.06
2	Boardman	17997.4	25yr	1400	591.69	1.55	0.06
2	Boardman	17997.4	50yr	1600	591.88	1.68	0.08
2	Boardman	17997.4	100yr	1700	592.12	1.68	0.07
2	Boardman	17997.4	200yr	1900	592.44	1.74	0.08
2	Boardman	17997.4	500yr	2000	593.08	1.58	0.06
	Boardman	17938		Culvert			
2	Boardman	17927.71	2yr	800	590.8	1.18	0.04
2	Boardman	17927.71	5yr	1000	591.13	1.33	0.05
2	Boardman	17927.71	10yr	1200	591.41	1.48	0.06
2	Boardman	17927.71	25yr	1400	591.67	1.61	0.07
2	Boardman	17927.71	50yr	1600	591.86	1.74	0.08
2	Boardman	17927.71	100yr	1700	592.09	1.74	0.08
2	Boardman	17927.71	200yr	1900	592.42	1.79	0.08
2	Boardman	17927.71	500yr	2000	593.06	1.61	0.06
2	Boardman	17782.47	2yr	800	590.76	1.61	0.07
2	Boardman	17782.47	5yr	1000	591.07	1.89	0.09
2	Boardman	17782.47	10yr	1200	591.34	2.15	0.11
2	Boardman	17782.47	25yr	1400	591.59	2.39	0.14
2	Boardman	17782.47	50yr	1600	591.77	2.64	0.17

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
2	Boardman	17782.47	100yr	1700	591.99	2.68	0.17
2	Boardman	17782.47	200yr	1900	592.32	2.81	0.19
2	Boardman	17782.47	500yr	2000	592.98	2.57	0.15
2	Boardman	17371.19	2yr	800	590.67	1.44	0.07
2	Boardman	17371.19	5yr	1000	590.96	1.7	0.09
2	Boardman	17371.19	10yr	1200	591.19	1.95	0.12
2	Boardman	17371.19	25yr	1400	591.42	2.17	0.14
2	Boardman	17371.19	50yr	1600	591.56	2.4	0.18
2	Boardman	17371.19	100yr	1700	591.8	2.41	0.17
2	Boardman	17371.19	200yr	1900	592.12	2.48	0.18
2	Boardman	17371.19	500yr	2000	592.85	2.14	0.13
2	Boardman	17321.7*	2yr	800	590.68	0.49	0.01
2	Boardman	17321.7*	5yr	1000	590.97	0.58	0.01
2	Boardman	17321.7*	10yr	1200	591.21	0.66	0.01
2	Boardman	17321.7*	25yr	1400	591.43	0.74	0.02
2	Boardman	17321.7*	50yr	1600	591.58	0.83	0.02
2	Boardman	17321.7*	100yr	1700	591.82	0.84	0.02
2	Boardman	17321.7*	200yr	1900	592.14	0.9	0.02
2	Boardman	17321.7*	500yr	2000	592.86	0.84	0.02
2	Boardman	17272.3*	2yr	800	590.68	0.28	0
2	Boardman	17272.3*	5yr	1000	590.97	0.33	0
2	Boardman	17272.3*	10yr	1200	591.21	0.38	0
2	Boardman	17272.3*	25yr	1400	591.44	0.42	0
2	Boardman	17272.3*	50yr	1600	591.59	0.47	0.01
2	Boardman	17272.3*	100yr	1700	591.82	0.48	0.01
2	Boardman	17272.3*	200yr	1900	592.15	0.51	0.01
2	Boardman	17272.3*	500yr	2000	592.86	0.48	0.01
2	Boardman	17222.9*	2yr	800	590.68	0.23	0
2	Boardman	17222.9*	5yr	1000	590.97	0.26	0
2	Boardman	17222.9*	10yr	1200	591.21	0.3	0
2	Boardman	17222.9*	25yr	1400	591.44	0.33	0
2	Boardman	17222.9*	50yr	1600	591.59	0.37	0
2	Boardman	17222.9*	100yr	1700	591.82	0.38	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
2	Boardman	17222.9*	200yr	1900	592.15	0.4	0
2	Boardman	17222.9*	500yr	2000	592.86	0.37	0
2	Boardman	17124.18	2yr	800	590.68	0.21	0
2	Boardman	17124.18	5yr	1000	590.97	0.24	0
2	Boardman	17124.18	10yr	1200	591.21	0.27	0
2	Boardman	17124.18	25yr	1400	591.44	0.3	0
2	Boardman	17124.18	50yr	1600	591.59	0.33	0
2	Boardman	17124.18	100yr	1700	591.82	0.33	0
2	Boardman	17124.18	200yr	1900	592.15	0.34	0
2	Boardman	17124.18	500yr	2000	592.86	0.31	0
2	Boardman	16961.9*	2yr	800	590.68	0.16	0
2	Boardman	16961.9*	5yr	1000	590.97	0.19	0
2	Boardman	16961.9*	10yr	1200	591.21	0.21	0
2	Boardman	16961.9*	25yr	1400	591.44	0.23	0
2	Boardman	16961.9*	50yr	1600	591.59	0.26	0
2	Boardman	16961.9*	100yr	1700	591.82	0.26	0
2	Boardman	16961.9*	200yr	1900	592.15	0.27	0
2	Boardman	16961.9*	500yr	2000	592.86	0.25	0
2	Boardman	16799.74	2yr	800	590.68	0.14	0
2	Boardman	16799.74	5yr	1000	590.97	0.16	0
2	Boardman	16799.74	10yr	1200	591.21	0.18	0
2	Boardman	16799.74	25yr	1400	591.44	0.2	0
2	Boardman	16799.74	50yr	1600	591.59	0.23	0
2	Boardman	16799.74	100yr	1700	591.82	0.23	0
2	Boardman	16799.74	200yr	1900	592.15	0.24	0
2	Boardman	16799.74	500yr	2000	592.86	0.22	0
2	Boardman	16344.43	2yr	800	590.68	0.11	0
2	Boardman	16344.43	5yr	1000	590.97	0.13	0
2	Boardman	16344.43	10yr	1200	591.21	0.15	0
2	Boardman	16344.43	25yr	1400	591.44	0.17	0
2	Boardman	16344.43	50yr	1600	591.59	0.19	0
2	Boardman	16344.43	100yr	1700	591.82	0.19	0
2	Boardman	16344.43	200yr	1900	592.14	0.2	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
2	Boardman	16344.43	500yr	2000	592.86	0.2	0
2	Boardman	15887.36	2yr	800	590.68	0.09	0
2	Boardman	15887.36	5yr	1000	590.97	0.11	0
2	Boardman	15887.36	10yr	1200	591.21	0.12	0
2	Boardman	15887.36	25yr	1400	591.44	0.14	0
2	Boardman	15887.36	50yr	1600	591.59	0.16	0
2	Boardman	15887.36	100yr	1700	591.82	0.16	0
2	Boardman	15887.36	200yr	1900	592.14	0.17	0
2	Boardman	15887.36	500yr	2000	592.86	0.17	0
2	Boardman	15427.05	2yr	800	590.68	0.07	0
2	Boardman	15427.05	5yr	1000	590.97	0.08	0
2	Boardman	15427.05	10yr	1200	591.21	0.1	0
2	Boardman	15427.05	25yr	1400	591.44	0.11	0
2	Boardman	15427.05	50yr	1600	591.59	0.12	0
2	Boardman	15427.05	100yr	1700	591.82	0.13	0
2	Boardman	15427.05	200yr	1900	592.14	0.14	0
2	Boardman	15427.05	500yr	2000	592.86	0.13	0
2	Boardman	14935.18	2yr	800	590.68	0.04	0
2	Boardman	14935.18	5yr	1000	590.97	0.05	0
2	Boardman	14935.18	10yr	1200	591.21	0.06	0
2	Boardman	14935.18	25yr	1400	591.44	0.06	0
2	Boardman	14935.18	50yr	1600	591.59	0.07	0
2	Boardman	14935.18	100yr	1700	591.82	0.08	0
2	Boardman	14935.18	200yr	1900	592.14	0.08	0
2	Boardman	14935.18	500yr	2000	592.86	0.08	0
2	Boardman	14425.1	2yr	800	590.68	0.02	0
2	Boardman	14425.1	5yr	1000	590.97	0.03	0
2	Boardman	14425.1	10yr	1200	591.21	0.03	0
2	Boardman	14425.1	25yr	1400	591.44	0.03	0
2	Boardman	14425.1	50yr	1600	591.59	0.04	0
2	Boardman	14425.1	100yr	1700	591.82	0.04	0
2	Boardman	14425.1	200yr	1900	592.14	0.05	0
2	Boardman	14425.1	500yr	2000	592.86	0.05	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
2	Boardman	13964.46	2yr	800	590.68	0.02	0
2	Boardman	13964.46	5yr	1000	590.97	0.02	0
2	Boardman	13964.46	10yr	1200	591.21	0.03	0
2	Boardman	13964.46	25yr	1400	591.44	0.03	0
2	Boardman	13964.46	50yr	1600	591.59	0.03	0
2	Boardman	13964.46	100yr	1700	591.82	0.04	0
2	Boardman	13964.46	200yr	1900	592.14	0.04	0
2	Boardman	13964.46	500yr	2000	592.86	0.04	0
2	Boardman	13428.4	2yr	800	590.68	0.02	0
2	Boardman	13428.4	5yr	1000	590.97	0.02	0
2	Boardman	13428.4	10yr	1200	591.21	0.02	0
2	Boardman	13428.4	25yr	1400	591.44	0.03	0
2	Boardman	13428.4	50yr	1600	591.59	0.03	0
2	Boardman	13428.4	100yr	1700	591.82	0.03	0
2	Boardman	13428.4	200yr	1900	592.14	0.04	0
2	Boardman	13428.4	500yr	2000	592.86	0.04	0
2	Boardman	12996.67	2yr	800	590.68	0.01	0
2	Boardman	12996.67	5yr	1000	590.97	0.02	0
2	Boardman	12996.67	10yr	1200	591.21	0.02	0
2	Boardman	12996.67	25yr	1400	591.44	0.02	0
2	Boardman	12996.67	50yr	1600	591.59	0.02	0
2	Boardman	12996.67	100yr	1700	591.82	0.03	0
2	Boardman	12996.67	200yr	1900	592.14	0.03	0
2	Boardman	12996.67	500yr	2000	592.86	0.03	0
2	Boardman	12517.11	2yr	800	590.68	0.01	0
2	Boardman	12517.11	5yr	1000	590.97	0.01	0
2	Boardman	12517.11	10yr	1200	591.21	0.01	0
2	Boardman	12517.11	25yr	1400	591.44	0.02	0
2	Boardman	12517.11	50yr	1600	591.59	0.02	0
2	Boardman	12517.11	100yr	1700	591.82	0.02	0
2	Boardman	12517.11	200yr	1900	592.14	0.02	0
2	Boardman	12517.11	500yr	2000	592.86	0.02	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
2	Boardman	12084.83	2yr	800	590.68	0.01	0
2	Boardman	12084.83	5yr	1000	590.97	0.01	0
2	Boardman	12084.83	10yr	1200	591.21	0.01	0
2	Boardman	12084.83	25yr	1400	591.44	0.01	0
2	Boardman	12084.83	50yr	1600	591.59	0.02	0
2	Boardman	12084.83	100yr	1700	591.82	0.02	0
2	Boardman	12084.83	200yr	1900	592.14	0.02	0
2	Boardman	12084.83	500yr	2000	592.86	0.02	0
2	Boardman	11511.48	2yr	800	590.68	0.01	0
2	Boardman	11511.48	5yr	1000	590.97	0.01	0
2	Boardman	11511.48	10yr	1200	591.21	0.01	0
2	Boardman	11511.48	25yr	1400	591.44	0.02	0
2	Boardman	11511.48	50yr	1600	591.59	0.02	0
2	Boardman	11511.48	100yr	1700	591.82	0.02	0
2	Boardman	11511.48	200yr	1900	592.14	0.02	0
2	Boardman	11511.48	500yr	2000	592.86	0.02	0
2	Boardman	11014.43	2yr	800	590.68	0.01	0
2	Boardman	11014.43	5yr	1000	590.97	0.01	0
2	Boardman	11014.43	10yr	1200	591.21	0.01	0
2	Boardman	11014.43	25yr	1400	591.44	0.02	0
2	Boardman	11014.43	50yr	1600	591.59	0.02	0
2	Boardman	11014.43	100yr	1700	591.82	0.02	0
2	Boardman	11014.43	200yr	1900	592.14	0.02	0
2	Boardman	11014.43	500yr	2000	592.86	0.02	0
1	Boardman	10530.56	2yr	800	590.68	0.01	0
1	Boardman	10530.56	5yr	1000	590.97	0.01	0
1	Boardman	10530.56	10yr	1200	591.21	0.02	0
1	Boardman	10530.56	25yr	1400	591.44	0.02	0
1	Boardman	10530.56	50yr	1600	591.59	0.02	0
1	Boardman	10530.56	100yr	1700	591.82	0.02	0
1	Boardman	10530.56	200yr	1900	592.14	0.03	0
1	Boardman	10530.56	500yr	2000	592.86	0.03	0
1	Boardman	10040.67	2yr	800	590.68	0.01	0

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	10040.67	5yr	1000	590.97	0.01	0
1	Boardman	10040.67	10yr	1200	591.21	0.02	0
1	Boardman	10040.67	25yr	1400	591.44	0.02	0
1	Boardman	10040.67	50yr	1600	591.59	0.02	0
1	Boardman	10040.67	100yr	1700	591.82	0.02	0
1	Boardman	10040.67	200yr	1900	592.14	0.02	0
1	Boardman	10040.67	500yr	2000	592.86	0.03	0
1	Boardman	9576.14	2yr	800	590.68	0.01	0
1	Boardman	9576.14	5yr	1000	590.97	0.01	0
1	Boardman	9576.14	10yr	1200	591.21	0.02	0
1	Boardman	9576.14	25yr	1400	591.44	0.02	0
1	Boardman	9576.14	50yr	1600	591.59	0.02	0
1	Boardman	9576.14	100yr	1700	591.82	0.02	0
1	Boardman	9576.14	200yr	1900	592.14	0.03	0
1	Boardman	9576.14	500yr	2000	592.86	0.03	0
1	Boardman	9070.87	2yr	800	590.68	0.05	0
1	Boardman	9070.87	5yr	1000	590.97	0.07	0
1	Boardman	9070.87	10yr	1200	591.21	0.08	0
1	Boardman	9070.87	25yr	1400	591.44	0.09	0
1	Boardman	9070.87	50yr	1600	591.59	0.1	0
1	Boardman	9070.87	100yr	1700	591.82	0.11	0
1	Boardman	9070.87	200yr	1900	592.14	0.12	0
1	Boardman	9070.87	500yr	2000	592.86	0.12	0
1	Boardman	8757.497	2yr	800	590.67	0.48	0
1	Boardman	8757.497	5yr	1000	590.96	0.58	0
1	Boardman	8757.497	10yr	1200	591.2	0.68	0.01
1	Boardman	8757.497	25yr	1400	591.43	0.78	0.01
1	Boardman	8757.497	50yr	1600	591.57	0.87	0.01
1	Boardman	8757.497	100yr	1700	591.8	0.91	0.01
1	Boardman	8757.497	200yr	1900	592.13	0.98	0.01
1	Boardman	8757.497	500yr	2000	592.84	0.97	0.01
1	Boardman	8669.233	2yr	800	590.67	0.48	0
1	Boardman	8669.233	5yr	1000	590.96	0.58	0

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	8669.233	10yr	1200	591.2	0.68	0.01
1	Boardman	8669.233	25yr	1400	591.42	0.78	0.01
1	Boardman	8669.233	50yr	1600	591.57	0.87	0.01
1	Boardman	8669.233	100yr	1700	591.8	0.91	0.01
1	Boardman	8669.233	200yr	1900	592.13	0.98	0.01
1	Boardman	8669.233	500yr	2000	592.84	0.97	0.01
	Boardman	8660.5		Bridge			
1	Boardman	8631.384	2yr	800	590.67	0.48	0.01
1	Boardman	8631.384	5yr	1000	590.96	0.58	0.01
1	Boardman	8631.384	10yr	1200	591.2	0.68	0.01
1	Boardman	8631.384	25yr	1400	591.42	0.78	0.01
1	Boardman	8631.384	50yr	1600	591.57	0.87	0.02
1	Boardman	8631.384	100yr	1700	591.8	0.91	0.02
1	Boardman	8631.384	200yr	1900	592.12	0.98	0.02
1	Boardman	8631.384	500yr	2000	592.84	0.97	0.02
1	Boardman	8236.965	2yr	800	590.66	0.69	0.01
1	Boardman	8236.965	5yr	1000	590.95	0.84	0.02
1	Boardman	8236.965	10yr	1200	591.18	0.99	0.02
1	Boardman	8236.965	25yr	1400	591.4	1.13	0.03
1	Boardman	8236.965	50yr	1600	591.54	1.27	0.03
1	Boardman	8236.965	100yr	1700	591.77	1.32	0.04
1	Boardman	8236.965	200yr	1900	592.09	1.43	0.04
1	Boardman	8236.965	500yr	2000	592.81	1.41	0.04
1	Boardman	7938.074	2yr	800	590.65	0.79	0.01
1	Boardman	7938.074	5yr	1000	590.94	0.95	0.02
1	Boardman	7938.074	10yr	1200	591.16	1.12	0.03
1	Boardman	7938.074	25yr	1400	591.38	1.28	0.03
1	Boardman	7938.074	50yr	1600	591.51	1.44	0.04
1	Boardman	7938.074	100yr	1700	591.74	1.49	0.05
1	Boardman	7938.074	200yr	1900	592.06	1.62	0.05
1	Boardman	7938.074	500yr	2000	592.78	1.59	0.05
1	Boardman	7847.033	2yr	800	590.61	1.68	0.07

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	7847.033	5yr	1000	590.87	2.03	0.09
1	Boardman	7847.033	10yr	1200	591.08	2.37	0.13
1	Boardman	7847.033	25yr	1400	591.27	2.7	0.17
1	Boardman	7847.033	50yr	1600	591.38	3.05	0.21
1	Boardman	7847.033	100yr	1700	591.6	3.15	0.22
1	Boardman	7847.033	200yr	1900	591.89	3.41	0.26
1	Boardman	7847.033	500yr	2000	592.62	3.31	0.24
	Boardman	7807.08		Bridge			
1	Boardman	7747.801	2yr	850	590.59	1.79	0.07
1	Boardman	7747.801	5yr	1100	590.84	2.24	0.12
1	Boardman	7747.801	10yr	1300	591.04	2.58	0.15
1	Boardman	7747.801	25yr	1500	591.21	2.91	0.19
1	Boardman	7747.801	50yr	1600	591.3	3.08	0.22
1	Boardman	7747.801	100yr	1800	591.52	3.37	0.26
1	Boardman	7747.801	200yr	1900	591.8	3.44	0.26
1	Boardman	7747.801	500yr	2100	592.55	3.5	0.27
1	Boardman	7507.13*	2yr	850	590.58	1.03	0.03
1	Boardman	7507.13*	5yr	1100	590.83	1.29	0.04
1	Boardman	7507.13*	10yr	1300	591.02	1.48	0.05
1	Boardman	7507.13*	25yr	1500	591.2	1.66	0.07
1	Boardman	7507.13*	50yr	1600	591.29	1.75	0.07
1	Boardman	7507.13*	100yr	1800	591.51	1.91	0.09
1	Boardman	7507.13*	200yr	1900	591.79	1.94	0.09
1	Boardman	7507.13*	500yr	2100	592.55	1.94	0.08
1	Boardman	7266.473	2yr	850	590.58	0.59	0.01
1	Boardman	7266.473	5yr	1100	590.83	0.74	0.01
1	Boardman	7266.473	10yr	1300	591.02	0.85	0.02
1	Boardman	7266.473	25yr	1500	591.19	0.95	0.02
1	Boardman	7266.473	50yr	1600	591.28	1	0.02
1	Boardman	7266.473	100yr	1800	591.5	1.09	0.03
1	Boardman	7266.473	200yr	1900	591.79	1.11	0.03
1	Boardman	7266.473	500yr	2100	592.55	1.1	0.03

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	6848.329	2yr	850	590.57	0.65	0.01
1	Boardman	6848.329	5yr	1100	590.81	0.82	0.01
1	Boardman	6848.329	10yr	1300	591	0.95	0.02
1	Boardman	6848.329	25yr	1500	591.17	1.08	0.03
1	Boardman	6848.329	50yr	1600	591.26	1.14	0.03
1	Boardman	6848.329	100yr	1800	591.47	1.26	0.03
1	Boardman	6848.329	200yr	1900	591.75	1.29	0.04
1	Boardman	6848.329	500yr	2100	592.52	1.33	0.04
1	Boardman	6487.463	2yr	850	590.56	0.54	0.01
1	Boardman	6487.463	5yr	1100	590.81	0.68	0.01
1	Boardman	6487.463	10yr	1300	590.99	0.79	0.01
1	Boardman	6487.463	25yr	1500	591.16	0.89	0.02
1	Boardman	6487.463	50yr	1600	591.25	0.94	0.02
1	Boardman	6487.463	100yr	1800	591.46	1.04	0.02
1	Boardman	6487.463	200yr	1900	591.74	1.07	0.02
1	Boardman	6487.463	500yr	2100	592.51	1.1	0.02
1	Boardman	6401.623	2yr	850	590.55	0.84	0.01
1	Boardman	6401.623	5yr	1100	590.79	1.06	0.02
1	Boardman	6401.623	10yr	1300	590.97	1.23	0.03
1	Boardman	6401.623	25yr	1500	591.13	1.41	0.04
1	Boardman	6401.623	50yr	1600	591.22	1.49	0.04
1	Boardman	6401.623	100yr	1800	591.42	1.65	0.05
1	Boardman	6401.623	200yr	1900	591.7	1.7	0.06
1	Boardman	6401.623	500yr	2100	592.46	1.78	0.06
	Boardman	6368.86		Bridge			
1	Boardman	6315.974	2yr	850	590.55	0.81	0.02
1	Boardman	6315.974	5yr	1100	590.78	1.04	0.03
1	Boardman	6315.974	10yr	1300	590.96	1.21	0.04
1	Boardman	6315.974	25yr	1500	591.11	1.38	0.06
1	Boardman	6315.974	50yr	1600	591.19	1.46	0.06
1	Boardman	6315.974	100yr	1800	591.39	1.62	0.08
1	Boardman	6315.974	200yr	1900	591.67	1.68	0.08
1	Boardman	6315.974	500yr	2100	592.42	1.76	0.09

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	6284.15*	2yr	850	590.55	0.6	0.01
1	Boardman	6284.15*	5yr	1100	590.78	0.76	0.02
1	Boardman	6284.15*	10yr	1300	590.96	0.88	0.02
1	Boardman	6284.15*	25yr	1500	591.12	1	0.03
1	Boardman	6284.15*	50yr	1600	591.2	1.06	0.04
1	Boardman	6284.15*	100yr	1800	591.4	1.18	0.04
1	Boardman	6284.15*	200yr	1900	591.68	1.21	0.05
1	Boardman	6284.15*	500yr	2100	592.43	1.26	0.05
1	Boardman	6252.33*	2yr	850	590.55	0.47	0.01
1	Boardman	6252.33*	5yr	1100	590.78	0.6	0.01
1	Boardman	6252.33*	10yr	1300	590.96	0.7	0.02
1	Boardman	6252.33*	25yr	1500	591.12	0.8	0.02
1	Boardman	6252.33*	50yr	1600	591.2	0.84	0.02
1	Boardman	6252.33*	100yr	1800	591.4	0.93	0.03
1	Boardman	6252.33*	200yr	1900	591.68	0.96	0.03
1	Boardman	6252.33*	500yr	2100	592.43	1	0.03
1	Boardman	6220.50*	2yr	850	590.55	0.41	0.01
1	Boardman	6220.50*	5yr	1100	590.78	0.51	0.01
1	Boardman	6220.50*	10yr	1300	590.96	0.6	0.01
1	Boardman	6220.50*	25yr	1500	591.12	0.68	0.01
1	Boardman	6220.50*	50yr	1600	591.2	0.72	0.02
1	Boardman	6220.50*	100yr	1800	591.4	0.8	0.02
1	Boardman	6220.50*	200yr	1900	591.68	0.82	0.02
1	Boardman	6220.50*	500yr	2100	592.43	0.85	0.02
1	Boardman	6188.686	2yr	850	590.55	0.34	0
1	Boardman	6188.686	5yr	1100	590.78	0.43	0
1	Boardman	6188.686	10yr	1300	590.96	0.5	0
1	Boardman	6188.686	25yr	1500	591.12	0.56	0.01
1	Boardman	6188.686	50yr	1600	591.2	0.6	0.01
1	Boardman	6188.686	100yr	1800	591.4	0.66	0.01
1	Boardman	6188.686	200yr	1900	591.68	0.68	0.01
1	Boardman	6188.686	500yr	2100	592.44	0.71	0.01

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	6134.35*	2yr	850	590.55	0.39	0
1	Boardman	6134.35*	5yr	1100	590.78	0.49	0.01
1	Boardman	6134.35*	10yr	1300	590.96	0.57	0.01
1	Boardman	6134.35*	25yr	1500	591.12	0.65	0.01
1	Boardman	6134.35*	50yr	1600	591.2	0.68	0.01
1	Boardman	6134.35*	100yr	1800	591.4	0.75	0.01
1	Boardman	6134.35*	200yr	1900	591.68	0.77	0.01
1	Boardman	6134.35*	500yr	2100	592.43	0.8	0.01
1	Boardman	6080.02*	2yr	850	590.55	0.46	0
1	Boardman	6080.02*	5yr	1100	590.78	0.58	0.01
1	Boardman	6080.02*	10yr	1300	590.96	0.67	0.01
1	Boardman	6080.02*	25yr	1500	591.11	0.75	0.01
1	Boardman	6080.02*	50yr	1600	591.19	0.8	0.01
1	Boardman	6080.02*	100yr	1800	591.39	0.88	0.02
1	Boardman	6080.02*	200yr	1900	591.67	0.9	0.02
1	Boardman	6080.02*	500yr	2100	592.43	0.92	0.02
	Boardman	6031		Inl Struct			
1	Boardman	6030	2yr	850	588.18	0.87	0.01
1	Boardman	6030	5yr	1100	588.94	0.95	0.01
1	Boardman	6030	10yr	1300	589.54	1.01	0.01
1	Boardman	6030	25yr	1500	590.16	1.05	0.02
1	Boardman	6030	50yr	1600	590.47	1.06	0.02
1	Boardman	6030	100yr	1800	591.13	1.08	0.02
1	Boardman	6030	200yr	1900	591.52	1.09	0.02
1	Boardman	6030	500yr	2100	592.35	1.08	0.01
1	Boardman	6025.686	2yr	850	588.11	2.03	0.06
1	Boardman	6025.686	5yr	1100	588.85	2.24	0.07
1	Boardman	6025.686	10yr	1300	589.44	2.37	0.08
1	Boardman	6025.686	25yr	1500	590.05	2.47	0.08
1	Boardman	6025.686	50yr	1600	590.37	2.51	0.09
1	Boardman	6025.686	100yr	1800	591.02	2.57	0.09
1	Boardman	6025.686	200yr	1900	591.41	2.57	0.09

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	6025.686	500yr	2100	592.24	2.57	0.08
	Boardman	5970		Culvert			
1	Boardman	5820.188	2yr	850	582.91	1.12	0.02
1	Boardman	5820.188	5yr	1100	583.68	1.31	0.02
1	Boardman	5820.188	10yr	1300	584.24	1.44	0.03
1	Boardman	5820.188	25yr	1500	584.77	1.56	0.03
1	Boardman	5820.188	50yr	1600	585.02	1.62	0.03
1	Boardman	5820.188	100yr	1800	585.5	1.73	0.04
1	Boardman	5820.188	200yr	1900	585.72	1.78	0.04
1	Boardman	5820.188	500yr	2100	586.16	1.88	0.04
1	Boardman	5810.188	2yr	850	582.9	1.34	0.03
1	Boardman	5810.188	5yr	1100	583.66	1.53	0.03
1	Boardman	5810.188	10yr	1300	584.23	1.66	0.04
1	Boardman	5810.188	25yr	1500	584.75	1.78	0.04
1	Boardman	5810.188	50yr	1600	585	1.83	0.04
1	Boardman	5810.188	100yr	1800	585.48	1.94	0.05
1	Boardman	5810.188	200yr	1900	585.71	1.99	0.05
1	Boardman	5810.188	500yr	2100	586.14	2.08	0.05
1	Boardman	5648.273	2yr	850	582.84	1.94	0.06
1	Boardman	5648.273	5yr	1100	583.59	2.15	0.07
1	Boardman	5648.273	10yr	1300	584.15	2.28	0.07
1	Boardman	5648.273	25yr	1500	584.68	2.39	0.08
1	Boardman	5648.273	50yr	1600	584.92	2.44	0.08
1	Boardman	5648.273	100yr	1800	585.4	2.52	0.09
1	Boardman	5648.273	200yr	1900	585.63	2.57	0.09
1	Boardman	5648.273	500yr	2100	586.07	2.64	0.09
1	Boardman	5618.903	2yr	850	582.85	1.74	0.04
1	Boardman	5618.903	5yr	1100	583.6	1.99	0.05
1	Boardman	5618.903	10yr	1300	584.16	2.16	0.06
1	Boardman	5618.903	25yr	1500	584.68	2.31	0.07
1	Boardman	5618.903	50yr	1600	584.93	2.38	0.07
1	Boardman	5618.903	100yr	1800	585.4	2.51	0.08

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	5618.903	200yr	1900	585.63	2.57	0.08
1	Boardman	5618.903	500yr	2100	586.07	2.68	0.09
	Boardman	5595.9		Bridge			
1	Boardman	5552.795	2yr	850	582.84	1.74	0.04
1	Boardman	5552.795	5yr	1100	583.59	1.99	0.05
1	Boardman	5552.795	10yr	1300	584.15	2.16	0.06
1	Boardman	5552.795	25yr	1500	584.67	2.31	0.07
1	Boardman	5552.795	50yr	1600	584.91	2.38	0.07
1	Boardman	5552.795	100yr	1800	585.39	2.51	0.08
1	Boardman	5552.795	200yr	1900	585.61	2.58	0.08
1	Boardman	5552.795	500yr	2100	586.05	2.69	0.09
1	Boardman	5524.195	2yr	850	582.82	1.95	0.06
1	Boardman	5524.195	5yr	1100	583.57	2.16	0.07
1	Boardman	5524.195	10yr	1300	584.13	2.29	0.08
1	Boardman	5524.195	25yr	1500	584.65	2.4	0.08
1	Boardman	5524.195	50yr	1600	584.9	2.45	0.08
1	Boardman	5524.195	100yr	1800	585.38	2.54	0.09
1	Boardman	5524.195	200yr	1900	585.6	2.58	0.09
1	Boardman	5524.195	500yr	2100	586.04	2.66	0.09
1	Boardman	5027.329	2yr	850	582.63	2.63	0.11
1	Boardman	5027.329	5yr	1100	583.36	2.94	0.13
1	Boardman	5027.329	10yr	1300	583.9	3.15	0.14
1	Boardman	5027.329	25yr	1500	584.41	3.34	0.16
1	Boardman	5027.329	50yr	1600	584.65	3.42	0.16
1	Boardman	5027.329	100yr	1800	585.12	3.57	0.17
1	Boardman	5027.329	200yr	1900	585.34	3.64	0.18
1	Boardman	5027.329	500yr	2100	585.77	3.77	0.19
1	Boardman	4385.854	2yr	850	582.49	2.07	0.06
1	Boardman	4385.854	5yr	1100	583.2	2.36	0.08
1	Boardman	4385.854	10yr	1300	583.73	2.56	0.09
1	Boardman	4385.854	25yr	1500	584.23	2.72	0.1
1	Boardman	4385.854	50yr	1600	584.47	2.8	0.11

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	4385.854	100yr	1800	584.93	2.93	0.12
1	Boardman	4385.854	200yr	1900	585.16	2.98	0.12
1	Boardman	4385.854	500yr	2100	585.59	3.07	0.13
1	Boardman	4113.364	2yr	850	582.17	4.07	0.28
1	Boardman	4113.364	5yr	1100	582.84	4.44	0.32
1	Boardman	4113.364	10yr	1300	583.34	4.69	0.34
1	Boardman	4113.364	25yr	1500	583.81	4.91	0.37
1	Boardman	4113.364	50yr	1600	584.03	5.02	0.38
1	Boardman	4113.364	100yr	1800	584.47	5.21	0.4
1	Boardman	4113.364	200yr	1900	584.68	5.31	0.41
1	Boardman	4113.364	500yr	2100	585.09	5.48	0.43
1	Boardman	4047.066	2yr	850	582.07	4.23	0.3
1	Boardman	4047.066	5yr	1100	582.74	4.61	0.33
1	Boardman	4047.066	10yr	1300	583.24	4.88	0.36
1	Boardman	4047.066	25yr	1500	583.71	5.13	0.39
1	Boardman	4047.066	50yr	1600	583.93	5.25	0.4
1	Boardman	4047.066	100yr	1800	584.36	5.46	0.42
1	Boardman	4047.066	200yr	1900	584.57	5.57	0.43
1	Boardman	4047.066	500yr	2100	584.98	5.76	0.45
	Boardman	4029.47		Bridge			
1	Boardman	3972.369	2yr	850	581.94	4.39	0.32
1	Boardman	3972.369	5yr	1100	582.62	4.76	0.36
1	Boardman	3972.369	10yr	1300	583.11	5.02	0.38
1	Boardman	3972.369	25yr	1500	583.58	5.26	0.41
1	Boardman	3972.369	50yr	1600	583.81	5.37	0.42
1	Boardman	3972.369	100yr	1800	584.24	5.59	0.44
1	Boardman	3972.369	200yr	1900	584.45	5.69	0.45
1	Boardman	3972.369	500yr	2100	584.85	5.89	0.48
1	Boardman	3906.538	2yr	850	581.81	4.52	0.35
1	Boardman	3906.538	5yr	1100	582.5	4.82	0.38
1	Boardman	3906.538	10yr	1300	583.01	5.04	0.4
1	Boardman	3906.538	25yr	1500	583.49	5.24	0.42

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	3906.538	50yr	1600	583.72	5.33	0.43
1	Boardman	3906.538	100yr	1800	584.16	5.51	0.45
1	Boardman	3906.538	200yr	1900	584.37	5.6	0.46
1	Boardman	3906.538	500yr	2100	584.78	5.77	0.48
1	Boardman	3617.274	2yr	850	581.67	3.01	0.14
1	Boardman	3617.274	5yr	1100	582.36	3.39	0.17
1	Boardman	3617.274	10yr	1300	582.87	3.64	0.19
1	Boardman	3617.274	25yr	1500	583.35	3.86	0.21
1	Boardman	3617.274	50yr	1600	583.58	3.96	0.22
1	Boardman	3617.274	100yr	1800	584.02	4.15	0.24
1	Boardman	3617.274	200yr	1900	584.23	4.24	0.25
1	Boardman	3617.274	500yr	2100	584.64	4.4	0.27
1	Boardman	3161.758	2yr	850	581.48	2.79	0.12
1	Boardman	3161.758	5yr	1100	582.15	3.15	0.15
1	Boardman	3161.758	10yr	1300	582.64	3.39	0.17
1	Boardman	3161.758	25yr	1500	583.11	3.6	0.19
1	Boardman	3161.758	50yr	1600	583.34	3.7	0.19
1	Boardman	3161.758	100yr	1800	583.78	3.87	0.21
1	Boardman	3161.758	200yr	1900	583.99	3.95	0.22
1	Boardman	3161.758	500yr	2100	584.39	4.1	0.23
1	Boardman	3041.044	2yr	850	581.32	3.62	0.21
1	Boardman	3041.044	5yr	1100	581.96	4.06	0.26
1	Boardman	3041.044	10yr	1300	582.44	4.34	0.29
1	Boardman	3041.044	25yr	1500	582.89	4.59	0.32
1	Boardman	3041.044	50yr	1600	583.11	4.71	0.33
1	Boardman	3041.044	100yr	1800	583.53	4.92	0.35
1	Boardman	3041.044	200yr	1900	583.73	5.02	0.36
1	Boardman	3041.044	500yr	2100	584.13	5.2	0.39
	Boardman	3006.45		Bridge			
1	Boardman	2966.444	2yr	850	581.19	3.73	0.23
1	Boardman	2966.444	5yr	1100	581.81	4.18	0.27
1	Boardman	2966.444	10yr	1300	582.28	4.48	0.31

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	2966.444	25yr	1500	582.73	4.74	0.34
1	Boardman	2966.444	50yr	1600	582.94	4.85	0.35
1	Boardman	2966.444	100yr	1800	583.36	5.07	0.38
1	Boardman	2966.444	200yr	1900	583.56	5.17	0.39
1	Boardman	2966.444	500yr	2100	583.95	5.35	0.41
1	Boardman	2849.621	2yr	850	581.16	2.99	0.14
1	Boardman	2849.621	5yr	1100	581.79	3.38	0.17
1	Boardman	2849.621	10yr	1300	582.26	3.65	0.2
1	Boardman	2849.621	25yr	1500	582.71	3.87	0.22
1	Boardman	2849.621	50yr	1600	582.93	3.97	0.23
1	Boardman	2849.621	100yr	1800	583.35	4.16	0.24
1	Boardman	2849.621	200yr	1900	583.55	4.24	0.25
1	Boardman	2849.621	500yr	2100	583.94	4.4	0.27
1	Boardman	2638.419	2yr	850	581.11	2.4	0.09
1	Boardman	2638.419	5yr	1100	581.73	2.74	0.11
1	Boardman	2638.419	10yr	1300	582.2	2.97	0.13
1	Boardman	2638.419	25yr	1500	582.65	3.18	0.15
1	Boardman	2638.419	50yr	1600	582.87	3.27	0.15
1	Boardman	2638.419	100yr	1800	583.29	3.45	0.17
1	Boardman	2638.419	200yr	1900	583.49	3.53	0.17
1	Boardman	2638.419	500yr	2100	583.89	3.69	0.19
1	Boardman	2592.456	2yr	850	581.1	2.39	0.09
1	Boardman	2592.456	5yr	1100	581.72	2.72	0.11
1	Boardman	2592.456	10yr	1300	582.19	2.95	0.13
1	Boardman	2592.456	25yr	1500	582.64	3.15	0.14
1	Boardman	2592.456	50yr	1600	582.85	3.24	0.15
1	Boardman	2592.456	100yr	1800	583.27	3.41	0.16
1	Boardman	2592.456	200yr	1900	583.48	3.5	0.17
1	Boardman	2592.456	500yr	2100	583.87	3.65	0.18
	Boardman	2588.94		Bridge			
1	Boardman	2580.448	2yr	850	581.09	2.39	0.09
1	Boardman	2580.448	5yr	1100	581.71	2.73	0.11

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	2580.448	10yr	1300	582.18	2.95	0.13
1	Boardman	2580.448	25yr	1500	582.63	3.15	0.14
1	Boardman	2580.448	50yr	1600	582.84	3.25	0.15
1	Boardman	2580.448	100yr	1800	583.26	3.42	0.16
1	Boardman	2580.448	200yr	1900	583.46	3.5	0.17
1	Boardman	2580.448	500yr	2100	583.86	3.66	0.18
1	Boardman	2539.875	2yr	850	581.07	2.41	0.09
1	Boardman	2539.875	5yr	1100	581.69	2.75	0.11
1	Boardman	2539.875	10yr	1300	582.16	2.98	0.13
1	Boardman	2539.875	25yr	1500	582.6	3.19	0.15
1	Boardman	2539.875	50yr	1600	582.82	3.29	0.15
1	Boardman	2539.875	100yr	1800	583.24	3.46	0.17
1	Boardman	2539.875	200yr	1900	583.44	3.55	0.18
1	Boardman	2539.875	500yr	2100	583.83	3.71	0.19
1	Boardman	2334.211	2yr	850	580.78	4.03	0.27
1	Boardman	2334.211	5yr	1100	581.33	4.59	0.34
1	Boardman	2334.211	10yr	1300	581.75	4.96	0.38
1	Boardman	2334.211	25yr	1500	582.15	5.29	0.43
1	Boardman	2334.211	50yr	1600	582.35	5.44	0.45
1	Boardman	2334.211	100yr	1800	582.73	5.72	0.49
1	Boardman	2334.211	200yr	1900	582.91	5.85	0.5
1	Boardman	2334.211	500yr	2100	583.27	6.1	0.54
1	Boardman	2289.212	2yr	850	580.79	3.45	0.17
1	Boardman	2289.212	5yr	1100	581.34	4.06	0.23
1	Boardman	2289.212	10yr	1300	581.75	4.48	0.28
1	Boardman	2289.212	25yr	1500	582.15	4.87	0.32
1	Boardman	2289.212	50yr	1600	582.34	5.05	0.34
1	Boardman	2289.212	100yr	1800	582.72	5.4	0.38
1	Boardman	2289.212	200yr	1900	582.9	5.56	0.4
1	Boardman	2289.212	500yr	2100	583.24	5.88	0.44
	Boardman	2270.56		Bridge			
1	Boardman	2246.92	2yr	850	580.77	3.46	0.17

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	2246.92	5yr	1100	581.31	4.08	0.23
1	Boardman	2246.92	10yr	1300	581.72	4.51	0.28
1	Boardman	2246.92	25yr	1500	582.12	4.9	0.32
1	Boardman	2246.92	50yr	1600	582.31	5.08	0.34
1	Boardman	2246.92	100yr	1800	582.68	5.43	0.39
1	Boardman	2246.92	200yr	1900	582.85	5.59	0.41
1	Boardman	2246.92	500yr	2100	583.2	5.91	0.45
1	Boardman	2244.046	2yr	850	580.68	4.11	0.28
1	Boardman	2244.046	5yr	1100	581.21	4.7	0.35
1	Boardman	2244.046	10yr	1300	581.62	5.08	0.4
1	Boardman	2244.046	25yr	1500	582.02	5.41	0.45
1	Boardman	2244.046	50yr	1600	582.22	5.57	0.47
1	Boardman	2244.046	100yr	1800	582.59	5.85	0.51
1	Boardman	2244.046	200yr	1900	582.77	5.98	0.53
1	Boardman	2244.046	500yr	2100	583.13	6.23	0.57
1	Boardman	2005.013	2yr	850	580.61	3.01	0.13
1	Boardman	2005.013	5yr	1100	581.12	3.54	0.18
1	Boardman	2005.013	10yr	1300	581.52	3.91	0.22
1	Boardman	2005.013	25yr	1500	581.91	4.23	0.25
1	Boardman	2005.013	50yr	1600	582.1	4.38	0.27
1	Boardman	2005.013	100yr	1800	582.47	4.65	0.3
1	Boardman	2005.013	200yr	1900	582.66	4.78	0.31
1	Boardman	2005.013	500yr	2100	583	5.03	0.34
1	Boardman	1958.548	2yr	850	580.59	3.03	0.14
1	Boardman	1958.548	5yr	1100	581.09	3.57	0.18
1	Boardman	1958.548	10yr	1300	581.49	3.93	0.22
1	Boardman	1958.548	25yr	1500	581.88	4.26	0.25
1	Boardman	1958.548	50yr	1600	582.07	4.41	0.27
1	Boardman	1958.548	100yr	1800	582.43	4.69	0.3
1	Boardman	1958.548	200yr	1900	582.61	4.82	0.32
1	Boardman	1958.548	500yr	2100	582.96	5.06	0.34
	Boardman	1955.88		Bridge			

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	1948.237	2yr	850	580.58	3.03	0.14
1	Boardman	1948.237	5yr	1100	581.08	3.57	0.18
1	Boardman	1948.237	10yr	1300	581.48	3.94	0.22
1	Boardman	1948.237	25yr	1500	581.86	4.27	0.26
1	Boardman	1948.237	50yr	1600	582.05	4.42	0.27
1	Boardman	1948.237	100yr	1800	582.42	4.7	0.3
1	Boardman	1948.237	200yr	1900	582.6	4.83	0.32
1	Boardman	1948.237	500yr	2100	582.94	5.08	0.35
1	Boardman	1902.016	2yr	850	580.56	3.04	0.14
1	Boardman	1902.016	5yr	1100	581.06	3.58	0.19
1	Boardman	1902.016	10yr	1300	581.45	3.96	0.22
1	Boardman	1902.016	25yr	1500	581.83	4.29	0.26
1	Boardman	1902.016	50yr	1600	582.02	4.44	0.27
1	Boardman	1902.016	100yr	1800	582.38	4.72	0.31
1	Boardman	1902.016	200yr	1900	582.56	4.85	0.32
1	Boardman	1902.016	500yr	2100	582.9	5.1	0.35
1	Boardman	1606.955	2yr	850	580.32	3.66	0.21
1	Boardman	1606.955	5yr	1100	580.74	4.32	0.29
1	Boardman	1606.955	10yr	1300	581.08	4.77	0.35
1	Boardman	1606.955	25yr	1500	581.41	5.16	0.4
1	Boardman	1606.955	50yr	1600	581.58	5.34	0.43
1	Boardman	1606.955	100yr	1800	581.91	5.67	0.47
1	Boardman	1606.955	200yr	1900	582.07	5.83	0.5
1	Boardman	1606.955	500yr	2100	582.38	6.12	0.54
1	Boardman	1583.948	2yr	850	580.33	3.21	0.16
1	Boardman	1583.948	5yr	1100	580.77	3.8	0.21
1	Boardman	1583.948	10yr	1300	581.11	4.2	0.26
1	Boardman	1583.948	25yr	1500	581.46	4.56	0.3
1	Boardman	1583.948	50yr	1600	581.63	4.72	0.32
1	Boardman	1583.948	100yr	1800	581.96	5.02	0.35
1	Boardman	1583.948	200yr	1900	582.12	5.16	0.37
1	Boardman	1583.948	500yr	2100	582.44	5.43	0.4
1	Boardman	1561.446	2yr	850	580.26	3.72	0.22

HSI	Reach	River Sta	Profile	Q Total	W.S. Elev	Vel Chnl	Shear Chan
Segment				(cfs)	(ft)	(ft/s)	lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	1561.446	5yr	1100	580.66	4.41	0.3
1	Boardman	1561.446	10yr	1300	580.98	4.88	0.36
1	Boardman	1561.446	25yr	1500	581.31	5.28	0.42
1	Boardman	1561.446	50yr	1600	581.47	5.47	0.45
1	Boardman	1561.446	100yr	1800	581.78	5.81	0.5
1	Boardman	1561.446	200yr	1900	581.94	5.98	0.52
1	Boardman	1561.446	500yr	2100	582.24	6.28	0.57
	Boardman	1535.8		Bridge			
1	Boardman	1505.25	2yr	850	580.2	3.77	0.23
1	Boardman	1505.25	5yr	1100	580.59	4.48	0.31
1	Boardman	1505.25	10yr	1300	580.9	4.96	0.38
1	Boardman	1505.25	25yr	1500	581.21	5.38	0.44
1	Boardman	1505.25	50yr	1600	581.36	5.58	0.47
1	Boardman	1505.25	100yr	1800	581.67	5.93	0.52
1	Boardman	1505.25	200yr	1900	581.82	6.1	0.55
1	Boardman	1505.25	500yr	2100	582.11	6.41	0.6
1	Boardman	915.252	2yr	850	579.77	3.25	0.17
1	Boardman	915.252	5yr	1100	579.99	3.99	0.25
1	Boardman	915.252	10yr	1300	580.18	4.5	0.32
1	Boardman	915.252	25yr	1500	580.39	4.94	0.38
1	Boardman	915.252	50yr	1600	580.51	5.14	0.41
1	Boardman	915.252	100yr	1800	580.75	5.49	0.46
1	Boardman	915.252	200yr	1900	580.87	5.64	0.49
1	Boardman	915.252	500yr	2100	581.12	5.92	0.53
1	Boardman	332.257	2yr	850	579.43	2.88	0.13
1	Boardman	332.257	5yr	1100	579.44	3.72	0.22
1	Boardman	332.257	10yr	1300	579.45	4.38	0.31
1	Boardman	332.257	25yr	1500	579.47	5.03	0.41
1	Boardman	332.257	50yr	1600	579.48	5.36	0.46
1	Boardman	332.257	100yr	1800	579.5	5.99	0.58
1	Boardman	332.257	200yr	1900	579.51	6.31	0.64
1	Boardman	332.257	500yr	2100	579.54	6.93	0.77

HSI Segment	Reach	River Sta	Profile	Q Total (cfs)	W.S. Elev (ft)	Vel Chnl (ft/s)	Shear Chan lb/ft2
5	Boardman	43013.5	2yr	750	664.78	4.08	0.6
5	Boardman	43013.5	5yr	950	665.16	4.32	0.64
5	Boardman	43013.5	10yr	1100	665.4	4.53	0.68
1	Boardman	146.48	2yr	850	579.42	2.03	0.06
1	Boardman	146.48	5yr	1100	579.42	2.63	0.1
1	Boardman	146.48	10yr	1300	579.42	3.1	0.14
1	Boardman	146.48	25yr	1500	579.43	3.58	0.19
1	Boardman	146.48	50yr	1600	579.43	3.81	0.22
1	Boardman	146.48	100yr	1800	579.44	4.28	0.27
1	Boardman	146.48	200yr	1900	579.44	4.52	0.3
1	Boardman	146.48	500yr	2100	579.45	4.99	0.37
	Boardman	101.1		Bridge			
1	Boardman	56.212	2yr	850	579.4	2.04	0.06
1	Boardman	56.212	5yr	1100	579.39	2.64	0.1
1	Boardman	56.212	10yr	1300	579.38	3.12	0.14
1	Boardman	56.212	25yr	1500	579.37	3.61	0.19
1	Boardman	56.212	50yr	1600	579.36	3.86	0.22
1	Boardman	56.212	100yr	1800	579.35	4.35	0.28
1	Boardman	56.212	200yr	1900	579.34	4.59	0.31
1	Boardman	56.212	500yr	2100	579.33	5.09	0.39
1	Boardman	0.007	2yr	850	579.41	1.52	0.03
1	Boardman	0.007	5yr	1100	579.41	1.96	0.06
1	Boardman	0.007	10yr	1300	579.41	2.32	0.08
1	Boardman	0.007	25yr	1500	579.41	2.68	0.1
1	Boardman	0.007	50yr	1600	579.41	2.85	0.12
1	Boardman	0.007	100yr	1800	579.41	3.21	0.15
1	Boardman	0.007	200yr	1900	579.41	3.39	0.16
1	Boardman	0.007	500yr	2100	579.41	3.75	0.2

US Army Corps
of Engineers
Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

CITY OF TRAVERSE CITY AND GRAND TRAVERSE COUNTY, MICHIGAN

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

ATTACHMENT 2

FEASIBILITY STUDY COST LEVEL ESTIMATES

US Army Engineer District, Detroit
477 Michigan Avenue
Detroit, MI 48226-2523

Conceptual River Restoration Boardman River - Union Street Dam
Dam Modification Measures
Date: 10/9/2012

Item No.	Description	Estimated Quantity	Units		Unit Cost		Total Cost
DOWNSTREAM FISH PASSAGE							
1.	Demolition of Existing Auxillary Spillway	200	CY	$	60	$	12,000
2.	Structural Concrete / cast in place	200	CY	$	500	$	100,000
3.	48" Culvert	300	LF	$	200	$	60,000
4.	Gate	1	EA	$	50,000	$	50,000
5.	Earthworks	1500	CY	$	10	$	15,000
6.	Site Clearing	0.5	AC	$	7,500	$	3,750
7.	Fencing / Railings	60	LF	$	15	$	900
UPSTREAM FISH PASSAGE							
8.	Steel Framing	0.32	Tons	$	5,000	$	1,600
9.	Metal Deck	32	SF	$	25	$	800
10.	Mechanical Lift	1	LS	$	170,000	$	170,000
INCIDENTAL CONSTRUCTION AND REVEGETATION							
11.	Construction Office	4	Month	$	750	$	3,000
12.	Temporary Construction Entrance	2	EA	$	2,000	$	4,000
13.	Temporary Sheet Piling	720	SF	$	25	$	18,000
14.	Sheet Pile Mobilization	1	LS	$	10,000	$	10,000
15.	Erosion Control	0.5	AC	$	2,000	$	1,000
16.	6" Topsoil (furnished)	0.5	AC	$	7,000	$	3,500
17.	Seeding and Restoration	0.5	AC	$	1,500	$	750
18.	Signage	1	Lump Sum	$	5,500	$	5,500
	Total Construction Cost					**$**	**459,800**
	Estimated Engineering Costs (20%)					$	91,960
	Estimated Administration Costs (5%)					$	22,990
	Subtotal Project Cost					**$**	**574,750**
	Contingency (20%)					$	114,950
	Total Estimated Project Cost					**$**	**689,700**

Conceptual River Restoration Boardman River - Sabin Dam
Dam Modification Measures
Date: 7/2/2012

Item No.	Description	Estimated Quantity	Units		Unit Cost		Total Cost
DOWNSTREAM FISH PASSAGE							
1.	Site Clearing	3.2	AC	$	7,500	$	24,000
2.	Structural Concrete / cast in place	3750	CY	$	500	$	1,875,000
3.	Natural Substrate (various sized cobble)	695	CY	$	30	$	20,850
4.	Gate	1	EA	$	50,000	$	50,000
5.	Earthworks	36300	CY	$	10	$	363,000
6.	Fencing / Railings	2500	LF	$	15	$	37,500
UPSTREAM PASSAGE - FISH ELEVATOR							
7.	Steel Framing	8	Tons	$	5,000	$	40,000
8.	Metal Decking	800	SF	$	25	$	20,000
9.	Structural Concrete	29	CY	$	650	$	18,850
9.	Tremie Concrete	97	CY	$	200	$	19,400
10.	Foundation Piles	600	LF	$	50	$	30,000
11.	Cofferdam	1	Lump Sum	$	100,000	$	100,000
12.	Mechanical Lift	1	Lump Sum	$	180,000	$	180,000
UPSTREAM PASSAGE - SLUICEWAY							
13.	Structural Concrete	320	CY	$	650	$	208,000
14.	Tremie Concrete	135	CY	$	200	$	27,000
15.	Foundation Piles	1500	LF	$	50	$	75,000
INCIDENTAL CONSTRUCTION AND REVEGETATION							
16.	Construction Office	4	Month	$	750	$	3,000
17.	Temporary Construction Entrance	1	EA	$	2,000	$	2,000
18.	Pile Driving Mobilization	1	Lump Sum	$	10,000	$	10,000
19.	Erosion Control	4	AC	$	2,000	$	8,000
20.	Seeding and Restoration	4	AC	$	1,500	$	6,000
21.	Signage	1	Lump Sum	$	5,500	$	5,500
	Total Construction Cost					**$**	**3,123,100**
	Estimated Engineering Costs (20%)					$	624,620
	Estimated Administration Costs (5%)					$	156,155
	Subtotal Project Cost					**$**	**3,903,875**
	Contingency (20%)					$	780,775
	Total Estimated Project Cost					**$**	**4,684,650**

Conceptual River Restoration Boardman River - Boardman Dam
Dam Modification Measures
Date: 7/2/2012

Item No.	Description	Estimated Quantity	Units		Unit Cost		Total Cost
DOWNSTREAM FISH PASSAGE							
1.	Site Clearing	4	AC	$	7,500	$	30,000
2.	Structural Concrete / cast in place	7875	CY	$	500	$	3,937,500
3.	Natural Substrate (various sized cobble)	1170	CY	$	30	$	35,100
4.	Gate	1	EA	$	50,000	$	50,000
5.	Earthworks	60980	CY	$	10	$	609,800
6.	Fencing / Railings	4200	LF	$	15	$	63,000
7.	Cass Road Culvert	1	Lump Sum	$	300,000	$	300,000
UPSTREAM PASSAGE - FISH ELEVATOR							
8.	Steel Framing	12	Tons	$	5,000	$	60,000
9.	Metal Decking	1200	SF	$	25	$	30,000
10.	Structural Concrete	29	CY	$	650	$	18,850
10.	Tremie Concrete	139	CY	$	200	$	27,800
11.	Foundation Piles	720	LF	$	50	$	36,000
12.	Cofferdam	1	Lump Sum	$	100,000	$	100,000
13.	Mechanical Lift	1	Lump Sum	$	210,000	$	210,000
UPSTREAM PASSAGE - SLUICEWAY							
14.	Structural Concrete	766	CY	$	650	$	497,900
15.	Tremie Concrete	274	CY	$	200	$	54,800
16.	Foundation Piles	2160	LF	$	50	$	108,000
INCIDENTAL CONSTRUCTION AND REVEGETATION							
17.	Construction Office	4	Month	$	750	$	3,000
18.	Temporary Construction Entrance	1	EA	$	2,000	$	2,000
19.	Pile Driving Mobilization	1	Lump Sum	$	10,000	$	10,000
20.	Erosion Control	4	AC	$	2,000	$	8,000
21.	Seeding and Restoration	4	AC	$	1,500	$	6,000
22.	Signage	1	Lump Sum	$	5,500	$	5,500
	Total Construction Cost					**$**	**6,203,250**
	Estimated Engineering Costs (20%)					$	1,240,650
	Estimated Administration Costs (5%)					$	310,163
	Subtotal Project Cost					**$**	**7,754,063**
	Contingency (20%)					$	1,550,813
	Total Estimated Project Cost					**$**	**9,304,875**

Conceptual River Restoration Boardman River - Sabin Dam
Alternative 1: Dam Removal / Breach Plan
Date: 10/9/2012

Item No.	Description	Estimated Quantity	Units	Unit Cost	Total Cost
EARTHWORKS AND SITE PREPARATION					
1.	Site Clearing	5	AC	$ 7,500	$ 37,500
2.	Channel Bottom Dredging	200	CY	$ 15	$ 3,000
3.	Floodplain and Dry Channel Excavation	26800	CY	$ 10	$ 268,000
4.	Dam Excavation	20000	CY	$ 8	$ 160,000
5.	Embankment Earth (Engineered Fill)	0	CY	$ 5	$ -
6.	2" Topsoil (salvaged)	20	AC	$ 7,000	$ 140,000
7.	6" Topsoil (furnished)	0	AC	$ 14,000	$ -
8.	Sediment Trap Cleaning	47800	CY	$ 10	$ 478,000
STREAM RESTORATION					
9.	Bank Stabilization (As Needed)	600	LF	$ 50	$ 30,000
10.	Rock Cross Vanes		CY	$ 90	$ -
11.	Rock W Weirs		CY	$ 90	$ -
12.	J Hook Vanes		CY	$ 90	$ -
13.	Engineered Riffle	1340	SY	$ 50	$ 67,000
DAM REMOVAL					
13.	Breach Dam	1	Lump Sum	$ 100,000	$ 100,000
14.	Remove Spillway	1	Lump Sum	$ 150,000	$ 150,000
INCIDENTAL CONSTRUCTION AND REVEGETATION					
15.	Construction Office	4	Month	$ 750	$ 3,000
16.	Temporary Construction Entrance	1	EA	$ 2,000	$ 2,000
17.	Temporary Stream Crossing / Ford	2	EA	$ 3,000	$ 6,000
18.	Temporary Haul Road	8000	LF	$ 20	$ 160,000
17.	Erosion Control	10000	SY	$ 5	$ 50,000
18.	Temporary Seeding	5	AC	$ 125	$ 625
19.	Permanent Seeding	10	AC	$ 1,500	$ 15,000
20.	Live Staking and Plantings	1	AC	$ 12,000	$ 12,000
21.	Signage	1	Lump Sum	$ 5,500	$ 5,500
	Total Construction Cost				**$ 1,687,625**
	Estimated Engineering Costs (20%)				$ 337,525
	Estimated Administration Costs (5%)				$ 84,381
	Subtotal Project Cost				**$ 2,109,531**
	Contingency (20%)				$ 421,906
	Total Estimated Project Cost				**$ 2,531,438**

Conceptual River Restoration Boardman River - Boardman Dam
Alternative 1: Dam Removal / Breach Plan
Date: 1/6/2014

Item No.	Description	Estimated Quantity	Units	Unit Cost	Total Cost
EARTHWORKS AND SITE PREPARATION					
1.	Site Clearing	5	AC	$7,500	$37,500
2.	Channel Bottom Dredging	1000	CY	$15	$15,000
3.	Floodplain and Dry Channel Excavation	42400	CY	$10	$424,000
4.	Road & Dam Excavation	58400	CY	$8	$467,200
5.	Embankment Earth (Fill for Cass Rd and Bridge)	20000	CY	$5	$100,000
6.	2" Topsoil (salvaged)	100	AC	$7,000	$700,000
7.	6" Topsoil (furnished)	0	AC	$14,000	$0
8.	Sediment Trap Cleaning	85600	CY	$10	$856,000
STREAM RESTORATION					
9.	Bank Stabilization (As Needed)	1000	LF	$50	$50,000
10.	Rock Cross Vanes	0	CY	$90	$0
11.	Rock W Weirs	0	CY	$90	$0
12.	Step Pools	0	CY	$90	$0
13.	J Hook Vanes	0	CY	$90	$0
14.	Engineered Riffle	1340	SY	$50	$67,000
DAM REMOVAL					
15.	Breach Embankment	1	Lump Sum	$790,000	$790,000
	Breaching Operation	$ 30,000			
	Core Wall Demo	$ 60,000			
	ArmorFlex Matting	$ 100,000			
	Bypass Pumping	$ 600,000			
16.	Remove Powerhouse and appurtenances	0	Lump Sum	$680,000	$0
17.	Remove Cass Street Bridge	0	Lump Sum	$200,000	$0
18.	Proposed Cass Street Crossing	0	LS	$1,173,915	$0
19.	Cass Street Reconstruction	0	LF	$150	$0
INCIDENTAL CONSTRUCTION AND REVEGETATION					
20.	Construction Office	4	Month	$750	$3,000
21.	Temporary Construction Entrance	1	EA	$2,000	$2,000
22.	Temporary Stream Crossing / Ford	2	EA	$3,000	$6,000
23.	Temporary Haul Road	10000	LF	$20	$200,000
22.	Erosion Control	20000	SY	$5	$100,000
23.	Temporary Seeding	10	AC	$125	$1,250
24.	Permanent Seeding	25	AC	$1,500	$37,500
25.	Live Staking and Plantings	2	AC	$12,000	$24,000
26.	Signage	1	Lump Sum	$5,500	$5,500
	Total Construction Cost				$3,885,950
	Estimated Engineering Costs (20%)				$777,190
	Estimated Administration Costs (5%)				$194,298
	Subtotal Project Cost				$4,857,438
	Contingency (20%)				$971,488
	Total Estimated Project Cost				$5,828,925

US Army Corps
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Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

CITY OF TRAVERSE CITY AND GRAND TRAVERSE COUNTY, MICHIGAN

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

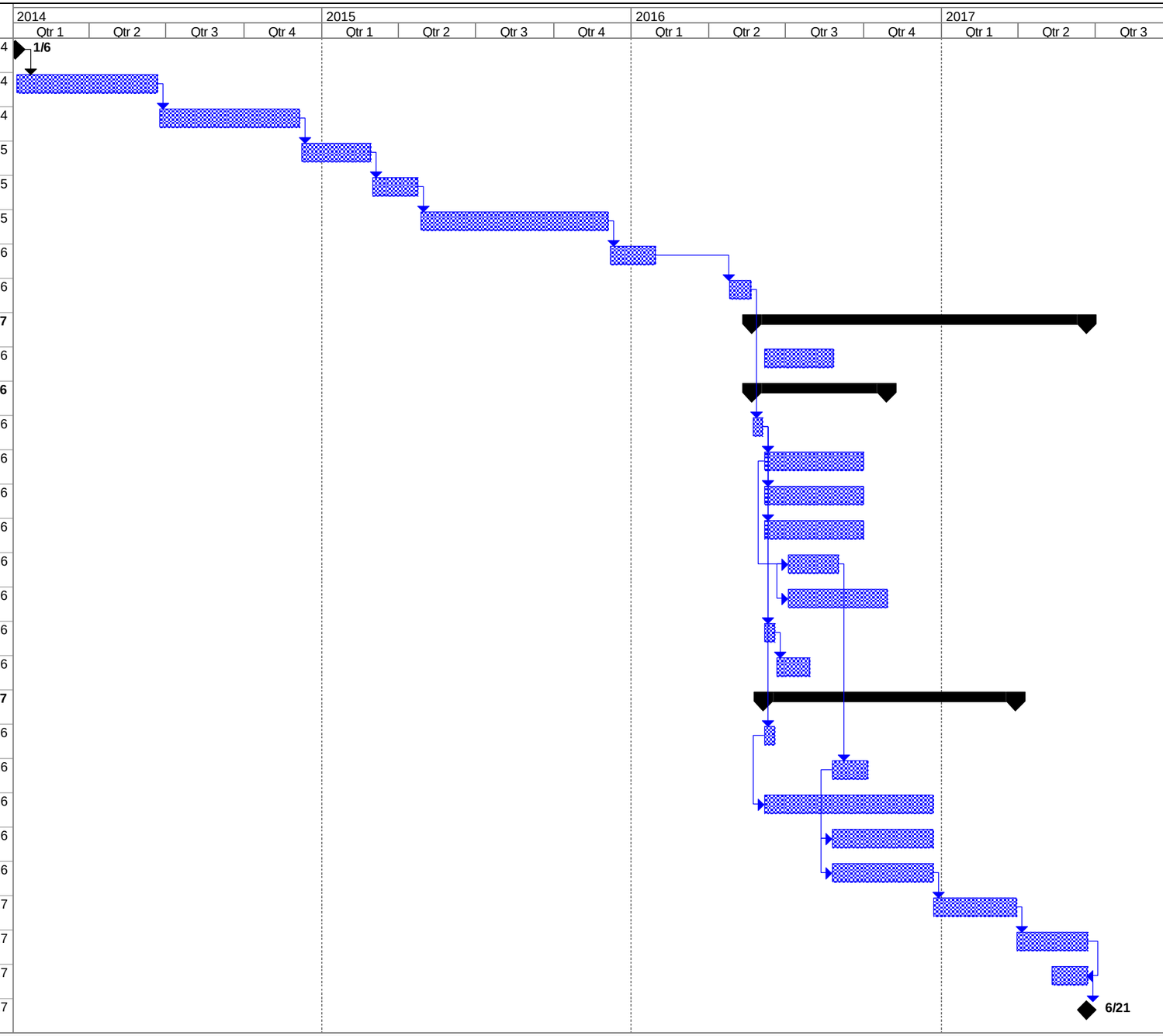
ATTACHMENT 3

DESIGN AND CONSTRUCTION SCHEDULE

US Army Engineer District, Detroit
477 Michigan Avenue
Detroit, MI 48226-2523

BOARDMAN RIVER FEASIBILITY STUDY
DESIGN/CONSTRUCTION SCHEDULE

ID		Task Name	Duration	Start	Finish
1		Final LDR Approval	0 days	Mon 1/6/14	Mon 1/6/14
2		Preliminary Engineering Design	6 mons	Mon 1/6/14	Fri 6/20/14
3		Development of Plans and Specs	6 mons	Mon 6/23/14	Fri 12/5/14
4		Design Documentation Report (DDR)	3 mons	Mon 12/8/14	Fri 2/27/15
5		ITR Review of DDR	2 mons	Mon 3/2/15	Fri 4/24/15
6		Easement Acquisition	8 mons	Mon 4/27/15	Fri 12/4/15
7		Bidding / Award	2 mons	Mon 12/7/15	Fri 1/29/16
8		Mobilization	20 days	Mon 4/25/16	Fri 5/20/16
9		**Construction**	**283 days**	**Mon 5/23/16**	**Wed 6/21/17**
10		**Union Street Dam Modifications**	60 days	Mon 6/6/16	Fri 8/26/16
11		**Boardman Dam**	**115 days**	**Mon 5/23/16**	**Fri 10/28/16**
12		Clearing and Erosion Control	10 days	Mon 5/23/16	Fri 6/3/16
13		Cass Road Bridge Construction	85 days	Mon 6/6/16	Fri 9/30/16
14		Sediment Trap/Sediment Mgmt.	85 days	Mon 6/6/16	Fri 9/30/16
15		Earthwork	85 days	Mon 6/6/16	Fri 9/30/16
16		Dam Breaching	43 days	Mon 7/4/16	Wed 8/31/16
17		Stream Restoration	85 days	Mon 7/4/16	Fri 10/28/16
18		Old Cass Road Bridge Demolition	10 days	Mon 6/6/16	Fri 6/17/16
19		Cass Road Reconstruction	30 days	Mon 6/20/16	Fri 7/29/16
20		**Sabin Dam**	**213 days**	**Mon 6/6/16**	**Wed 3/29/17**
21		Clearing and Erosion Control	10 days	Mon 6/6/16	Fri 6/17/16
22		Dam Removal	30 days	Thu 8/25/16	Wed 10/5/16
23		Sediment Trap/Sediment Mgmt.	143 days	Mon 6/6/16	Wed 12/21/16
24		Earthwork	85 days	Thu 8/25/16	Wed 12/21/16
25		Stream Restoration	85 days	Thu 8/25/16	Wed 12/21/16
26		Winter Shutdown	70 days	Thu 12/22/16	Wed 3/29/17
27		Final Site Restoration	60 days	Thu 3/30/17	Wed 6/21/17
28		Closeout and Demobilization	30 days	Thu 5/11/17	Wed 6/21/17
29		Project Completion	0 mons	Wed 6/21/17	Wed 6/21/17



Project: Design and Construction Schei
Date: Mon 4/15/13

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

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Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

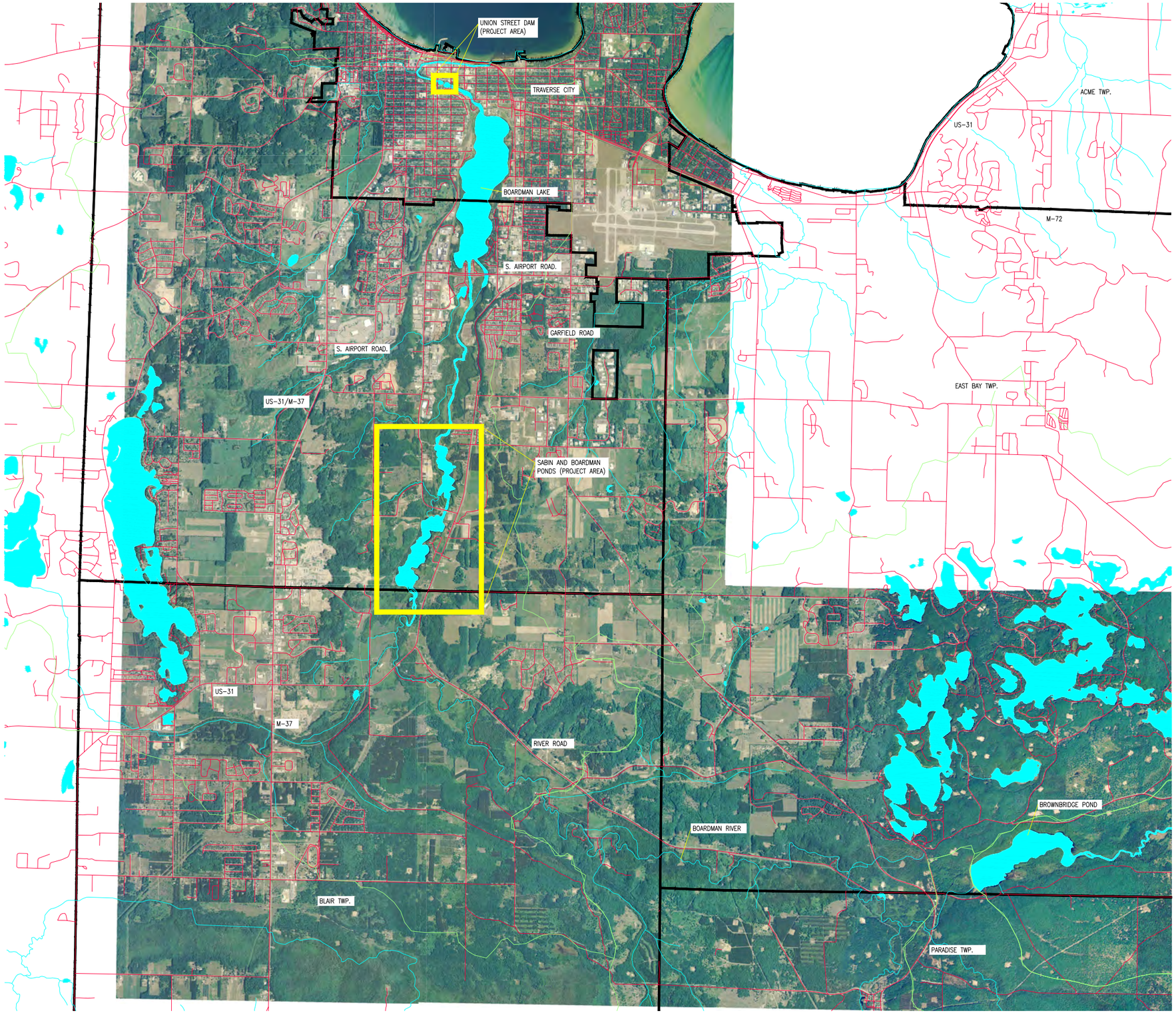
CITY OF TRAVERSE CITY AND GRAND TRAVERSE COUNTY, MICHIGAN

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

ATTACHMENT 4

PROJECT PLATES

US Army Engineer District, Detroit
477 Michigan Avenue
Detroit, MI 48226-2523



NORTH

GRAPHIC SCALE
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BOARDMAN PLANS — SHEET NUMBER

TITLE SHEET..... 1
WATERSHED MAP..... 2
BOARDMAN DAM..... 3
SABIN DAM..... 4
UNION STREET DAM..... 5
SABIN/BOARDMAN PROJECT AREA..... 6
DAM REMOVAL MEASURES..... 7
DAM MODIFICATION MEASURES..... 8
BRIDGE AND RIVER TYPICAL SECTIONS..... 9

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BOARDMAN RIVER FEASIBILITY STUDY
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KALKASKA AND GRAND TRAVERSE COUNTIES, MICHIGAN

TITLE SHEET

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1

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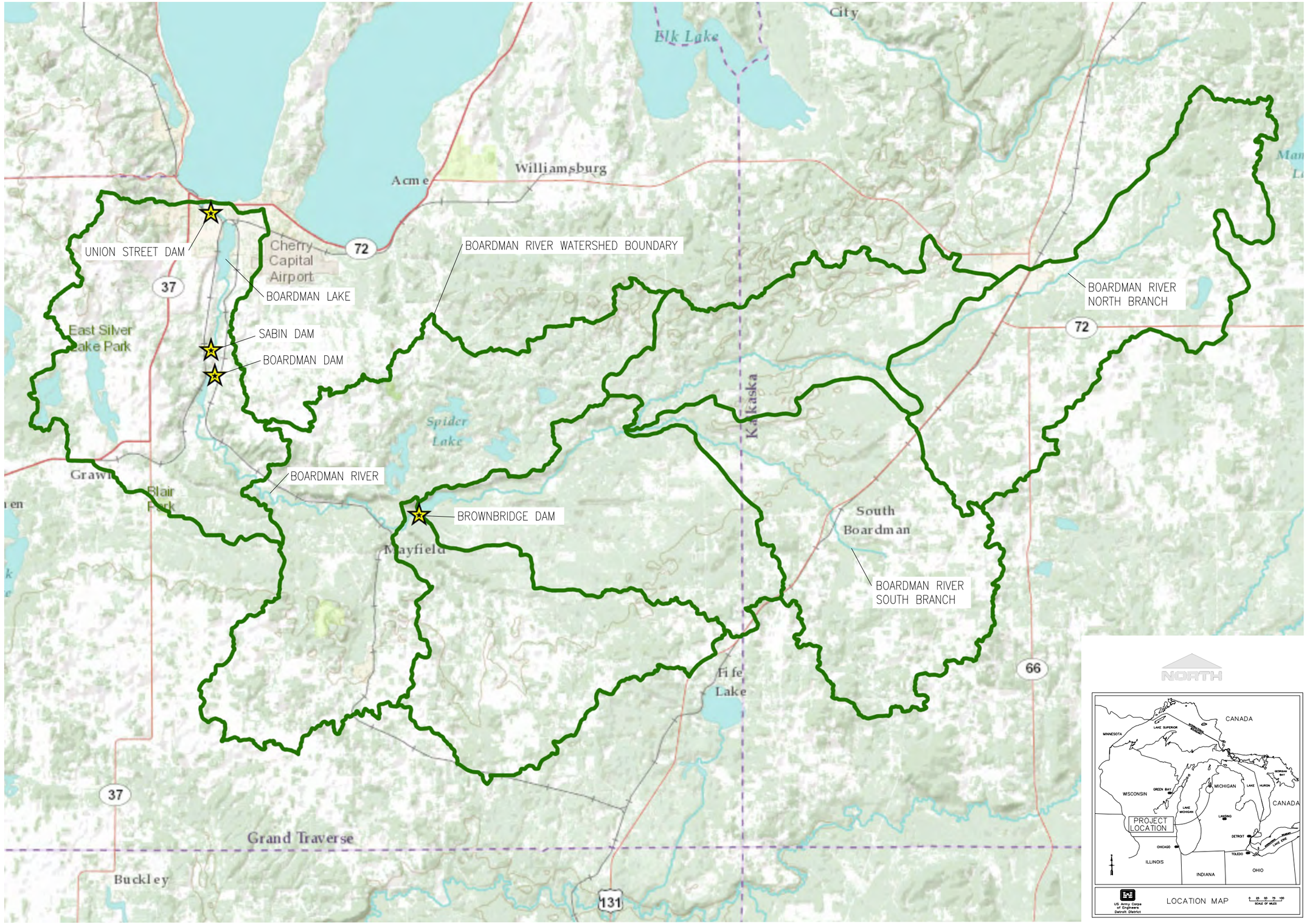

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BOARDMAN RIVER WATERSHED

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2

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NORTH

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100 0 50 100

BOARDMAN DAM

POWERHOUSE

SPILLWAY

PENSTOCKS

BRIDGE

INTAKE

INTAKE CHANNEL

EARTHEN DAM

EARTHEN DAM

IMPOUNDMENT

IMPOUNDMENT

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BOARDMAN DAM

Sheet ID
3

SABIN DAM

NORTH

GRAPHIC SCALE
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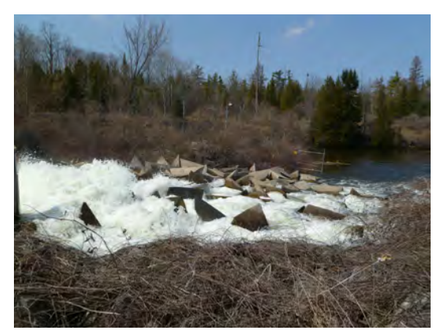
POWERHOUSE

SECONDARY SPILLWAY GATES

SECONDARY SPILLWAY

SECONDARY SPILLWAY

TAILRACE



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SABIN DAM

Sheet ID
4

UNION STREET DAM

GRAPHIC SCALE
20 0 10 20

DOWNSTREAM FACE

UNION STREET DAM TOP

UNION STREET DAM INLET

FISH LADDER

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UNION STREET DAM

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5

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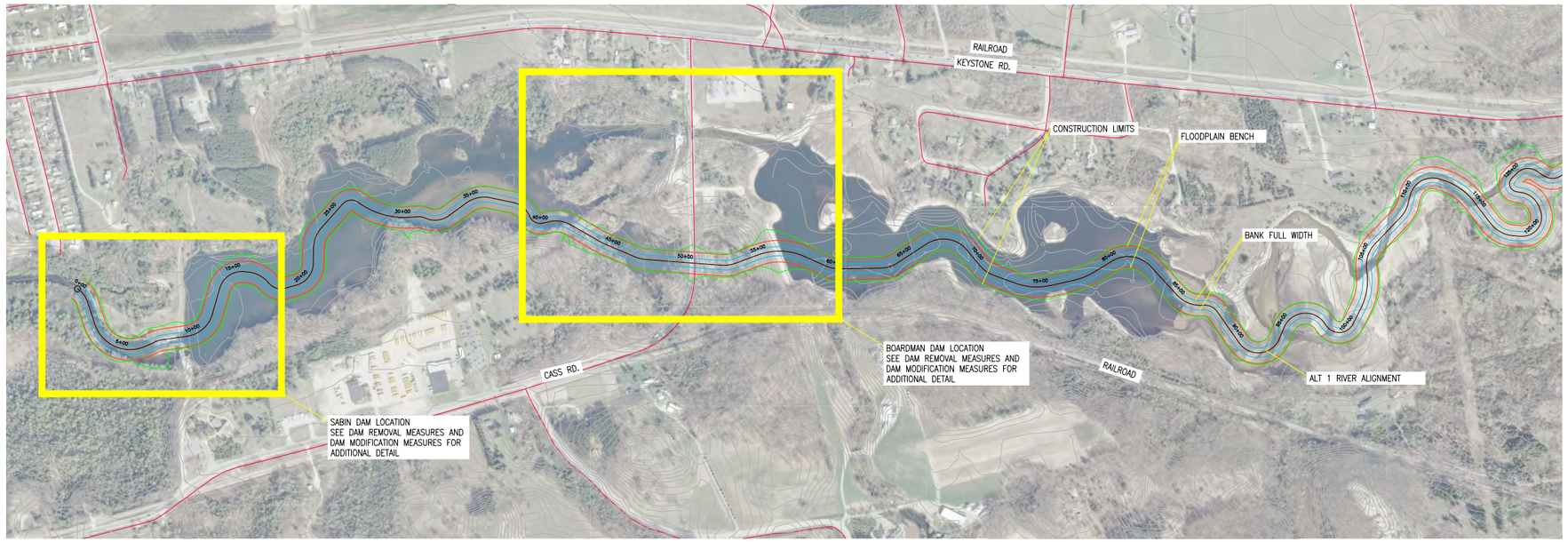

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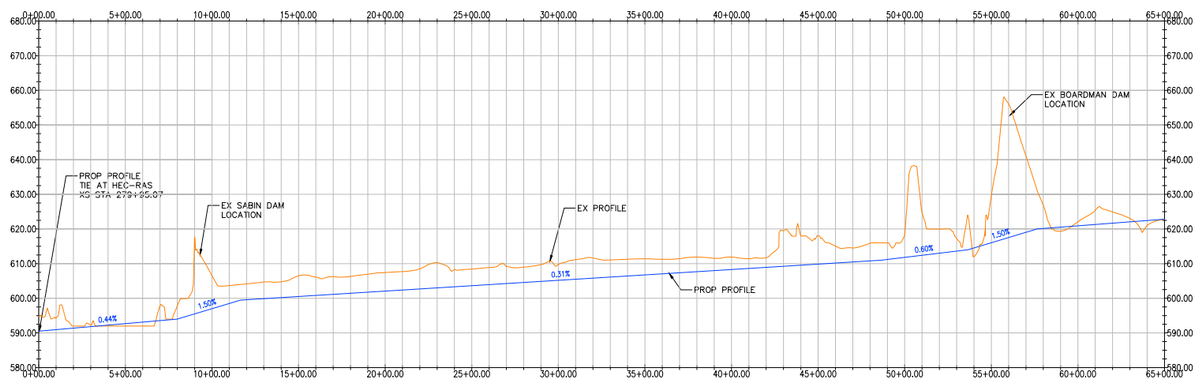

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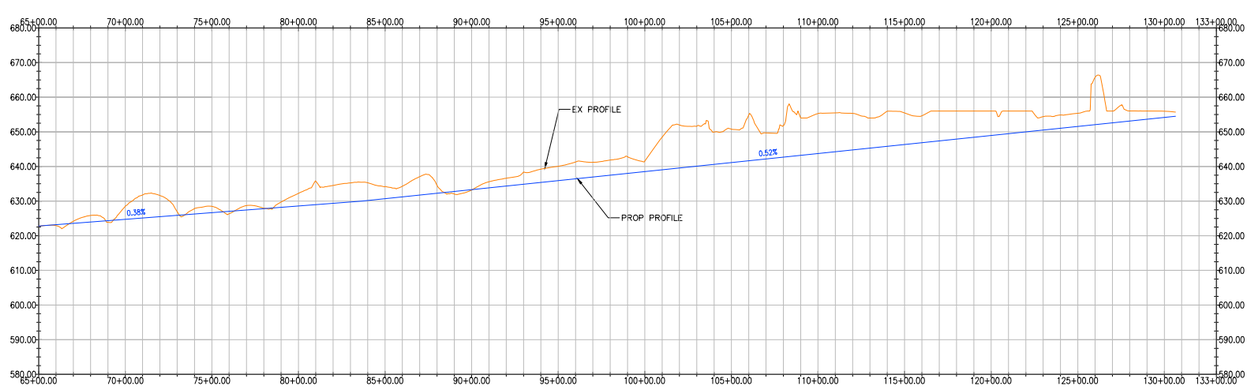

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SABIN AND BOARDMAN POND PROJECT AREA

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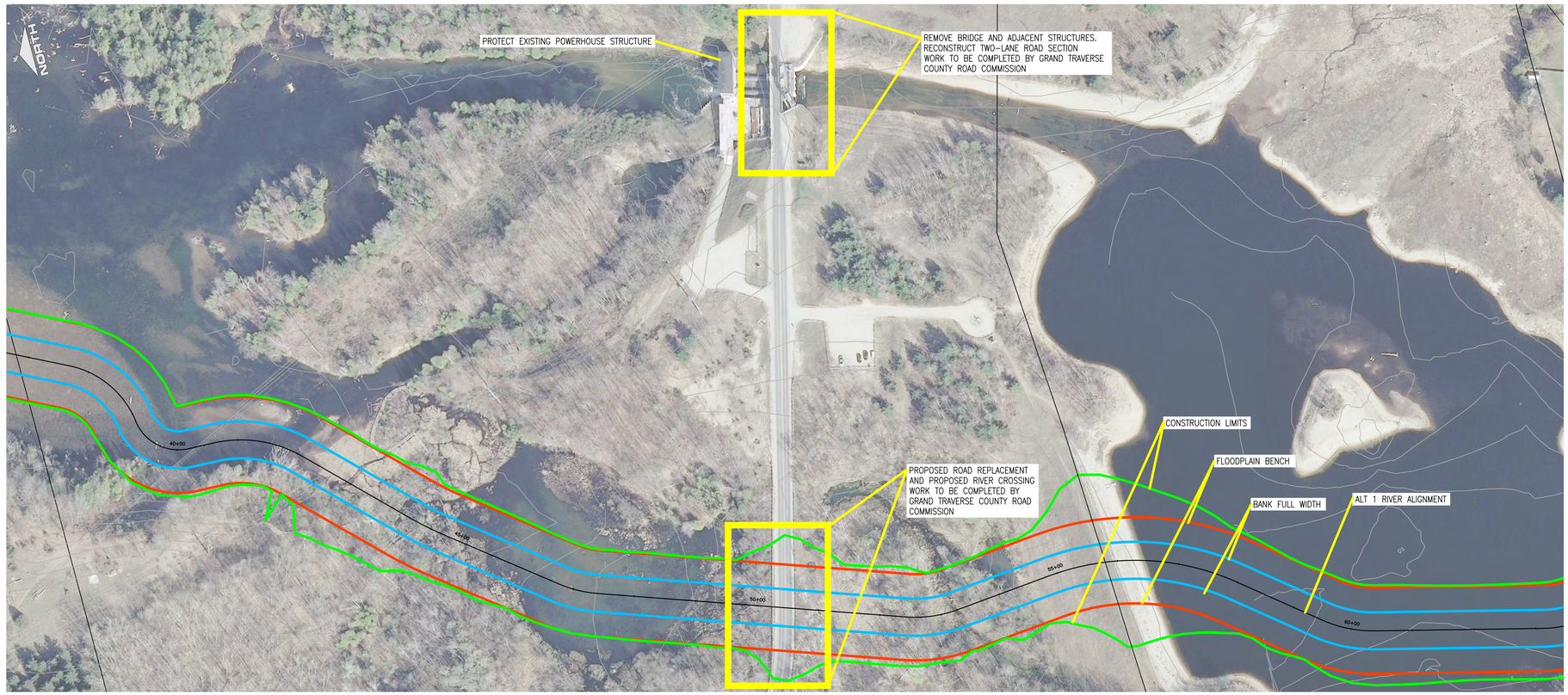

BOARDMAN DAM
REMOVAL MEASURES

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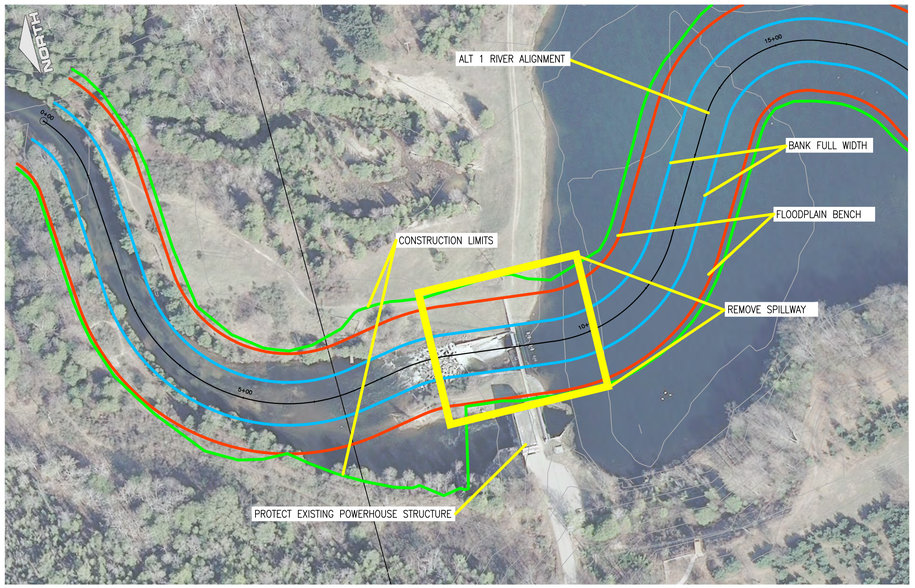

SABIN DAM
REMOVAL MEASURES

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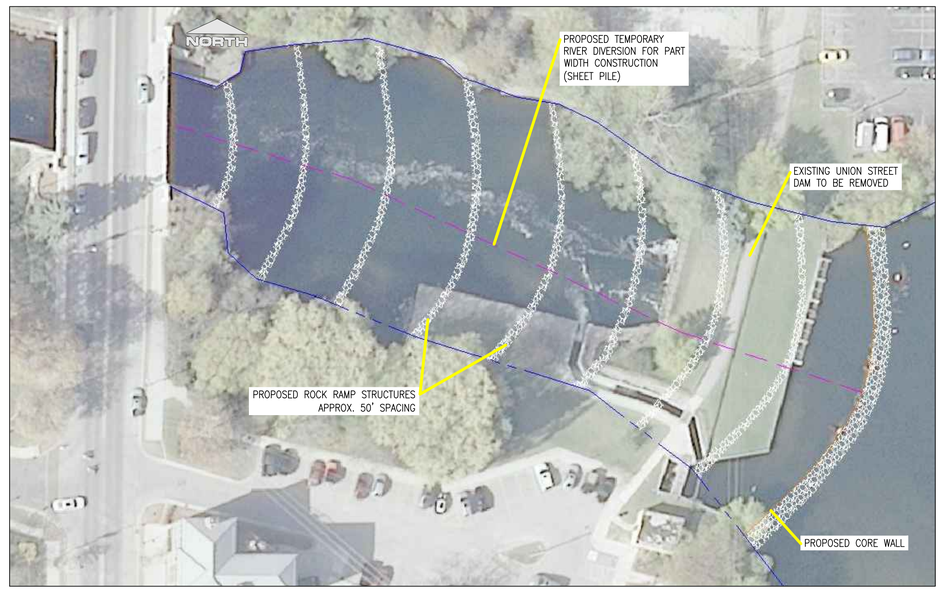

UNION STREET DAM
OVERFLOW MEASURES

GRAPHIC SCALE
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BOARDMAN RIVER FEASIBILITY STUDY
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DAM REMOVAL MEASURES

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7

BOARDMAN DAM
MODIFICATION MEASURES

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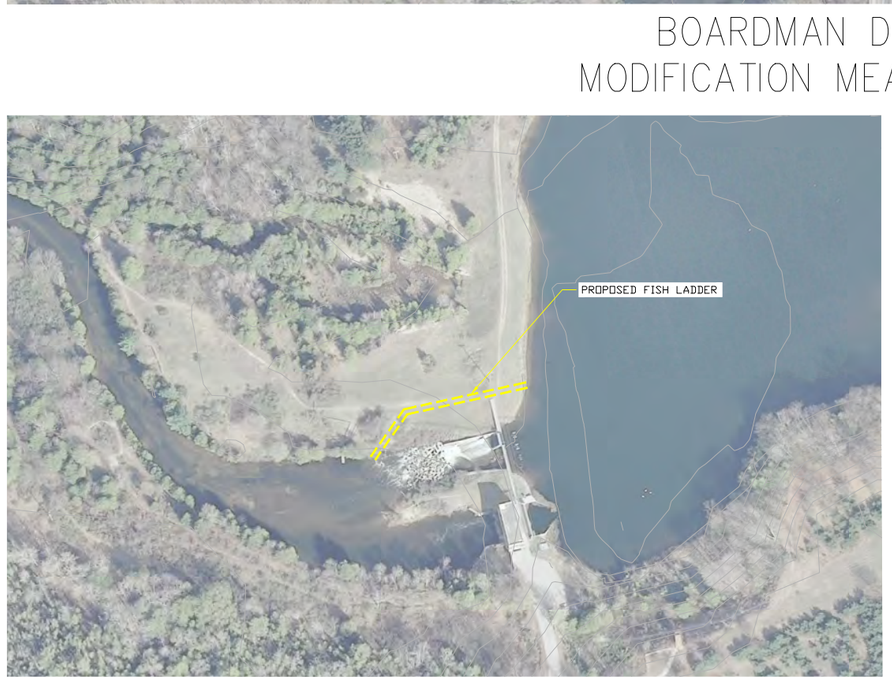

SABIN DAM
MODIFICATION MEASURES

GRAPHIC SCALE
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UNION STREET DAM
MODIFICATION MEASURES

GRAPHIC SCALE
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DAM MODIFICATION MEASURES

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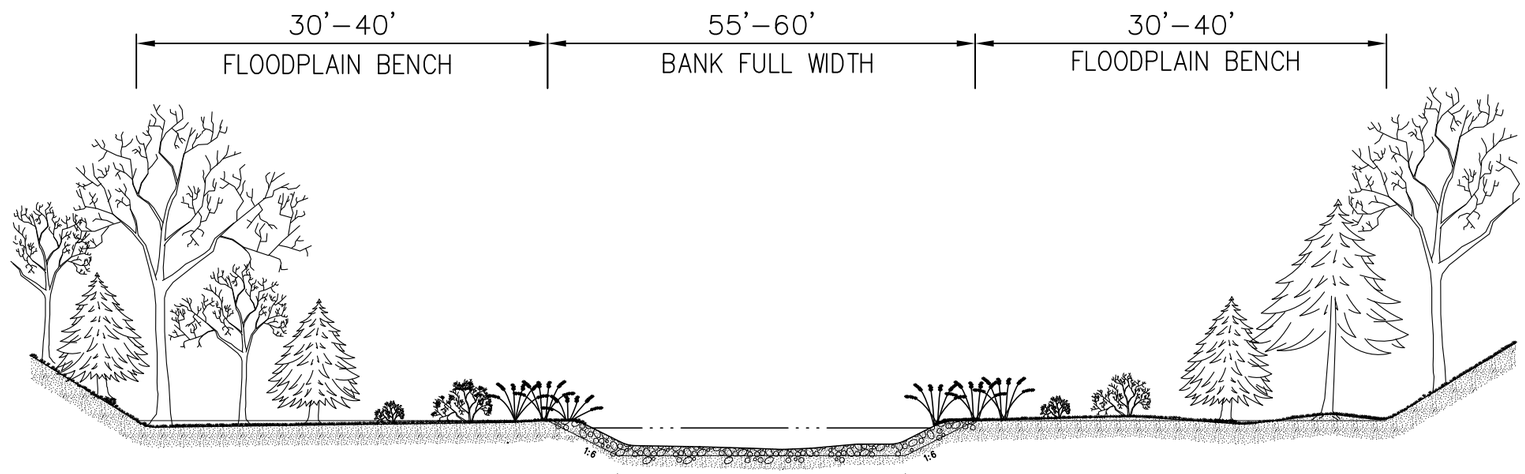
8



AVG. BANK FULL DEPTH 2.4'–2.8'

THALWEG VARIES DEPENDING ON CHANNEL PATTERN

TYPICAL SECTION

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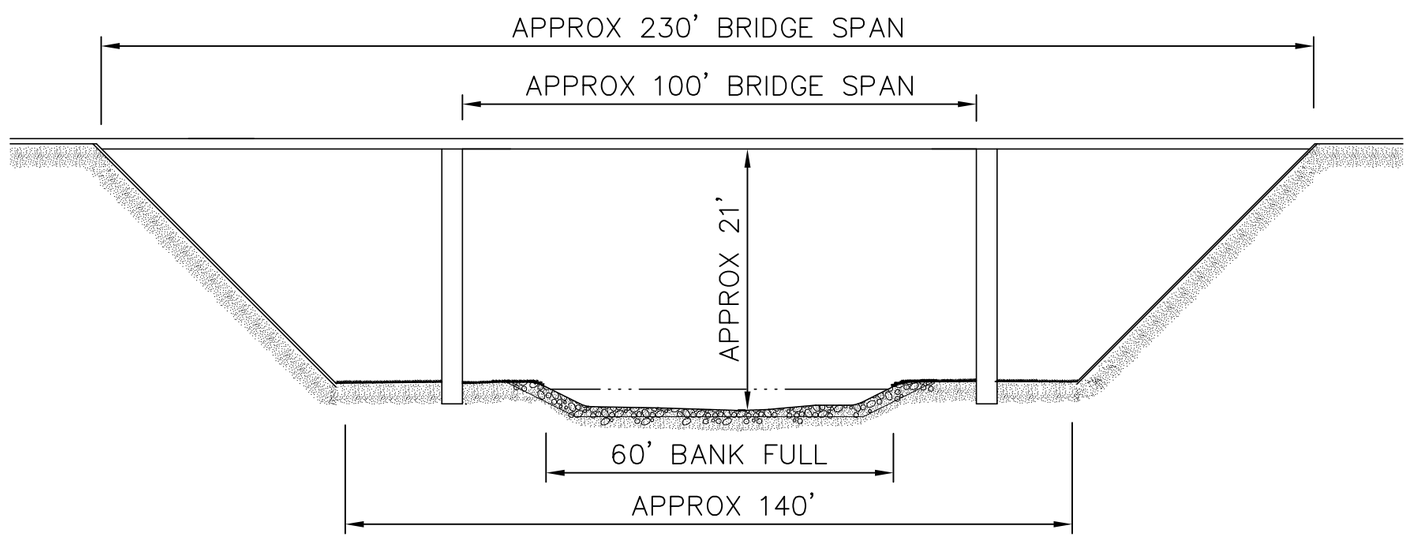

PROPOSED CASS ROAD BRIDGE SECTION (TO BE CONSTRUCTED BY GRAND TRAVERSE COUNTY ROAD COMMISSION)

NOT TO SCALE

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DESIGNED BY: DD | DATE: 201210
DWN BY: CM | CKD BY: TN | SOLICITATION NO.:
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U.S. ARMY CORPS OF ENGINEERS
DETROIT DISTRICT
DETROIT, MICHIGAN

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BOARDMAN RIVER FEASIBILITY STUDY
AND ENVIRONMENTAL IMPACT STATEMENT
FOR THE BOARDMAN RIVER
KALKASKA AND GRAND TRAVERSE COUNTIES , MICHIGAN

RIVER AND BRIDGE
TYPICAL SECTIONS

Sheet ID
9

Value Engineering Study

FEASIBILITY STUDY FOR ECOSYSTEM RESTORATION OF THE BOARDMAN RIVER

KALKASKA AND GRAND TRAVERSE COUNTIES, MICHIGAN

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

Study Date: July 24-26, 2012

U.S. Army Corps of Engineers
Detroit District
Detroit, Michigan

URS

FEASIBILITY STUDY FOR ECOSYSTEM RESTORATION OF THE BOARDMAN RIVER

GRAND TRAVERSE COUNTY, MICHIGAN

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

VALUE ENGINEERING STUDY
for
U.S. Army Corps of Engineers
Detroit District

Study Date: July 24 - 26, 2012

URS

EXECUTIVE SUMMARY

General

URS conducted a value engineering (VE) study of the Feasibility Study for Ecosystem Restoration of the Boardman River in Kalkaska and Grand Traverse Counties, Michigan. The project is part of the Great Lakes Fisheries and Ecosystem Restoration Program. The topic was the 95 percent draft submission prepared by URS for the U.S. Army Corps of Engineers, Detroit District (USACE).

The VE Team undertook the task assignment using the value engineering work plan and approach. The ideas generated from this process and chosen for full development as VE Team Recommendations are presented in Section 3 of this report. These recommendations are presented to all project stakeholders for judgment as to whether they should be implemented.

Estimate of Construction Costs and Budget

The preliminary construction cost estimate provided to the VE Team with the project documents indicates a total construction cost of $12,233,000 including Construction Management, Planning, Engineering, and Design. This project is scheduled to be developed as a traditional design/bid/build project, thus the cost of construction will be determined on a contractor bid.

Summary of VE Study Results

During the speculation phase of this VE study, 37 creative ideas were identified; 12 of these ideas were developed into VE recommendations and 14 were developed into design comments with cost implications where applicable. Many of the ideas represent changes in design approach, reconsideration of criteria, and in some cases, modification of the project scope. In general, the idea evaluation took into account the economic impact, other benefits obtained, and the effect on the overall project objectives.

The following table presents a summary of the ideas developed into recommendations and design comments with cost implications where applicable. Since cost is an important issue for comparison of VE proposals, the costs presented in this report are based upon original design quantities with unit rates obtained from the estimate as prepared by the Design Team and included in their submission, published cost databases, and VE Team member experience.

The table also identifies the recommendations and alternatives that, in the opinion of the VE Team, are the best combination of all the VE recommendations. This selection takes into account that the cost savings of these recommendations can be added together (summarily additive), and it also considers whether the cost savings or project improvement potential are worth the change to the project design.

As a result of this VE study, should all of the VE Team's selected combination of recommendations be accepted for implementation, the potential cost savings for this project is $2,302,000. These potentials are based upon the VE Team's cost estimates of the individual recommendations selected by the VE Team as noted on the Summary of Recommendations table below. Total cost savings realized will be based upon the final implementation status of these VE recommendations.

SUMMARY OF VE RECOMMENDATIONS			
Rec #	Recommendation Title / Description	1st cost savings (or cost)	VE Selected Combo
VE-1	Retain Boardman Dam Powerhouse in lieu of removal	$720,000	X
VE-2	Retain Sabin Dam Powerhouse in lieu of removal	$534,000	X
VE-3	Utilize Sabin spillway alignment in lieu of the historical channel alignment	$147,000	X
VE-4	Utilize a partial removal of Sabin Dam spillway resulting in a higher profile alignment achieving 30% reduction in sediment disposal volumes	$662,000	
VE-5	Utilize a narrower excavated floodplain bench than the original design for the Sabin impoundment	$72,000	X
VE-6	Utilize a narrower excavated floodplain bench than the original design for the Boardman impoundment	$89,000	X
VE-7	Utilize higher piles of sediment disposal to improve the efficiency of material movement	$313,000	X*
VE-8	Utilize flexible pipes in conjunction with flex blocks to reduce the cost of breaching the dams in lieu of only using flex blocks	$82,000	
VE-9	Repurpose existing Union Street Dam auxiliary spillway/gates in lieu of constructing a new downstream fish passage	$372,000	X
VE-10	Reduce the width of the wildlife corridors below the bridge to the minimal width possible to reduce the length of the bridge	$72,000	
VE-11	Utilize 1v:3h side slopes for the bank full sides under the bridge in lieu of 1v:6h side slopes to reduce the total bridge span	$142,000	X
VE-12	Utilize targeted active restoration on stream banks and steep slopes in lieu of passive restoration	($24,000)	X
VE-13	Elevate the profile downstream of Boardman Dam to reduce the amount of sediment removed during construction	Comment	
VE-14	Allow sediment to travel down the river in the amount that will not degrade riffle pool habitat in lieu of not allowing sediment travel	Comment	
VE-15	Utilize temporary cofferdams (i.e. Hesco Baskets) to dry out work zones where applicable in lieu of working in the wet	Comment	
VE-16	Allow hydraulic methods of dredging in lieu of specifying only mechanical dredging	Comment	
VE-17	Conduct an “all-hands” meeting of regulators at all levels to review the project and verify regulatory requirements early in the process	Comment	
VE-18	Evaluate the real estate implications throughout the project to reduce total project cost	Comment	
VE-19	Allow the bridge to be designed and constructed by the county as an in-kind effort in lieu of integrating into USACE construction contract	Comment	

SUMMARY OF VE RECOMMENDATIONS			
Rec #	Recommendation Title / Description	1st cost savings (or cost)	VE Selected Combo
VE-20	Consider all contracting options (e.g. multiple contract, single contract) to improve the project schedule	Comment	
VE-21	Encourage Michigan Department of Natural Resources (MDNR) to begin a sturgeon monitoring program and initiate a rearing operation (if necessary) when the dams have been removed	Comment	
VE-22	Secure a long-term operation and maintenance agreement with a non-federal entity for the trap-transport operation	Comment	
VE-23	Utilize existing crane at the fish sorting facility in lieu of a new fish lift/elevator	Comment	
VE-24	Minimize the labor necessary associated with the fish elevator at Union Street Dam	Comment	
VE-25	Utilize a performance specification for the fish elevator/lift system in lieu of a proprietary system	Comment	
VE-26	Reduce the cost of the fish elevator by shopping multiple vendors	Comment	

VE Team's Selected Combination: $2,302,000

* If Recommendation VE-5 and VE-6 are implemented, the cost savings available by implementing Recommendation VE-7 would be reduced to approximately $250,000

Acknowledgments
A thank you is given to the staff members from USACE and Grand Traverse Band of Ottawa & Chippewa Indians for their participation. Special thanks are also extended to Ms. Leigh Ann Ryckeghem for her assistance in setting up this study.

Value Engineering Study Team

Name	Discipline / Role	Organization	Telephone
Mike Donahue, PhD	JV Project Manager	URS	248-204-4953
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Leigh Ann Ryckeghem, AVS	Civil Engineer/VEO	USACE	313-226-6371
Kyle Schafersman, PE, CVS	VE Team Leader	URS	913-344-1019
Shelley Tule, PE	Hydraulic Engineer	USACE	313-226-3403
Terry Woodward, PE	Cost Estimator	URS	248-204-5900

Certification
This is to verify that the Value Engineering study was conducted in accordance with standard value engineering principles and practices.

Kyle Schafersman, PE, CVS
Value Engineering Program Manager

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SECTION 1 - INTRODUCTION

This report documents the results of a value engineering study on the Feasibility Study for Ecosystem Restoration of the Boardman River in Kalkaska and Grand Traverse Counties, Michigan. The project is part of the Great Lakes Fisheries and Ecosystem Restoration Program. The study was held at the URS offices in Southfield, Michigan on July 24-26, 2012. The study team was from URS and USACE. Kyle Schafersman, a Certified Value Specialist (CVS), Professional Engineer (PE), and team leader from URS, facilitated the study. The names and telephone numbers of all participants in the study are listed in Appendix A.

The Job Plan

This study followed the value engineering methodology as endorsed by SAVE International, the professional organization of value engineering. This report does not include any detailed explanations of the value engineering / value analysis processes used during the workshop in development of the results presented herein. This would greatly expand the size of the report. The sole purpose of this report is to document the results of the study. Additional information regarding the processes used during the study can be obtained by contacting the Certified Value Specialist team leader that facilitated the study.

Ideas, Recommendations, and Design Comments

Part of the value engineering methodology is to generate as many ideas as is practical, evaluate each idea, and then select as candidates for further development only those ideas that offer added value to the project. If an idea thus selected, turns out to work in the manner expected, that idea is put forth as a formal value engineering recommendation. Recommendations represent only those ideas that are proven to the VE Team's satisfaction. Some ideas that did not make the selection for development as recommendations, were, nevertheless judged worthy of further consideration. These ideas have been written up as Design Comments and are included in Section 3 with the recommendations.

Level of Development

Value analysis studies are working sessions for the purpose of developing and recommending alternative approaches to a given project. As such, the results and recommendations presented are of a conceptual nature, and are not intended as a final design. Detailed feasibility assessment and final design development of any of the recommendations presented herein, should they be accepted, remain the responsibility of the owner. VE Team members have not and will not sign or seal any recommendations and comments contained in this report as certifiable engineering or architectural design. These value analysis alternatives have been developed by individual VE Team members and may not reflect the entire VE Team's opinion.

Organization of the Report

The report is organized in the following outline.

A. Introductory Information
    - Section 1- Introduction
    - Section 2- Project Description

B. Primary Body of Results
    - Section 3- Recommendations and Design Comments

C. Supporting Documentation
    - Appendices

SECTION 2 – PROJECT DESCRIPTION

The Feasibility Study for the Boardman River was conducted by the Detroit District, U.S. Army Corps of Engineers (USACE) in coordination with non-Federal sponsor to address the need for and desirability of undertaking actions to restore cold water aquatic habitat in the Boardman River. The purpose and scope of the Feasibility Study were to evaluate opportunities to restore the Boardman River habitat, a Great Lakes tributary, by modifying or removing three dams along the waterway, singly or in combination. This study was undertaken as a Section 206, Ecosystem Restoration Project and under Section 506 authority (Great Lakes Fishery and Ecosystem Restoration) of the Water Resources Development Act of 2000.

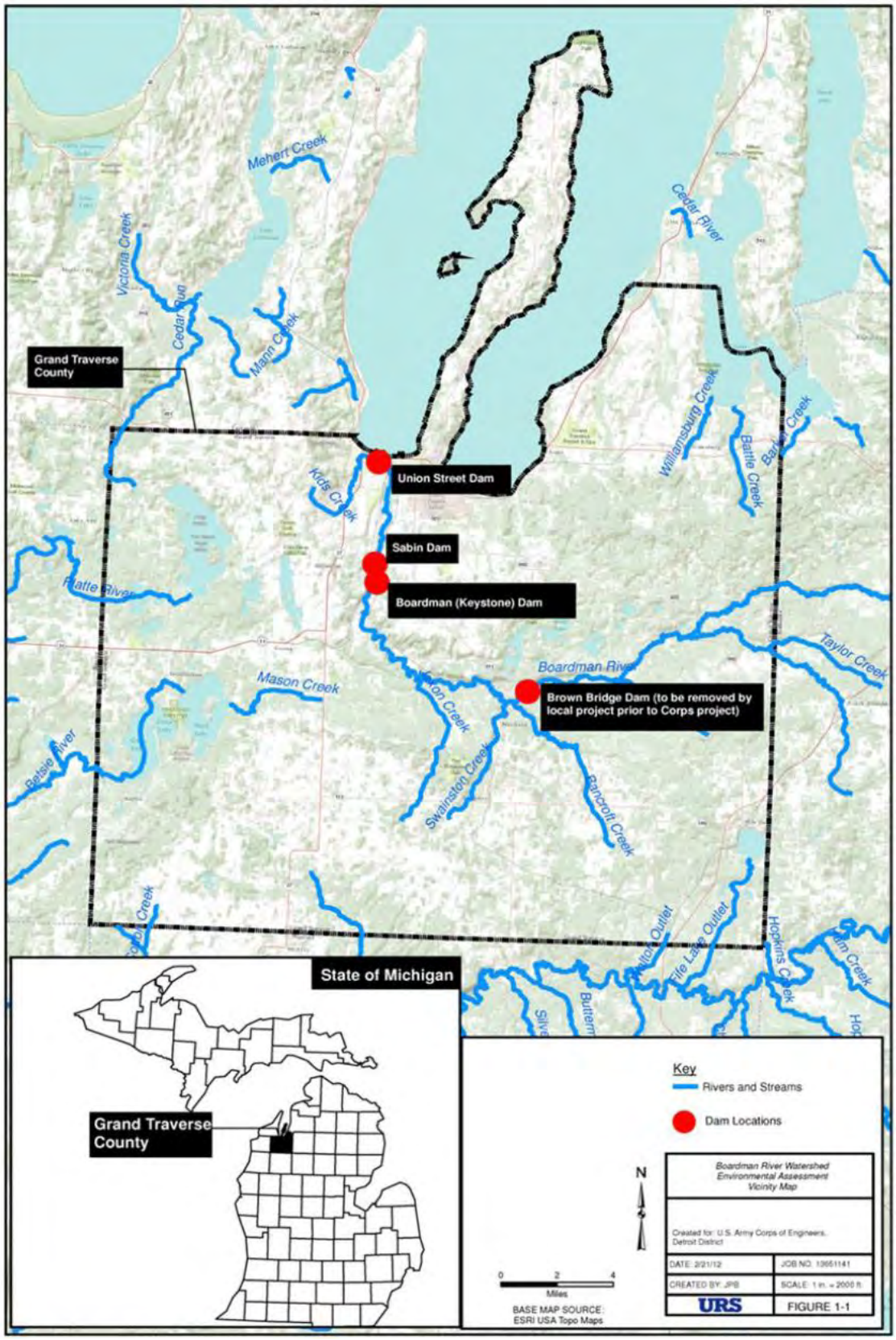
Located in the northwestern portion of Michigan's Lower Peninsula, the Boardman River flows into the West Grand Traverse Bay of Lake Michigan in Traverse City. The Boardman River is a high quality coldwater trout stream that is degraded in its lower reaches as a result of the presence of three dams —the Union Street Dam at river mile 1.5, Sabin Dam at river mile 5.3, and Boardman Dam at river mile 6.1— which damage the coldwater ecosystem through habitat fragmentation, habitat degradation, thermal disruptions and thermally induced species disruptions. This study evaluated the feasibility of restoring and reconnecting Great Lakes tributary habitat to restore the natural balance between coldwater and coolwater aquatic species, to allow unimpeded movement of woody debris and sediment, to negate thermal disruption and to facilitate the passage of various fish species upstream and downstream.

The preferred alternative consists of retaining the Union Street Dam, modifying the existing trap-and-transfer facility for moving desirable fish from Lake Michigan further up the Boardman River, and modifying the existing fish ladder to allow sturgeon to migrate downstream around the dam. Sabin Dam and Boardman Dam would be removed completely, allowing a free-flowing river to be restored from the Union Street Dam to Boardman Pond.

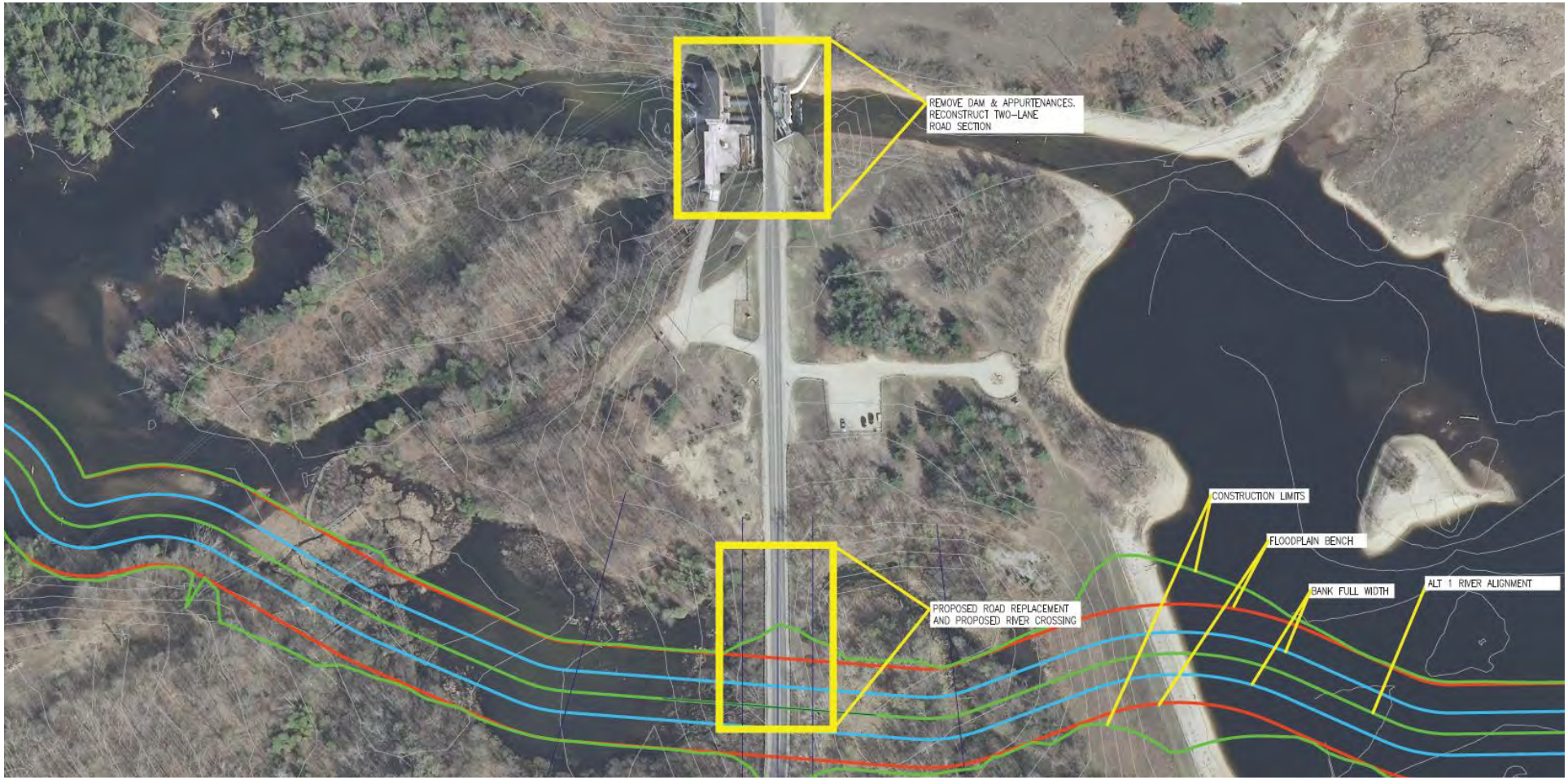
The preferred alternative would create an additional eight miles of stream habitat for coldwater species by negating the thermal disruption of the impoundments. The conversion of impoundment to riverine habitat would provide more usable habitat to various coldwater species, including the target species of brook trout, longnose dace, and lake sturgeon by lowering water temperatures and increasing the current.

The preferred alternative would meet the project objectives by reconnecting and restoring Great Lakes tributary habitat, allowing unimpeded movement of woody debris and sediment materials through the river system, negating thermal disruption, and restoring the natural balance between coldwater species. These objectives would be accomplished without transporting pollutants into the Grand Traverse Bay of Lake Michigan or allowing upstream migration of invasive aquatic species.

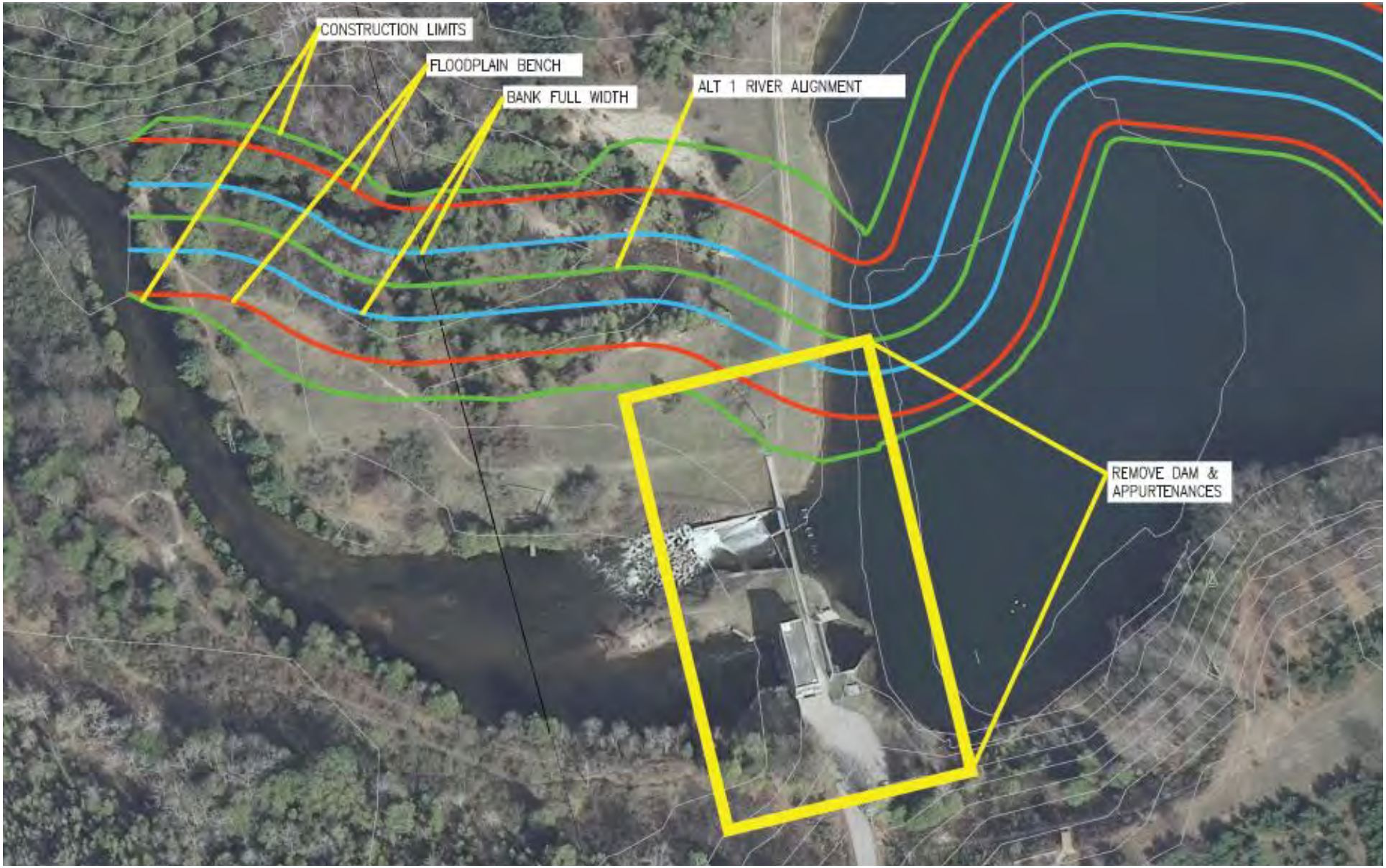
Boardman River Feasibility Study Area



Plan View of Boardman Dam Preferred Alternative



Plan View of Sabin Dam Preferred Alternative



Plan View of Union Street Dam Preferred Alternative

SECTION 3 - VE RECOMMENDATIONS & DESIGN COMMENTS

Organization of Recommendations
This section contains the complete documentation of all recommendations that have resulted from this study. Each recommendation has been marked by a unique identification number.

The parent idea, or ideas from which the recommendation began, can be determined from the Creative Idea List and Evaluation located in Appendix D of this report.

Each recommendation is documented by a separate write-up that includes:
- a description of both the original design and recommended change,
- a list of advantages and disadvantages,
- sketches where appropriate,
- calculations,
- estimate of initial or first cost,
- the economic impact of the recommendation on the first cost (i.e., amount of dollars saved or added),
- and where applicable, the life cycle (LC) cost.

The economic impact is shown in terms of savings or added cost.

Acceptance of VE Recommendations
The Summary of VE Recommendations table presented in the Executive Summary of this report identifies the recommendations that, in the opinion of the VE Team, are the best combination of all the VE recommendations. This selection takes into account not only that the recommendations, and likewise their cost savings, are summarily additive (can be added together), but also the likelihood and ease of implementing the recommendations.

However, this report also includes other recommendations that could enhance the value of this project. These recommendations are either mutually exclusive of the recommendations selected by the VE Team (i.e., implementing one immediately precludes the implementation of another) or they require additional design and/or evaluation prior to implementation. These recommendations should be evaluated individually to determine whether they are worthy of implementation or not. Consideration should be given to the areas within a recommendation that are acceptable and implement those parts only. Any recommendation can be accepted in whole or in part as the owner and Design Team see fit.

Design Comments
Design Comments are ideas that in the opinion of the VE Team were good ideas, but for any number of reasons were not selected for development as VE recommendations. Design Comments can be notes to the owner or designer, a documentation of various thoughts that come up during the course of the study, a reference to possible problems, suggested items that might need further study, or questions that the owner and designer might want to explore. These comments may have implications on project cost, but due to time constraints, the VE Team did not develop cost savings estimates for Design Comments. Some comments might relate to things of which the owner or designer is already aware. Because the study is done on a design in progress and as an independent team, the VE Team may not be aware of everything intended by the owner and designer. The following comments are presented with the intent that they may aid the Design Team in some way.

VALUE ENGINEERING RECOMMENDATION # VE-1

DESCRIPTIVE TITLE OF RECOMMENDATION:
Retain Boardman Dam Powerhouse in lieu of removal.

ORIGINAL DESIGN:
The original design specifies removal of Boardman Dam, including demolition and removal of the existing concrete spillway, the Boardman Dam powerhouse (and associated appurtenances), and a minimum of two bank full widths of the existing earthen dam. The exposed bottomlands would be restored to a free-flowing channel through the former impoundment and the river would be re-routed through the historical river channel, located west of the powerhouse. The dam removal operation would require replacement of the existing Cass Road Bridge with a new Cass Road crossing over the realigned channel. The roadway at the existing bridge location adjacent to the powerhouse would be reconstructed over top of material excavated from the earthen embankment.

RECOMMENDED CHANGE:
The VE Team recommends removal of Boardman Dam, including demolition and removal of the existing concrete spillway, and a minimum of two bank full widths of the earthen dam. However, the Boardman Dam powerhouse (and associated appurtenances) would remain in place with the river being re-routed through its historical channel location and through the earthen embankment.

ADVANTAGES:
- Less demolition
- No need to dispose building materials
- Shorten construction duration
- Allow for potential reuse of the building

DISADVANTAGES:
- Continued operation and maintenance requirements of building owner
- Less aesthetically pleasing
- Requires retaining wall installation along reconstructed roadway

JUSTIFICATION:
Leaving the Boardman Dam powerhouse in place would not impact the goal and objective of the project to restore aquatic ecosystem habitat in the Boardman River. The proximity of the powerhouse structure is such that it would not restrict passage of various fish species up and downstream if the river is rerouted through the existing earthen dam at its historical location. Furthermore, leaving the powerhouse in place would have no effect on sediment management and would not require disposal of building materials that may contain items which would require off-site disposal. Leaving the powerhouse in place will likely require construction of a concrete retaining wall to stabilize the re-constructed roadway at the existing Cass Road bridge location. This effort will be somewhat offset by the reduced effort no longer required with compaction, testing, etc. of roadway embankment material required with the original design.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$861,000	$0	$861,000
RECOMMENDED DESIGN	$141,000	$0	$141,000
ESTIMATED SAVINGS OR (COST)	$720,000	$0	$720,000

VALUE ENGINEERING RECOMMENDATION # VE-1

PHOTOGRAPH OF EXISTING CONDITION

VALUE ENGINEERING RECOMMENDATION # VE-1

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Remove Boardman Powerhouse	LS	$680,000	1	1	$680,000		
Reduced embankment earth – trucking difference only	CY	$2.54	1			5,000	$12,700
Construct concrete retaining wall	SF	$35.00	7			3,000	$105,000
Reduced embankment earth	CY	$5.00	1	7,500	$37,500		
Subtotal					$717,500		$117,700
Contingency	@	20%			$143,500		$23,540
Total					$861,000		$141,240

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-2

DESCRIPTIVE TITLE OF RECOMMENDATION:
Retain Sabin Dam Powerhouse in lieu of removal.

ORIGINAL DESIGN:
The original design specifies removal of Sabin Dam, including demolition and removal of the existing concrete spillway, the Sabin Dam powerhouse (and associated appurtenances), and a minimum of two bank full widths of the earthen dam. The exposed bottomlands would be restored to a free-flowing channel through the former impoundment. The breach point for the Sabin Dam is proposed to be at the current spillway location, and the river would be re-routed through the historical channel location.

RECOMMENDED CHANGE:
The VE Team recommends removal of Sabin Dam, including demolition and removal of the existing concrete spillway, and a minimum of two bank full widths of the earthen dam. However, the Sabin Dam powerhouse (and associated appurtenances) would remain in place with the river being re-routed through its historical channel location.

Note: A separate VE proposal is being evaluated to consider allowing the river to flow through its existing location adjacent to the powerhouse structure rather than re-routing it through its historical channel location. Potential adoption of that separate proposal would not have an impact on the conclusion of this proposal to leave the Sabin Dam powerhouse in place.

ADVANTAGES:
- Less demolition
- No need to dispose building materials
- Shorten construction duration
- Allow for potential reuse of the building

DISADVANTAGES:
- Continued operation and maintenance requirements of building owner
- Less aesthetically pleasing

JUSTIFICATION:
Leaving the Sabin Dam powerhouse in place would not impact the goal and objective of the project to restore aquatic ecosystem habitat in the Boardman River. The proximity of the powerhouse structure is such that it would not restrict passage of various fish species up and downstream if the river is rerouted through the existing earthen dam at its historical location, or if the channel is modified and maintained at its present location adjacent to the powerhouse structure. Furthermore, leaving the powerhouse in place would have no effect on sediment management and would not require disposal of building materials that may contain items which would require off-site disposal.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$540,000	$0	$540,000
RECOMMENDED DESIGN	$6,000	$0	$6,000
ESTIMATED SAVINGS OR (COST)	$534,000	$0	$534,000

VALUE ENGINEERING RECOMMENDATION # VE-2

PHOTOGRAPH OF EXISTING CONDITION

SABIN DAM

VALUE ENGINEERING RECOMMENDATION # VE-2

PHOTOGRAPH OF EXISTING CONDITION

VALUE ENGINEERING RECOMMENDATION # VE-2

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Remove Sabin Powerhouse	LS	$450,000	1	1	$450,000		
Reduced Embankment Earth – Trucking Difference Only	CY	$2.54	1			2,000	$5,080
Subtotal					$450,000		$5,080
Contingency	@	20%			$90,000		$1,016
Total					$540,000		$6,096

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-3

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize Sabin spillway alignment in lieu of the historical channel alignment.

ORIGINAL DESIGN:
The original design specifies the river channel will follow the natural river channel alignment downstream of the earthen embankment instead of the river alignment at the powerhouse.

RECOMMENDED CHANGE:
The VE Team recommends that the restored river channel follow the existing river path through the power house alignment, thus reducing the excavation and restoration earth moving quantities required for removal of the earthen embankment.

ADVANTAGES:

- River channel established
- Reduce potential changes in u/s river profile
- Reduce earthwork excavation amounts
- Use spillway for grade control
- Minimal clearing required

DISADVANTAGES:

- Requires removal of concrete and erosion control devices in spillway
- Gradient may affect fish passage
- May require grade control upstream and downstream
- Requires removal of dam foundation

JUSTIFICATION:
The existing river discharge alignment is stable and established. The comparative costs will drive the selected alternatives as habitat values are similar.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$1,341,000	$0	$1,341,000
RECOMMENDED DESIGN	$1,194,000	$0	$1,194,000
ESTIMATED SAVINGS OR (COST)	$147,000	$0	$147,000

VALUE ENGINEERING RECOMMENDATION # VE-3

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Dam excavation	CY	$8.00	1	30,000	$240,000	10,000	$80,000
Breach dam	LS	$100,000	1	1	$100,000	2	$200,000
Floodplain and dry channel excavation	CY	$10.00	1	74,000	$740,000	70,000	$700,000
Site clearing	AC	$7,500	1	5	$37,500	2	$15,000
Subtotal					$1,117,500		$995,000
Contingency	@	20%			$223,500		$199,000
Total					$1,341,000		$1,194,000

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-4

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize a partial removal of Sabin Dam spillway resulting in a higher profile alignment achieving 30% reduction in sediment disposal volumes.

ORIGINAL DESIGN:
The original design specifies restoring the Boardman River through the Sabin dam/impoundment to near its original thalweg elevation.

RECOMMENDED CHANGE:
The VE Team recommends elevating the channel profile through the Sabin Dam and impoundment. This will reduce the volume of sediment that needs to be moved to create the river channel and floodplain bench through the impoundment.

ADVANTAGES:

- Reduce sediment volumes requiring movement

DISADVANTAGES

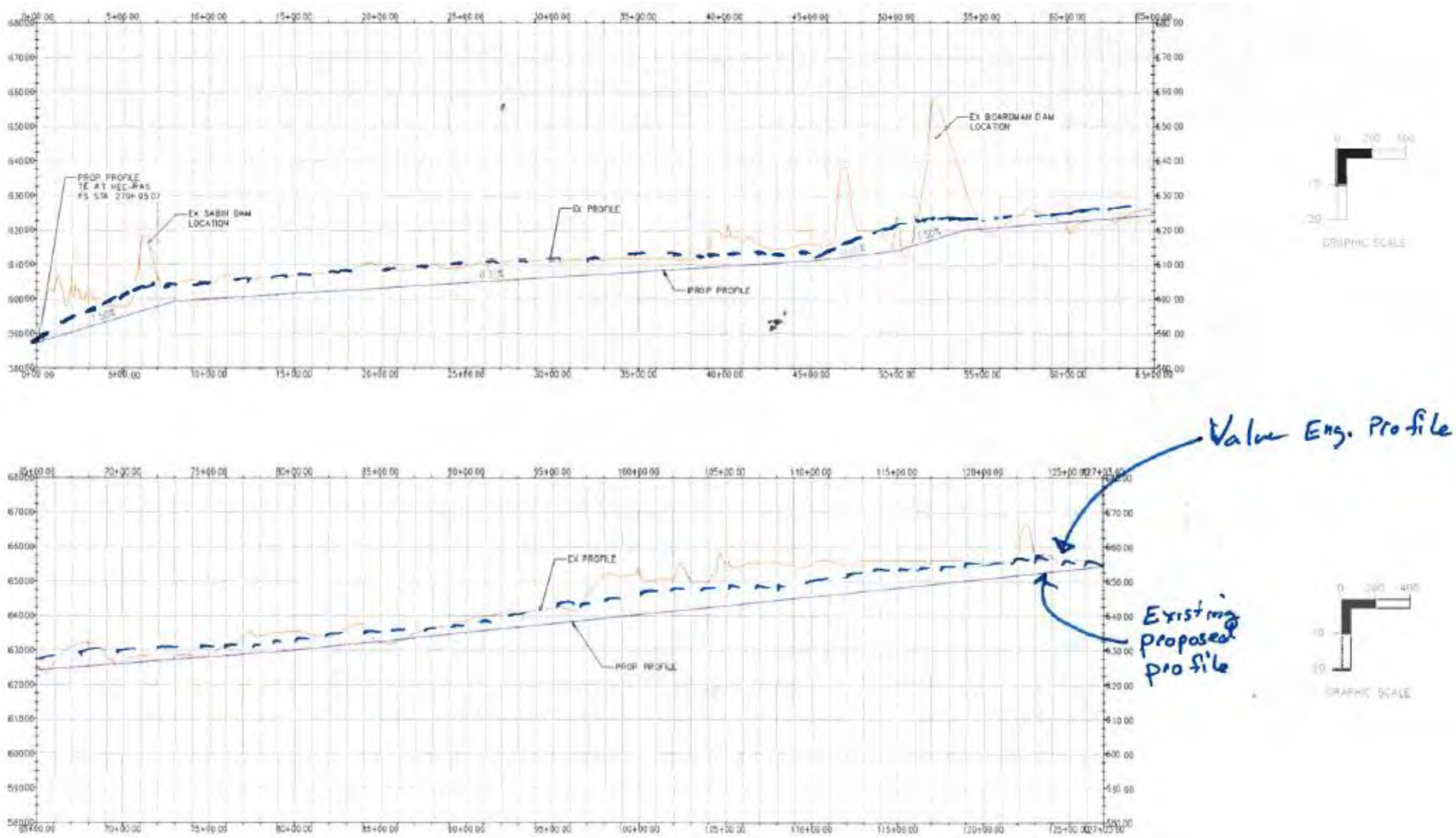
- Diminished habitat in restored channel from poor substrate
- Increase need for stream restoration measures
- Grade and velocity issues for fish passage

JUSTIFICATION:
Elevating the channel profile will allow less sediment to be mobilized and removed from the channel and flood bench area.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$2,208,000	$0	$2,208,000
RECOMMENDED DESIGN	$1,546,000	$0	$1,546,000
ESTIMATED SAVINGS OR (COST)	$662,000	$0	$662,000

VALUE ENGINEERING RECOMMENDATION # VE-4

SKETCH OF RECOMMENDED DESIGN



VALUE ENGINEERING RECOMMENDATION # VE-4

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Floodplain and dry channel excavation	CY	$10.00	1	74,000	$740,000	51,800	$518,000
Dam excavation	CY	$8.00	1	30,000	$240,000	21,000	$168,000
Sediment trap cleaning	CY	$10.00	1	76,000	$760,000	53,200	$532,000
Breach dam	LS	$100,000	1	1	$100,000	1	$70,000
Subtotal					$1,840,000		$1,288,000
Contingency	@	20%			$368,000		$257,600
Total					$2,208,000		$1,545,600

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-5

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize a narrower excavated floodplain bench than the original design for the Sabin impoundment.

ORIGINAL DESIGN:
The original design specifies a typical floodplain bench that is 40 feet wide on either side of the channel throughout the Sabin impoundment. This floodplain bench is required for floodplain storage and conveyance of flows exceeding the designed bank full flow. This design ensures that there are no upstream flooding impacts, and is a typical floodplain bench width which equals about twice the channel width.

RECOMMENDED CHANGE:
The VE Team recommends excavating a narrower floodplain bench in the lower portion of the Sabin impoundment to reduce the amount of sediment required to be excavated and replaced. This recommendation only applies to the lower portion of the Sabin impoundment so that there are no upstream flooding impacts. The VE Team assumes that reducing the floodplain benches to a width of 30 feet for the downstream portion of the Sabin impoundment will not create significant impacts, but these will have to be verified and quantified. This floodplain bench modification should be further analyzed to optimize the savings without causing upstream impacts.

ADVANTAGES:
- Reduced excavation
- Reduced replacement
- Shorter excavation duration

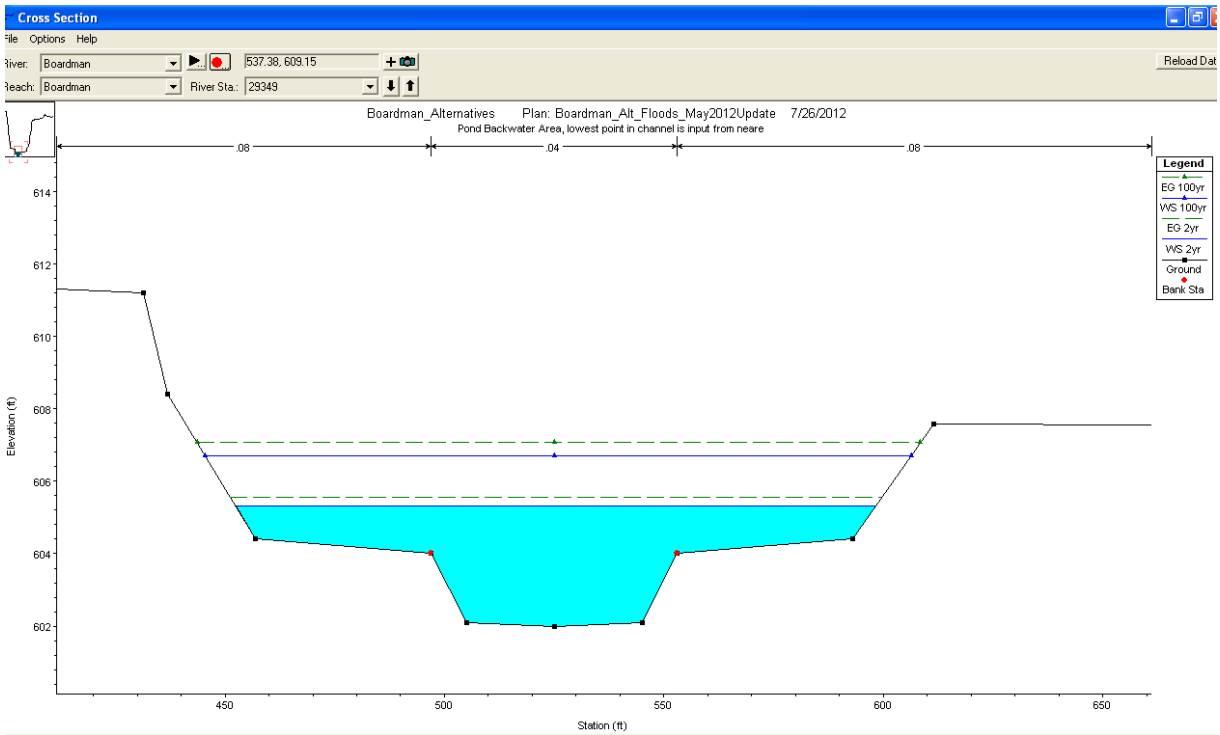
DISADVANTAGES:
- Could cause upstream flood impacts
- Could increase floodplain bench velocities and stresses

JUSTIFICATION:
The low flow channel will stay the same and the floodplain shelf width is only reduced by 25% for the lower portion of the Sabin impoundment. A quick check using the HEC-RAS hydraulic model shows that reducing the floodplain benches to 30 feet for the cross-sections located in the lower impoundment area (a river length of approximately 2,000 feet) will have minimal impacts at the modified cross-sections and no significant upstream impacts. While this will have to be studied in more detail, it looks to be a viable option.

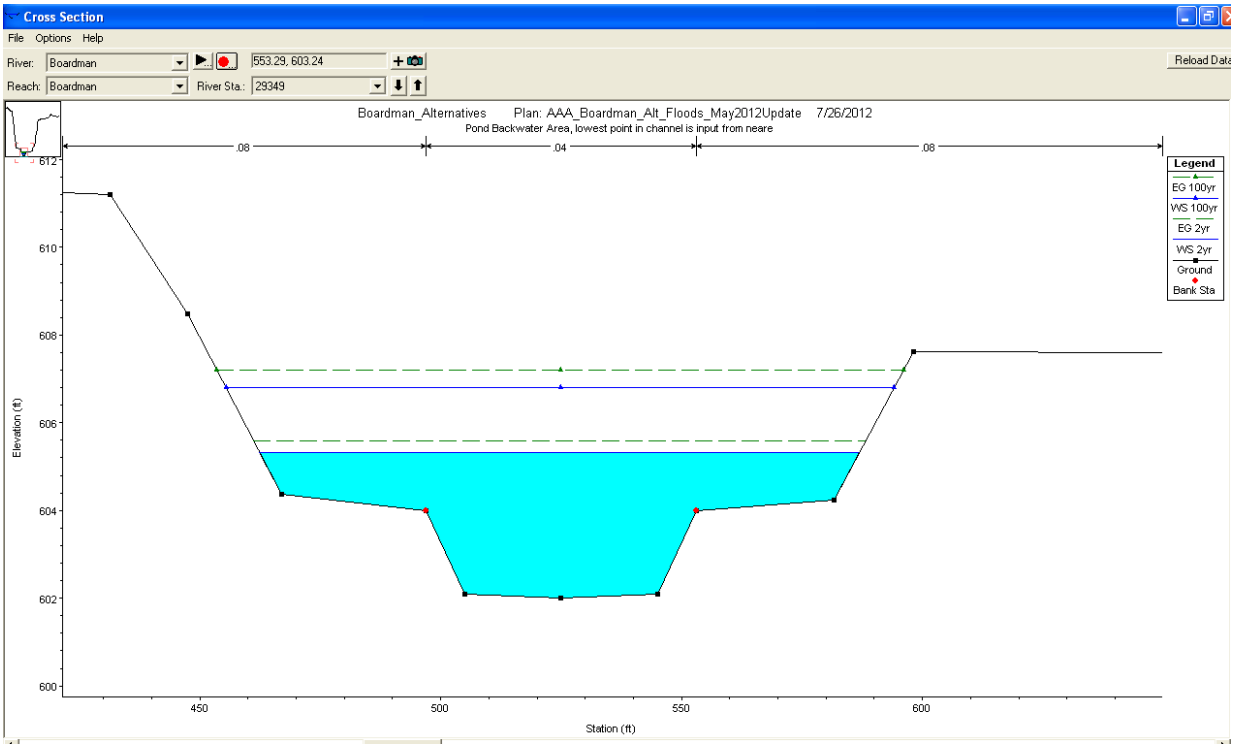
SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$888,000	$0	$888,000
RECOMMENDED DESIGN	$816,000	$0	$816,000
ESTIMATED SAVINGS OR (COST)	$72,000	$0	$72,000

VALUE ENGINEERING RECOMMENDATION # VE-5

ADDITIONAL GRAPHICS

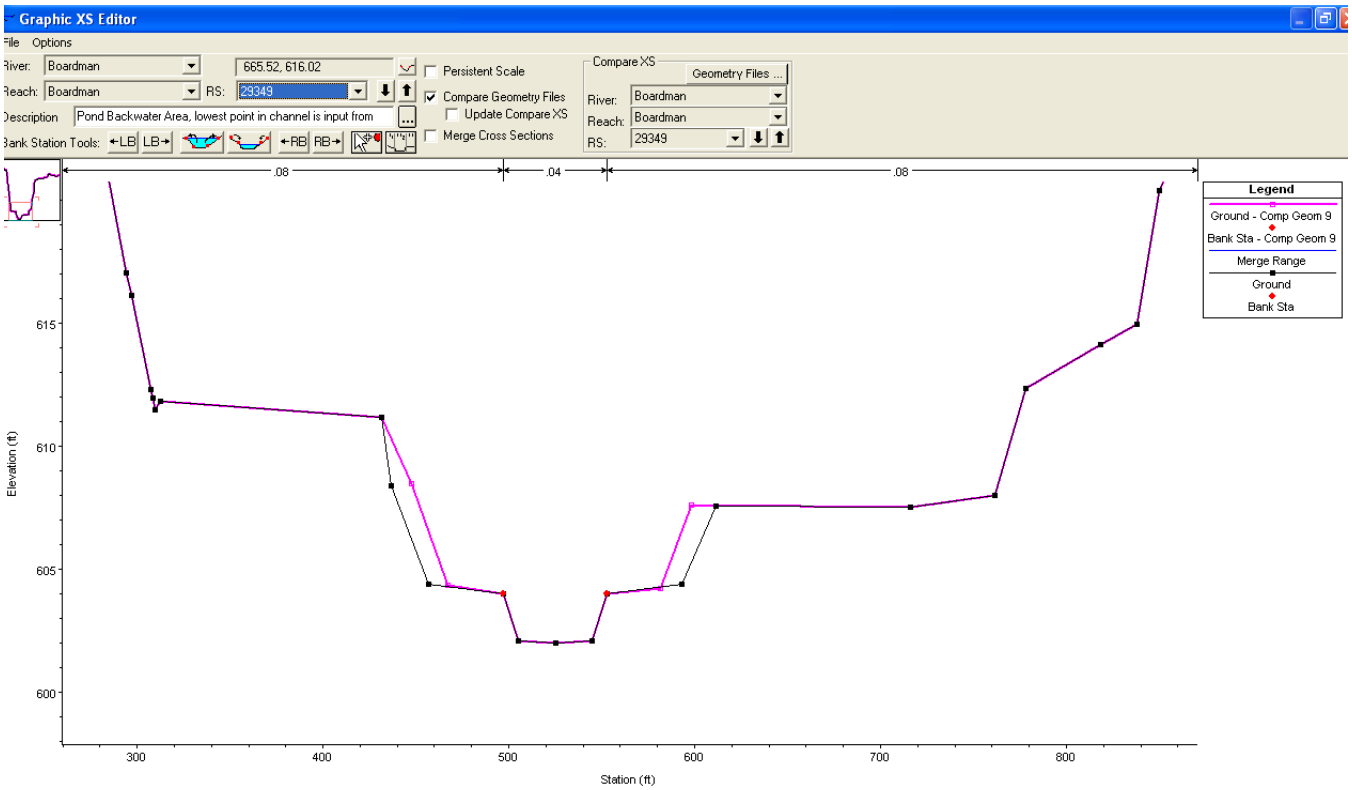


Original Design = 40 feet floodplain benches (XS 29349 in the hydraulic model)



Recommended Design = 30 feet floodplain benches (XS 29349 in the hydraulic model)

ADDITIONAL GRAPHICS



Comparison of Cross-sections – The black line is the original design and the red line is the recommended design (XS 29349 in the hydraulic model).

VALUE ENGINEERING RECOMMENDATION # VE-5

CALCULATIONS

Lower Sabin impoundment length = 2,000 feet
Depth of saved dredging = 4 feet
Width of saved dredging = 10 feet on each side = 20 feet

Volume of saved dredge material = 160,000 cubic feet = 5,926 CY = 5,900 CY less excavated

HEC-RAS River: Boardman Reach: Boardman

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Boardman	31960	2yr	Alt_Update_Flood	800.00	610.50	614.10		614.27	0.002006	3.64	297.28	140.91	0.36
Boardman	31960	2yr	AAA_Update_Flood	800.00	610.50	614.10		614.27	0.001998	3.63	297.73	140.92	0.35
Boardman	31960	100yr	Alt_Update_Flood	1700.00	610.50	615.20		615.53	0.002798	5.22	455.14	145.43	0.44
Boardman	31960	100yr	AAA_Update_Flood	1700.00	610.50	615.20		615.54	0.002789	5.21	455.65	145.45	0.44
Boardman	31520	2yr	Alt_Update_Flood	800.00	609.00	611.66	611.33	612.12	0.007686	5.68	194.38	202.74	0.66
Boardman	31520	2yr	AAA_Update_Flood	800.00	609.00	611.65	611.33	612.12	0.007800	5.71	192.75	201.84	0.66
Boardman	31520	100yr	Alt_Update_Flood	1700.00	609.00	612.78		613.20	0.005280	6.13	549.27	379.82	0.58
Boardman	31520	100yr	AAA_Update_Flood	1700.00	609.00	612.77		613.19	0.005350	6.16	545.94	379.14	0.59
Boardman	30860	2yr	Alt_Update_Flood	800.00	607.00	609.81		610.08	0.002614	4.61	294.27	220.30	0.52
Boardman	30860	2yr	AAA_Update_Flood	800.00	607.00	609.82		610.09	0.002563	4.58	297.01	221.01	0.51
Boardman	30860	100yr	Alt_Update_Flood	1700.00	607.00	610.87		611.30	0.002897	6.16	561.53	299.77	0.58
Boardman	30860	100yr	AAA_Update_Flood	1700.00	607.00	610.91		611.33	0.002791	6.09	573.45	307.71	0.57
Boardman	30346	2yr	Alt_Update_Flood	800.00	605.50	608.43		608.75	0.002670	4.81	281.63	255.60	0.53
Boardman	30346	2yr	AAA_Update_Flood	800.00	605.50	608.43		608.75	0.002721	4.85	270.66	237.50	0.53
Boardman	30346	100yr	Alt_Update_Flood	1700.00	605.50	609.66		610.01	0.002181	5.62	655.46	363.01	0.51
Boardman	30346	100yr	AAA_Update_Flood	1700.00	605.50	609.71		610.08	0.002155	5.65	644.17	355.05	0.51
Boardman	29892	2yr	Alt_Update_Flood	800.00	604.00	606.78		607.24	0.003876	5.57	184.64	141.87	0.63
Boardman	29892	2yr	AAA_Update_Flood	800.00	604.00	606.81		607.26	0.003737	5.51	182.11	125.28	0.62
Boardman	29892	100yr	Alt_Update_Flood	1700.00	604.00	608.03		608.69	0.003533	7.00	374.01	161.08	0.64
Boardman	29892	100yr	AAA_Update_Flood	1700.00	604.00	608.13		608.79	0.003361	6.95	356.86	139.51	0.63
Boardman	29349	2yr	Alt_Update_Flood	800.00	602.00	605.31		605.55	0.003044	4.22	259.77	145.83	0.43
Boardman	29349	2yr	AAA_Update_Flood	800.00	602.00	605.32		605.58	0.003167	4.31	240.57	124.51	0.44
Boardman	29349	100yr	Alt_Update_Flood	1700.00	602.00	606.71		607.06	0.002937	5.36	474.46	160.95	0.45
Boardman	29349	100yr	AAA_Update_Flood	1700.00	602.00	606.80		607.19	0.003008	5.50	436.31	138.79	0.46
Boardman	28900	2yr	Alt_Update_Flood	800.00	600.50	603.02	602.73	603.64	0.005933	6.39	148.37	138.37	0.76
Boardman	28900	2yr	AAA_Update_Flood	800.00	600.50	603.04	602.75	603.65	0.005780	6.34	147.21	118.16	0.75
Boardman	28900	100yr	Alt_Update_Flood	1700.00	600.50	603.91	603.91	605.00	0.007205	8.85	279.09	155.60	0.89
Boardman	28900	100yr	AAA_Update_Flood	1700.00	600.50	603.92	603.88	605.07	0.007419	8.99	256.92	130.41	0.90
Boardman	28519	2yr	Alt_Update_Flood	800.00	597.00	599.24	599.24	600.11	0.009817	7.49	112.06	221.61	0.96
Boardman	28519	2yr	AAA_Update_Flood	800.00	597.00	599.22	599.22	600.11	0.010163	7.57	109.27	209.47	0.97
Boardman	28519	100yr	Alt_Update_Flood	1700.00	597.00	600.40	600.40	601.51	0.007297	8.89	272.12	266.76	0.89

Output from Reality Check in HEC-RAS

VALUE ENGINEERING RECOMMENDATION # VE-5

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Floodplain and dry channel excavation	CY	$10.00	1	74,000	$740,000	68,000	$680,000
Subtotal					$740,000		$680,000
Contingency	@	20%			$148,000		$136,000
Total					$888,000		$816,000

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-6

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize a narrower excavated floodplain bench than the original design for the Boardman impoundment.

ORIGINAL DESIGN:
The original design specifies a typical floodplain bench that is at least 40 feet wide on either side of the channel throughout the Boardman impoundment. This floodplain bench is required for floodplain storage and conveyance of flows exceeding the designed bank full flow. This design ensures that there are no upstream flooding impacts, and is a typical floodplain bench width which equals about twice the channel width.

RECOMMENDED CHANGE:
The VE Team recommends excavating a narrower floodplain bench in the Boardman impoundment to reduce the amount of sediment required to be excavated and replaced. This recommendation only applies to the portion of the Boardman River through the Boardman impoundment so that there are no upstream flooding impacts. The VE Team assumes that reducing the floodplain benches to a minimum width of 30 feet will not create significant impacts, but these will have to be verified and quantified. This floodplain bench modification should be further analyzed to optimize the savings without causing upstream impacts.

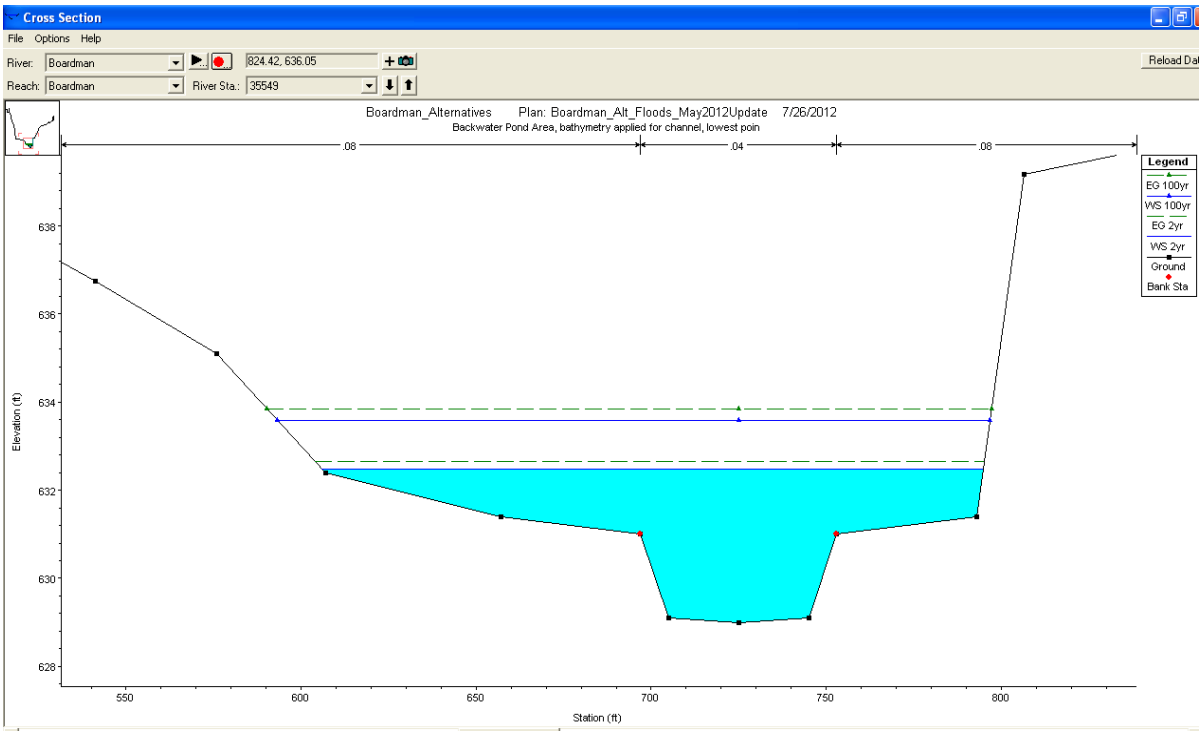
ADVANTAGES:
- Reduced floodplain excavation
- Reduced replacement of dredged material
- Shorter excavation duration

DISADVANTAGES:
- Could cause upstream flood impacts
- Could increase floodplain bench velocities and stresses

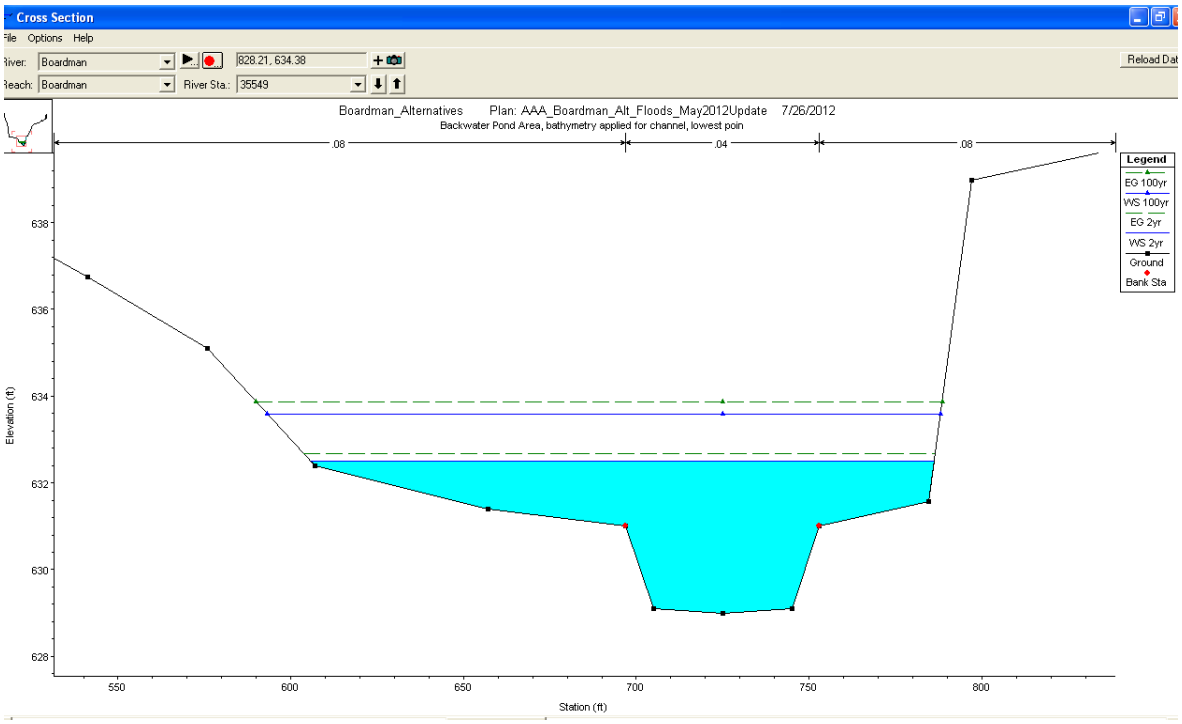
JUSTIFICATION:
The low flow channel will stay the same, and the minimum floodplain shelf width is only reduced by 25%. A quick check using the HEC-RAS hydraulic model shows that changing the minimum floodplain shelf widths only impact one overbank of the river at most of the cross-sections located in the Boardman impoundment; this is due to already lower overbank areas which do not appear to require excavation. Reducing the floodplain bench minimum width to 30 feet for the cross-sections located in the impoundment areas (a river length of approximately 4,000 feet) will have minimal impacts at the modified cross-sections and no significant upstream impacts. While this will have to be studied in more detail, it looks to be a viable option.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$1,104,000	$0	$1,104,000
RECOMMENDED DESIGN	$1,015,000	$0	$1,015,000
ESTIMATED SAVINGS OR (COST)	$89,000	$0	$89,000

ADDITIONAL GRAPHICS



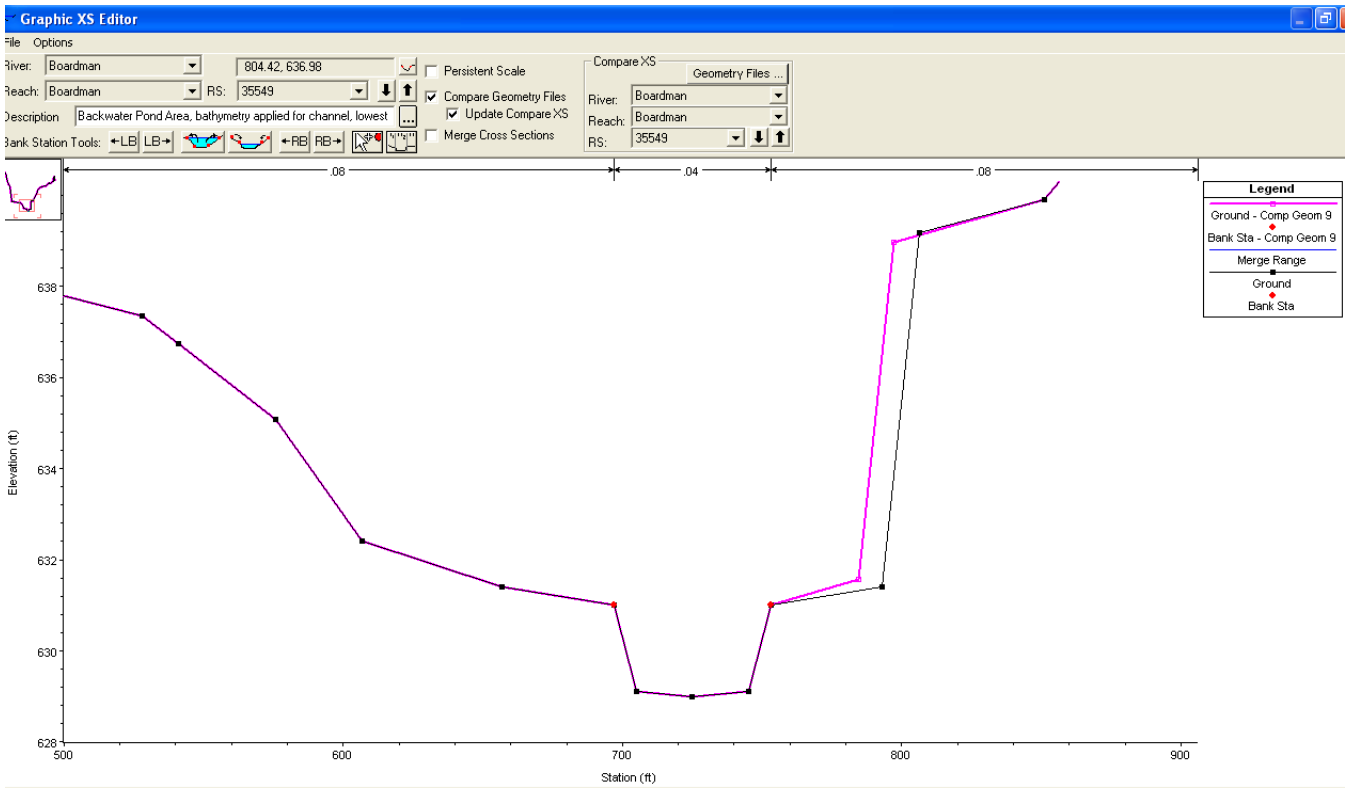
Original Design = 40 feet min floodplain benches (XS 35549 in the hydraulic model)



Recommended Design = 30 feet min floodplain benches (XS 35549 in the hydraulic model)

VALUE ENGINEERING RECOMMENDATION # VE-6

ADDITIONAL GRAPHICS



Comparison of Cross-sections – The black line is the original design and the red line is the recommended design (XS 35549 in the hydraulic model).

VALUE ENGINEERING RECOMMENDATION # VE-6

CALCULATIONS

Boardman impoundment length = 4,000 feet
Depth of saved dredging = 5 feet (some are 10 feet and some are only 3 feet)
Width of saved dredging = 10 feet (most cross-sections are only effected on one overbank)

Volume of saved dredge material = 200,000 cubic feet = 7,407 CY = 7,400 CY less excavated

HEC-RAS River: Boardman Reach: Boardman

Reach	River Sta	Profile	Plan	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Boardman	37769	2yr	Alt_Update_Flood	750.00	641.00	643.24	643.13	644.00	0.015240	7.01	112.31	103.82	0.89
Boardman	37769	2yr	AAA_Update_Flood	750.00	641.00	643.25	643.13	644.00	0.015065	6.98	112.97	105.08	0.89
Boardman	37769	100yr	Alt_Update_Flood	1500.00	641.00	644.20	644.20	645.16	0.012430	8.31	241.75	138.68	0.87
Boardman	37769	100yr	AAA_Update_Flood	1500.00	641.00	644.20	644.20	645.16	0.012430	8.31	241.75	138.68	0.87
Boardman	37241	2yr	Alt_Update_Flood	750.00	638.00	640.62	640.14	641.09	0.007661	5.62	162.58	716.83	0.65
Boardman	37241	2yr	AAA_Update_Flood	750.00	638.00	640.62	640.13	641.10	0.007724	5.64	158.14	702.03	0.66
Boardman	37241	100yr	Alt_Update_Flood	1500.00	638.00	641.79	641.23	642.33	0.005772	6.42	343.95	798.41	0.61
Boardman	37241	100yr	AAA_Update_Flood	1500.00	638.00	641.85	641.23	642.40	0.005666	6.43	335.66	794.42	0.60
Boardman	36974	2yr	Alt_Update_Flood	750.00	636.00	638.68	638.14	639.12	0.006916	5.43	171.86	262.01	0.62
Boardman	36974	2yr	AAA_Update_Flood	750.00	636.00	638.70	638.14	639.13	0.006800	5.41	169.63	251.38	0.62
Boardman	36974	100yr	Alt_Update_Flood	1500.00	636.00	639.29	639.23	640.15	0.010827	7.92	269.76	331.67	0.81
Boardman	36974	100yr	AAA_Update_Flood	1500.00	636.00	639.27	639.23	640.19	0.011465	8.12	255.56	320.20	0.83
Boardman	36546	2yr	Alt_Update_Flood	750.00	634.00	636.57	636.13	637.07	0.008352	5.77	177.63	370.18	0.68
Boardman	36546	2yr	AAA_Update_Flood	750.00	634.00	636.56	636.12	637.07	0.008587	5.84	170.74	366.48	0.69
Boardman	36546	100yr	Alt_Update_Flood	1500.00	634.00	637.40		637.81	0.006074	6.08	492.88	386.10	0.61
Boardman	36546	100yr	AAA_Update_Flood	1500.00	634.00	637.43		637.83	0.005848	6.00	500.05	386.56	0.60
Boardman	36010	2yr	Alt_Update_Flood	750.00	631.50	634.29		634.67	0.005796	5.12	185.82	142.17	0.58
Boardman	36010	2yr	AAA_Update_Flood	750.00	631.50	634.32		634.69	0.005578	5.06	185.40	130.96	0.57
Boardman	36010	100yr	Alt_Update_Flood	1500.00	631.50	635.39		635.89	0.005161	6.19	348.21	151.17	0.58
Boardman	36010	100yr	AAA_Update_Flood	1500.00	631.50	635.44		635.95	0.005109	6.21	338.59	141.39	0.58
Boardman	35549	2yr	Alt_Update_Flood	750.00	629.00	632.49		632.66	0.002050	3.60	310.39	188.99	0.36
Boardman	35549	2yr	AAA_Update_Flood	750.00	629.00	632.49		632.67	0.002132	3.67	296.96	180.37	0.36
Boardman	35549	100yr	Alt_Update_Flood	1500.00	629.00	633.59		633.84	0.002273	4.62	525.92	203.60	0.40
Boardman	35549	100yr	AAA_Update_Flood	1500.00	629.00	633.59		633.86	0.002392	4.74	503.03	194.92	0.41
Boardman	35120	2yr	Alt_Update_Flood	750.00	628.00	630.74		631.12	0.005982	5.14	189.78	173.93	0.58
Boardman	35120	2yr	AAA_Update_Flood	750.00	628.00	630.76		631.13	0.005726	5.05	195.43	174.40	0.57
Boardman	35120	100yr	Alt_Update_Flood	1500.00	628.00	631.50		632.07	0.007097	6.71	328.11	191.24	0.66
Boardman	35120	100yr	AAA_Update_Flood	1500.00	628.00	631.53		632.07	0.006761	6.59	335.85	191.84	0.65
Boardman	34963	2yr	Alt_Update_Flood	750.00	627.00	629.75	629.14	630.12	0.005813	5.07	196.50	201.40	0.58
Boardman	34963	2yr	AAA_Update_Flood	750.00	627.00	629.74	629.13	630.12	0.006062	5.16	187.61	179.13	0.59
Boardman	34963	100yr	Alt_Update_Flood	1500.00	627.00	630.70		631.04	0.004443	5.53	468.23	329.54	0.53
Boardman	34963	100yr	AAA_Update_Flood	1500.00	627.00	630.71		631.07	0.004498	5.58	457.20	320.65	0.54

Output from Reality Check in HEC-RAS

VALUE ENGINEERING RECOMMENDATION # VE-6

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Floodplain and dry channel excavation	CY	$10.00	1	92,000	$920,000	84,600	$846,000
Subtotal					$920,000		$846,000
Contingency	@	20%			$184,000		$169,200
Total					$1,104,000		$1,015,200

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-7

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize higher piles of sediment disposal to improve the efficiency of material movement.

ORIGINAL DESIGN:
The original design specifies using all 12 primary and 7 secondary disposal sites in Sabin and Boardman Ponds. On average this assumes approximate 3-4 feet deep sediment disposal areas.

RECOMMENDED CHANGE:
The VE Team recommends creating higher sediment disposal piles that are integrated with the existing valley walls (e.g. to create "fingers" into the valley) and reducing the number of disposal areas used.

ADVANTAGES:

- Reduce cycle times
- Increased non impacted surface area of former bottomlands/ reduced area of impact
- Design and shape landscape

DISADVANTAGES:

- Sufficient bearing capacity of soils
- Potential steep slopes to vegetate

JUSTIFICATION:
Concentrating disposal in few areas will reduce the area impacted by channel restoration. This could lead to increased areas of wetlands, improved vegetation growth success (due to less compaction) and more efficient sediment movement/ disposal operations.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$3,134,000	$0	$3,134,000
RECOMMENDED DESIGN	$2,821,000	$0	$2,821,000
ESTIMATED SAVINGS OR (COST)	$313,000	$0	$313,000

VALUE ENGINEERING RECOMMENDATION # VE-7

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Boardman Dam							
Channel bottom dredging	CY	$15.00	1	1,000	$15,000		
Floodplain and dry channel excavation	CY	$10.00	1	92,000	$920,000		
Road and dam excavation	CY	$8.00	1	68,000	$544,000		
Embankment earth	CY	$5.00	1	20,000	$100,000		
Channel bottom dredging	CY	$13.50	8			1,000	$13,500
Floodplain and dry channel excavation	CY	$9.00	8			92,000	$828,000
Road and dam excavation	CY	$7.20	8			68,000	$489,600
Embankment earth	CY	$4.50	8			20,000	$90,000
Sabin Dam							
Channel bottom dredging	CY	$15.00	1	200	$3,000		
Floodplain and dry channel excavation	CY	$10.00	1	74,000	$740,000		
Road and dam excavation	CY	$8.00	1	30,000	$240,000		
Embankment earth	CY	$5.00	1	10,000	$50,000		
Channel bottom dredging	CY	$13.50	8			200	$2,700
Floodplain and dry channel excavation	CY	$9.00	8			74,000	$666,000
Road and dam excavation	CY	$7.20	8			30,000	$216,000
Embankment earth	CY	$4.50	8			10,000	$45,000
Subtotal					$2,612,000		$2,350,800
Contingency	@	20%			$522,400		$470,160
Total					$3,134,400		$2,820,960

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-8

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize flexible pipes in conjunction with flex blocks to reduce the cost of breaching the dams in lieu of only using flex blocks.

ORIGINAL DESIGN:
The original design specifies using articulated concrete block maps to control erosion during breaching of Boardman Dam.

RECOMMENDED CHANGE:
The VE Team recommends using multiple 6-foot diameter flexible pipes to direct flow over Boardman Dam during the breaching operation.

ADVANTAGES:

- Reduces erosion/ scour potential during breaching
- Easy to move
- Reusable

DISADVANTAGES

- Potential for piping around conduit that could lead to dam failure
- Challenging to direct flow into conduit

JUSTIFICATION:
Using flexible pipe to transport water through the dam breach will meet design requirements for the breaching operations.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$312,000	$0	$312,000
RECOMMENDED DESIGN	$230,000	$0	$230,000
ESTIMATED SAVINGS OR (COST)	$82,000	$0	$82,000

VALUE ENGINEERING RECOMMENDATION # VE-8

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Armorflex	LS	$260,000	1	1	$260,000		
Flexible pipes	FT	$160.00	3			1,200	$192,000
Subtotal					$260,000		$192,000
Contingency	@	20%			$52,000		$38,400
Total					$312,000		$230,400

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-9

DESCRIPTIVE TITLE OF RECOMMENDATION:
Repurpose existing Union Street Dam auxiliary spillway/gates in lieu of constructing a new downstream fish passage.

ORIGINAL DESIGN:
The original design for fish passage at Union Street Dam specifies a "trap and transfer" operation at the Boardman River fish weir with modification to the dam to allow for downstream passage. Upstream passage would be accomplished by trapping sturgeon at the existing weir facility and transferring them to upstream locations. The operation would involve two fishery technicians with small craft-mounted electroshocking equipment to facilitate collecting the sturgeon, after which they would be lifted into a truck for transport upstream.

The original design provides for downstream passage by modifying the existing Union Street fish ladder location to be more conducive to passing adult sturgeon. This entails demolition of the existing structure and, on the same site, constructing new infrastructure that straightens, widens, and reduces the slope of the former ladder.

RECOMMENDED CHANGE:
The VE Team recommends that two additional alternatives for the downstream fish ladder be investigated in the interest of more fully utilizing existing infrastructure in meeting project objectives. These include:

1) Modify the existing auxiliary spillway (i.e., former millrace) to allow for downstream sturgeon passage; and
2) Modify the existing gate structure to allow for downstream sturgeon passage through one or more gates. This will entail some structural modifications, including a guidance/ attractant flow mechanism to direct sturgeon to the passage.

In both instances, the existing fish passage structure can remain in place for prospective use in passing other species.

VALUE ENGINEERING RECOMMENDATION # VE-9

DISCUSSION CONTINUED

ADVANTAGES:

- Maximizes use of existing infrastructure and site
- Reduces construction requirements
- Ease constructability
- Provides for design/ construction specific to sturgeon

DISADVANTAGES:

- Alternate sites may have flood control functions that may interfere/prevent usage for fish passage
- Gate modification may be substantial to ensure attractant/ guidance for sturgeon

JUSTIFICATION:

These two alternatives offer prospective means to facilitate downstream passage of sturgeon at available locations on the dam site, while taking advantage of existing infrastructure that can be modified. This will avoid demolition, re-design and construction requirements associated with the existing fish ladder, while meeting project objectives.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$432,000	$0	$432,000
RECOMMENDED DESIGN	$60,000	$0	$60,000
ESTIMATED SAVINGS OR (COST)	$372,000	$0	$372,000

VALUE ENGINEERING RECOMMENDATION # VE-9

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Demolition of Existing Spillway	CY	$60.00	1	345	$20,700		
Structural concrete (cast-in-place)	CY	$500.00	1	465	$232,500		
Gate	LS	$50,000	1	1	$50,000	1	$50,000
Earthworks	CY	$10.00	1	4,501	$45,007		
Site Clearing	AC	$7,500	1	1	$7,500		
Fencing/ Railings	FT	$15.00	1	310	$4,650		
Subtotal					$360,357		$50,000
Contingency	@	20%			$72,071		$10,000
Total					$432,429		$60,000

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-10

DESCRIPTIVE TITLE OF RECOMMENDATION:
Reduce the width of the wildlife corridors below the bridge to the minimal width possible to reduce the length of the bridge.

ORIGINAL DESIGN:
The original design specifies the replacement of the Cass Road Bridge once the Boardman Dam is removed. The design entails a three-span, side-by-side concrete box beam bridge that incorporates a "top-down" construction technique. The center span will be supported 36" diameter drilled shafts that would be poured up to the bottom of the proposed pier cap. The center span is assumed to be 100', allowing the contractor to do the excavation work for the Boardman River cross section after the drilled shafts are poured. Once the contractor has completed the excavation work, the drilled shafts above the new finished grade become columns supporting the proposed superstructure. The end spans would be approximately 65 feet long with short stub abutments at the top of a 1:2 slope. This will eliminate the need for expensive cofferdams, tremie concrete, and dewatering operations. In addition, equipment access will be easier given that the drilled shafts will be installed at the existing Cass Road elevation.

The original design provides for a 25-foot corridor on both sides of channel, at an approximate elevation of the floodplain bench.

RECOMMENDED CHANGE:
The VE Team recommends that the original design be modified to reduce the overall span length from 230 feet (100-foot center span and two 65-foot end spans) to 200 feet, comprised of a 70-foot center span and two end spans of 65 feet. This will reduce the wildlife corridor from 20 feet to 5 feet on each side of the channel.

ADVANTAGES:
- Reduce bridge span length
- Reduce prep work/excavation
- Shorten construction duration
- Ease constructability
- Minimize disruption during construction

DISADVANTAGES:
- Reduce desirable habitat
- Limit/prevent potential wildlife usage during high flow periods
- Reduce usage by species that prefer more corridor space/cover

JUSTIFICATION:
The modification will provide for a viable wildlife corridor while resulting in the several advantages identified above. It will have no adverse impact on the physical characteristics or ecological health of the restored river.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$1,178,000	$0	$1,178,000
RECOMMENDED DESIGN	$1,106,000	$0	$1,106,000
ESTIMATED SAVINGS OR (COST)	$72,000	$0	$72,000

VALUE ENGINEERING RECOMMENDATION # VE-10

CALCULATIONS

The original designed bridge length (at the top) is 230 feet. The bottom of the bridge it is 140 feet long with 1:2 slopes to short abutments.

The VE Team assumes the superstructure is 44% of the cost and the substructure is 56% of the cost ($518,000 / $1,174,000).

No substructure cost will be saved with this option. Assuming shortening the bridge from 140 feet to 100 feet at the bottom, the overall length of the bridge would change from 230 feet to 190 feet. This could save approximately:

40 feet/230 feet = 17% on the cost of the superstructure or 17% * $518,000 = $88,000 or to state it another way, 17% of 44% or 7.5% of the total cost of the bridge.

VALUE ENGINEERING RECOMMENDATION # VE-10

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Proposed Cass Street Bridge	LS	$970,000	1	1	$970,000	0.95	$921,500
Excavation	CY	$4.00	3	3,000	$12,000		
Subtotal					$982,000		$921,500
Contingency	@	20%			$196,400		$184,300
Total					$1,178,400		$1,105,800

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-11

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize 1v:3h side slopes for the bank full sides under the bridge in lieu of 1v:6h side slopes to reduce the total bridge span.

ORIGINAL DESIGN:
The original design specifies a 1v:6h side slope for the river banks up to the bank full capacity. At the Cass Road bridge, the span of the bridge (currently 100 feet) is established by the bank full width (60 feet), the bank side slopes and the width of the wildlife corridor (20 feet) on each side.

RECOMMENDED CHANGE:
The VE Team recommends increasing the side slopes from 1v:6h to 1v:3h to reduce the bridge span. Assuming a depth of flow at the bridge of 5 feet, the change in side slope would result in reducing the bridge span by 30 feet.

ADVANTAGES:
- Smaller bridge span
- Reduced excavation
- Ease constructability

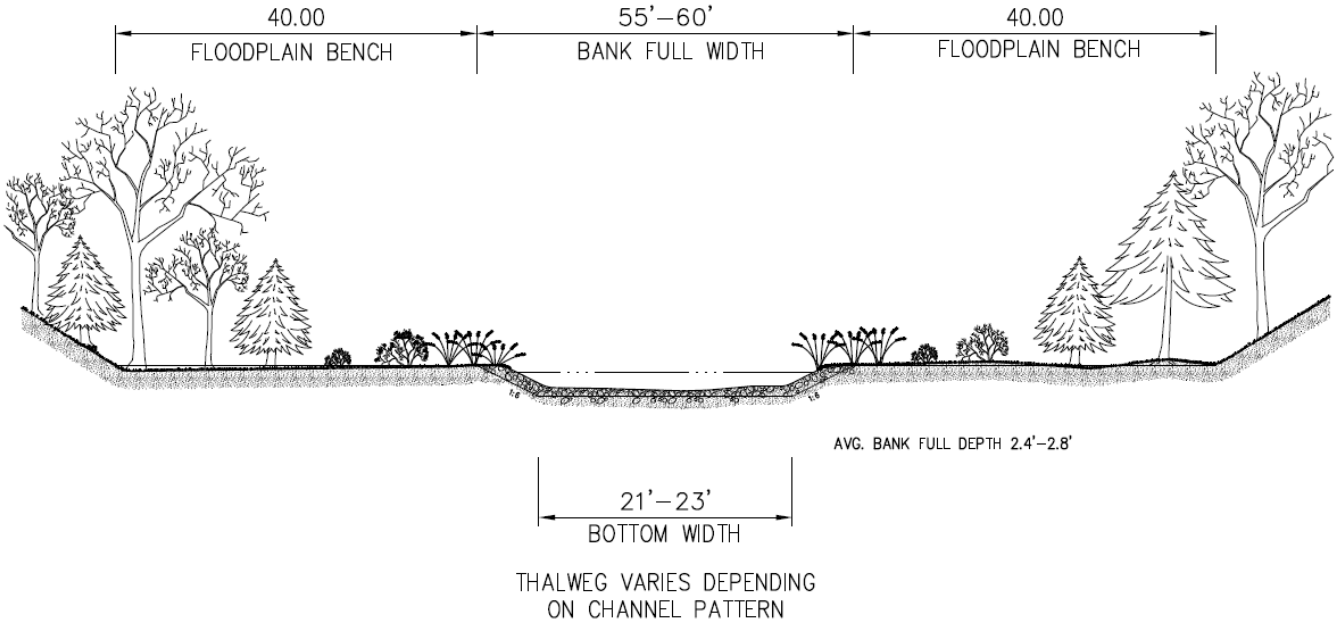
DISADVANTAGES:
- Increase in depth of flow under bridge
- Less maintainable slope
- Bank erosion control measures may be needed

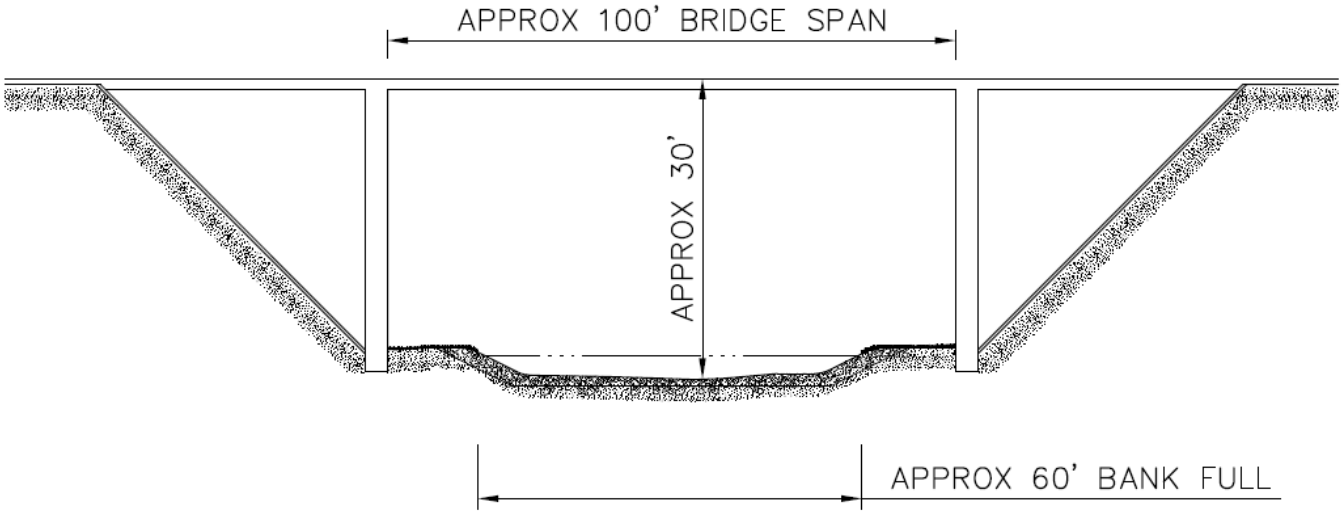
JUSTIFICATION:
An increase in side slope of the river bank will reduce the span of the bridge structure and result in a small reduction in the volume of excavation. Although the steeper slope will result in a less maintainable surface, erosion control measures along this short length of river section will be more than offset by the reduction in cost associated with the reduced bridge span.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$697,000	$0	$697,000
RECOMMENDED DESIGN	$555,000	$0	$555,000
ESTIMATED SAVINGS OR (COST)	$142,000	$0	$142,000

VALUE ENGINEERING RECOMMENDATION # VE-11

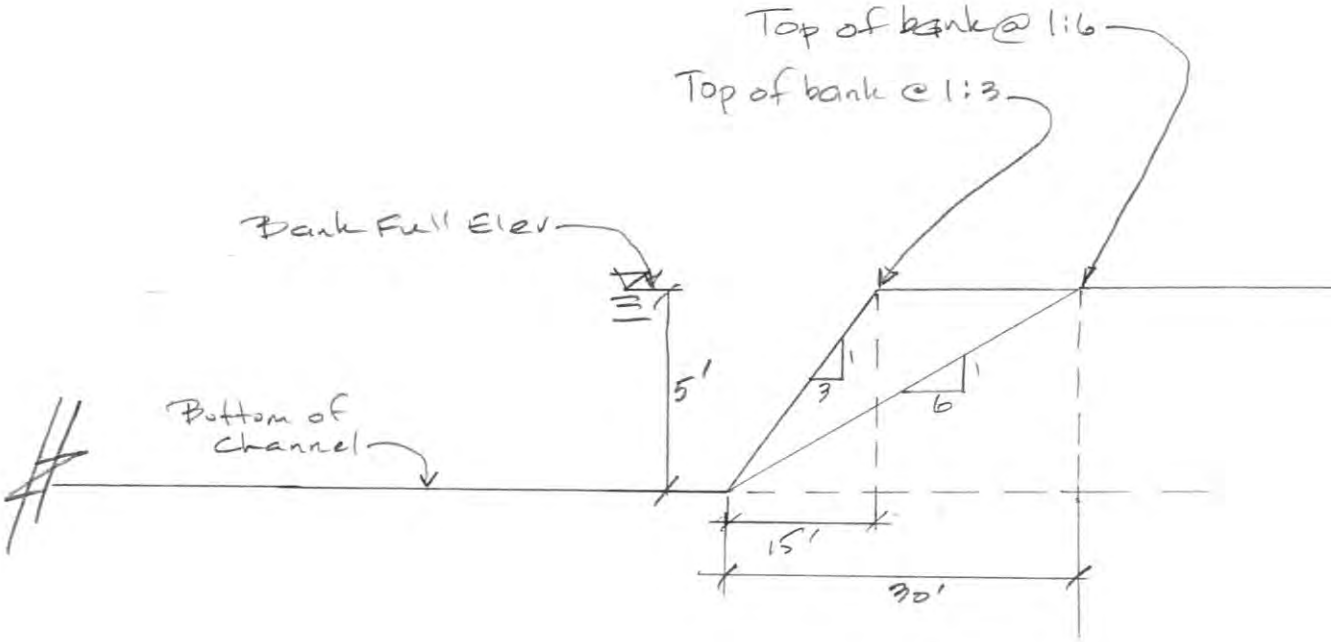
SKETCH OF ORIGINAL DESIGN





PROPOSED CASS ROAD BRIDGE SECTION

SKETCH OF RECOMMENDED DESIGN



Recommended River Cross Section

CALCULATIONS

Assume:

- 5 feet depth of flow under bridge
- 50 feet wide bridge deck
- 100 feet bridge span
- 160 feet total bridge length

At 1:6 side slope,
Length to top of bank = 5 feet * 6 = 30 feet

Excavation = (5 feet*30 feet) /2 * 2 sides = 120 SF *50 feet wide = 6,000 CF / 27 = 222.2 CY, say 225 CY

At 1:3 side slope,
Length to top of bank – 5 feet * 3 = 15 feet

Excavation = (5 feet * 15 feet) /2 * 2 sides = 75 SF *50 feet wide = 3750 CF / 27 = 138.9 CY, say 140 CY

Results in reduction in bridge span of 15 feet each side (30 feet total)

Original design = 50 feet * 160 feet deck with 320 feet of railing (160 feet each side)

Recommended design = 50 feet * 130 feet deck with 260 feet of railing (130 feet each side)

VALUE ENGINEERING RECOMMENDATION # VE-11

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Bridge deck	SF	$52.50	1	8,000	$420,000	6,500	$341,250
Bridge railing	LF	$465.00	3	320	$148,800	260	$120,900
Excavation	CY	$4.00	3	3,000	$12,000		
Subtotal					$580,800		$462,150
Contingency	@	20%			$116,160		$92,430
Total					$696,960		$554,580

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / detail
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING RECOMMENDATION # VE-12

DESCRIPTIVE TITLE OF RECOMMENDATION:
Utilize targeted active restoration on stream banks and steep slopes in lieu of passive restoration.

ORIGINAL DESIGN:
The original design specifies no active restoration on non steep slopes. Non steep slopes would self vegetate. The original design provides minimum restoration on steep slopes only.

RECOMMENDED CHANGE:
The VE Team recommends targeted active restoration on stream banks and steep slopes. Development of vegetation at the stream bank reduces erosion and stabilizes the stream bank channel which reduces downstream sedimentation and impacts to the aquatic resources. Active restoration includes placement of live stakes, top soil and seeding to establish a permanent vegetation cover.

Live stakes are live, woody cuttings which are inserted and tamped into the soil. If correctly handled, prepared, and placed, the live stake will root and grow. A system of live stakes is used to create a living root mat that stabilizes the soil by reinforcing and binding soil particles together, and by extracting excess soil moisture. Dense root masses also can prevent erosive forces from dislodging and moving soil particles. Examples of live stakes include; willow, tag elder, red ozer dogwood, or gray dogwood.

ADVANTAGES:
- Reduce erosion
- Stabilizes banks
- Minimize downstream sediment impacts
- Can be accomplish with unskilled labor

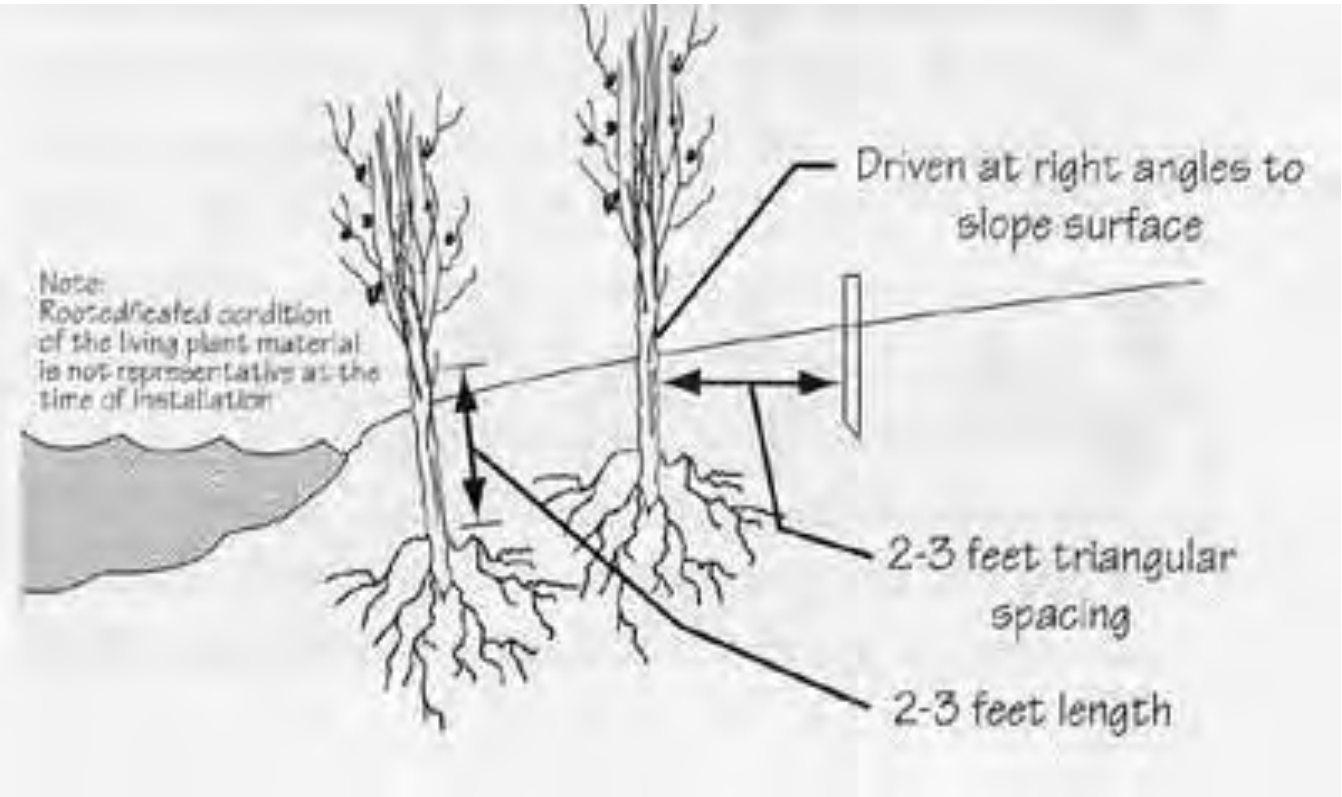
DISADVANTAGES:
- Additional labor efforts required
- Seasonally restricted, for best success must be completed early in spring

JUSTIFICATION:
The stream bank will be stabilized with vegetation thus providing shade for the river, a vegetated riparian corridor for streamside habitat, and minimize sediment input into the river system which protects the downstream habitat.

SUMMARY OF COST ANALYSIS			
	First Cost	O & M Costs (Present Worth)	Total LC Cost (Present Worth)
ORIGINAL DESIGN	$0	$0	$0
RECOMMENDED DESIGN	$24,000	$0	$24,000
ESTIMATED SAVINGS OR (COST)	($24,000)	$0	($24,000)

VALUE ENGINEERING RECOMMENDATION # VE-12

SKETCH OF RECOMMENDED DESIGN



VALUE ENGINEERING RECOMMENDATION # VE-12

COST ESTIMATE - FIRST COST

Cost Item	Units	$/Unit	Source Code	Original Design		Recommended Design	
				Num of Units	Total $	Num of Units	Total $
Live Stakes Installed	EA	$3.00	7			6,666	$19,998
Subtotal					$0		$19,998
Contingency	@	20%			$0		$4,000
Total					$0		$23,998

SOURCE CODE:
1 Project Cost Estimate
2 USACE Average Bid
3 TRACES Data Base
4 Means Estimating Manual
5 National Construction Estimator
6 Vendor Lit or Quote (list name / details)
7 Professional Experience (List job if applicable)
8 Other Sources (specify)

VALUE ENGINEERING DESIGN COMMENT # VE-13

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Elevate the profile downstream of Boardman Dam to reduce the amount of sediment removed during construction.

COMMENTARY:
Utilize a rock ramp or engineered riffle to raise the profile of the restored channel above the pre-dam grade. This will allow currently impounded sediment to remain in place; thus, reducing the volume of sediment that needs to be handled during construction and restoration of the impoundment. In addition, the depth of excavation at the dam could be reduced. To determine if this is a feasible approach and to quantify benefits and costs depth of refusal data for Boardman impoundment is required.

VALUE ENGINEERING DESIGN COMMENT # VE-14

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Allow sediment to travel down the river in the amount that will not degrade riffle pool habitat in lieu of not allowing sediment travel.

COMMENTARY:
The silt and clay fraction of the sediments in the impoundments is approximately 20-25%. A significant portion of these fines in the reconstructed river channel will migrate downstream but not degrade riffle and pools in the river because of the long settling times. Some of the fines will not settle out until the water velocity slows to allow setting in West Bay. Silt fence in the river flows is not considered a viable alternative because river velocity and flows are too great to capture the silt/clay faction. This can be estimated with sediment transport modeling, and it can be verified by monitoring in the field.

Construction of a new river channel in the dry and then routing the river will increase costs significantly and likely will not provide any additional benefits to the ecosystem restoration. The proposed plan does include a controlled drawdown at a rate that minimally impacts the downstream aquatic resources.

VALUE ENGINEERING DESIGN COMMENT # VE-15

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Utilize temporary cofferdams (i.e. Hesco Baskets) to dry out work zones where applicable in lieu of working in the wet.

COMMENTARY:
The preferred design alternative currently proposed removal of the Boardman and Sabin Dams either partially in the wet or entirely in the wet. These items are noted as "Critical" on the Feasibility Study Cost Risk Analysis, specifically noted as items CC-4 and CC-8. The noted risks associated with working in the wet is errors and mistakes could cause erosion and or loss of the dams, complexity of construction at Boardman due to the process of breaching the dam and the time it can take to lower the water, and potential unsafe working for the contractors equipment and personnel. One economical way to ensure a safer and less risky construction operation is to utilize temporary cofferdams to have operations of dam removal occur in the dry which is a much safer operation, allows for better quality control, and can help with higher production from the Contractor.

One economical temporary cofferdam that seems appropriate for this project is the use of Hesco Baskets (pictured below) or an equally performing product. The container basket design provides a cellular structure, using a welded mesh framework and geotextile lining. When joined and filled, the system can be used to create walls of exceptional strength and structural integrity. All products are pre-assembled and delivered packed flat, with joining pins to enable the connection of individual units. For this project on-site material and or sediment material could be utilized to fill the baskets.

Photograph of Hesco Baskets Holding Back Flood Waters

VALUE ENGINEERING DESIGN COMMENT # VE-16

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Allow hydraulic methods of dredging in lieu of specifying only mechanical dredging.

COMMENTARY:
Various methods of moving sediment from the proposed channel to a shoreline disposal area are available. These methods include hydraulic dredging, mechanical dredging using scrapers and mechanical dredging from a barge.

Hydraulic dredging would allow much of the sediment to be removed from the channel prior to drawdown. Hydraulic dredging would require a floating platform with pumps and piping to transfer the sediments to the disposal area.

Mechanical dredging using a scraper would require the area to be drained prior to removing sediment; however, the excavating equipment can be used to move the material to the disposal area.

Mechanical dredging from a barge would utilize a clamshell or dragline dumping into a hopper, then pumping to the shoreline disposal area. This method could also be used prior to drawdown of the river section.

VALUE ENGINEERING DESIGN COMMENT # VE-17

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Conduct an "all-hands" meeting of regulators at all levels to review the project and verify regulatory requirements early in the process.

COMMENTARY:
Time and cost savings will be realized if environmental compliance and associated permitting requirements at the federal, state and local levels can be coordinated and harmonized in the early stages of the project implementation process. To facilitate this, an "all hands" meeting should be held to:

1. Introduce all regulators and other relevant parties to project goals, objectives, designs and implementation plans;
2. Review all environmental compliance regulations/ permitting requirements in detail (including data/information needs, submittal requirements, review procedures, agency Points of Contact, and decision making timeframe);
3. Discuss means to coordinate the permitting submittal and review process among agencies to enhance efficiency and avoid "down time" and associated scheduling delays;
4. Develop a schedule addressing permit submittal and approval milestones, as well as initiation/ completion of permitted activity; and
5. Establish and maintain a mechanism for ongoing coordination/ communication among all regulatory agencies over the course of the project.

The "all hands" meeting should be designed and conducted soon after detailed design on the selected alternative is initiated. Meeting outcomes (e.g., schedule for permit submittal and approval, start-up/ completion of permitted activities) should then be fully integrated into the overall project implementation schedule. Cost savings will be realized due to avoidance of "down time" and other undue delays as permits are processed; efficiencies realized from fully coordinated environmental compliance activities; and reduced likelihood of "late stage" design changes due to unanticipated issues with permit applications.

VALUE ENGINEERING DESIGN COMMENT # VE-18

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Evaluate the real estate implications throughout the project to reduce total project cost.

COMMENTARY:
Real Estate acquisition and associated costs can be a significant factor in the potential viability of a recommended alternative, from both a cost and time perspective. As such, it is imperative that all real estate implications be identified and thoroughly evaluated as soon as possible in the project process. Efforts should be made to minimize obtaining private property easements/fee acquisitions to keep costs down and to avoid delays in project implementation.

VALUE ENGINEERING DESIGN COMMENT # VE-19

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Allow the bridge to be designed and constructed by the county as an in-kind effort in lieu of integrating into USACE construction contract.

COMMENTARY:
The recommended alternative includes relocating the Boardman River to its historical channel location, west of the existing Boardman Dam powerhouse structure. This alternative involves designing and constructing a new Cass River roadway bridge over relocated channel. These efforts are typically included in the USACE preparation of plans and specifications and in the USACE construction contract. However, given the potentially large cost of this specific effort and the fact that the State of Michigan intends to provide Grand Traverse County with funds for the bridge-related work, it may be prudent for the County to design and construct the relocated bridge independent of the USACE. Whether this work is performed as part of the USACE project or performed independently by the NFS, details of how these efforts would be included in overall project cost-sharing will be specified in the Project Partnership Agreement (PPA) based on USACE policy and GLFER authority guidance.

VALUE ENGINEERING DESIGN COMMENT # VE-20

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Consider all contracting options (e.g. multiple contract, single contract) to improve the project schedule.

COMMENTARY:
Upon approval of the Detailed Project Report (DPR) and execution of the Project Partnership Agreement (PPA), the project will proceed to the Implementation Phase upon receipt of additional project funds. The Implementation Phase consists of detailed design, preparation of Plans and Specifications, and construction of the project. Since the project will ultimately consist of construction efforts at three (3) different dams, it may be advantageous to utilize an acquisition strategy which would involve multiple contracts rather than one all-inclusive construction contract. If it is determined that this would expedite the overall project schedule or benefit overall implementation of the project, an acquisition strategy to reflect such would be pursued. As an alternative, it may be beneficial to consider one all-inclusive contract, consisting of a base portion and options.

VALUE ENGINEERING DESIGN COMMENT # VE-21

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Encourage Michigan Department of Natural Resources (MDNR) to begin a sturgeon monitoring program and initiate a rearing operation (if necessary) when the dams have been removed.

COMMENTARY:
Dam removal and restoration of the natural channel will provide suitable habitat for spawning of a variety of fishes. The VE Team recommends determining the number of adult sturgeon in the river in the spring spawning period (May-June), and if the adult numbers are insufficient to provide a suitable spawning population to move upstream by trap and transfer, then provide additional juveniles through outside or streamside hatchery facilities to establish a population for passage in the next 25 years.

VALUE ENGINEERING DESIGN COMMENT # VE-22

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Secure a long-term operation and maintenance agreement with a non-federal entity for the trap-transport operation.

COMMENTARY:
Both the City of Traverse City and Grand Traverse County are serving as the non-Federal Project Sponsors (NFS) for the Boardman River Dams project. In order for the project to proceed to the Implementation Phase, a Project Partnership Agreement (PPA) will need to be executed between the Corps of Engineers (USACE) and the NFS's. The proposed plan for modifications of Union Street Dam includes trapping sturgeon at the existing MDNR fish weir and transporting these trapped sturgeon for release in the Boardman River upstream of Union Street Dam. It is expected that MDNR employees will perform these trap and transfer efforts. However, since the PPA will be between the USACE and the joint NFS's rather than the MDNR, a separate long-term O&M agreement with the MDNR to perform this operation may be desired to ensure expected project benefits are achieved.

VALUE ENGINEERING DESIGN COMMENT # VE-23

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Utilize existing crane at the fish sorting facility in lieu of a new fish lift/elevator.

COMMENTARY:
Since there is an existing hoist/monorail at the fish processing facility, and the fish lift will require a lifting mechanism, it may be possible that the existing hoist could be used to lift a fabricated box to transfer sturgeon from the downstream side of the dam to the transfer vehicle.

Before deciding on this method, several items will need to be evaluated during the design phase. These items include:

- Is the capacity of the existing hoist adequate for lifting the transfer box, fish and water?
- Is the hoist cable of suitable capacity and length?
- Is the monorail located properly for access to both the transfer box and transfer onto a truck bed?
- Is there vehicle access to allow the transfer vehicle to back into the proper position?
- Is there space within the existing fish processing facility for the transfer box?
- What is the age and condition of the existing hoist/monorail?
- Is the hoist/monorail electric or manual?

VALUE ENGINEERING DESIGN COMMENT # VE-24

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Minimize the labor necessary associated with the fish elevator at the Boardman River Weir (i.e. the James T. Price Facility) downstream of the Union Street Dam.

COMMENTARY:
As currently proposed, costs associated with the fish elevator at the weir and downstream of Union Street Dam could prove to be substantial in terms of capital requirements (e.g., transport truck, boat, electroshocking equipment, related items), labor (two seasonal fishery technicians), and ongoing operations and maintenance costs. Cost savings may be realized by investigating and implementing various measures, such as:

1. Developing and adopting alternate fish handling strategies (e.g., attractant flow/ guidance into the fish lift) that may eliminate the need for fish capture as well as a boat, associated equipment and labor requirements); and/or

2. Securing the services of trained volunteers to operate the fish elevator.

VALUE ENGINEERING DESIGN COMMENT # VE-25

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Utilize a performance specification for the fish elevator/lift system in lieu of a proprietary system.

COMMENTARY:
Utilize a performance specification in the design phase of the project for the proposed elevator/lift system at the weir facility to bring sturgeon and water to truck level which allows the trap and transfer operation to take place. If a detailed specification with a specific manufacturer is utilized during design this can limit competition of other suitable manufacturers and will also require sole source approval from USACE Contracting Office to be in accordance with the Federal Acquisition Regulations. By utilizing a performance spec the offeror/contractors will be required to provide a fish elevator/lift system that meets certain criteria and has measurable performance requirements.

Two generic categories of program-unique specifications are performance specifications and detail specifications.

- **Performance Specifications —** States requirements in terms of the required results without stating the method for achieving the required results, functional and performance (what and how well), the environment in which product(s) must operate; interface and interchangeability characteristics, and criteria for verifying compliance.

- **Detail Specifications —** Specifies requirements in terms of material to be used; how a requirement is to be achieved; and how a product is to be assembled, integrated, fabricated or constructed. Applicable to development of contractor final design drawings as well as items being built, coded, purchased, or reused.

	Performance	**Detail / Design**
Design and Fabricate	Require desired outcomes or functions, specific design to contractor	Specify exact parts and components
Processes	Few, if any	Specify exact processes
Physical Characteristics	Give specifics only for interfaces, environment, or human factors	Specify more physical characteristics than for interfaces, environment, etc.
Interface Requirements	Detailed interface data do **not** solely make a perf. spec. a detail spec.	Detailed interface data
Materials	Leave specifics to contractor	Require specific materials
Test and Evaluation	State performance need; contractor picks test procedure	Prescribed testing process

VALUE ENGINEERING DESIGN COMMENT # VE-26

DESCRIPTIVE TITLE OF DESIGN COMMENT:
Reduce the cost of the fish elevator by shopping multiple vendors.

COMMENTARY:
The cost estimate for the fish lift (i.e., elevator) was derived from a quote provided by a single vendor. Cost savings may be realized by:

1. Identifying multiple additional vendors (as available), and bidding the purchase on a competitive basis; and/ or

2. Providing fish lift specifications to multiple manufacturers and solicit bids for construction and installation.

APPENDICES

The appendices in this report contain backup information supporting the body of the report, and the mechanics of the workshop. The following appendices are included.

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A. Study Participants A-2

B. Cost Information A-5

C. Function Analysis A-7

D. Creative Idea List and Evaluation A-10

E. VE Agenda A-13

F. Action Summary Sheet A-17

APPENDIX A
Study Participants

APPENDIX A – Study Participants

Workshop Attendance

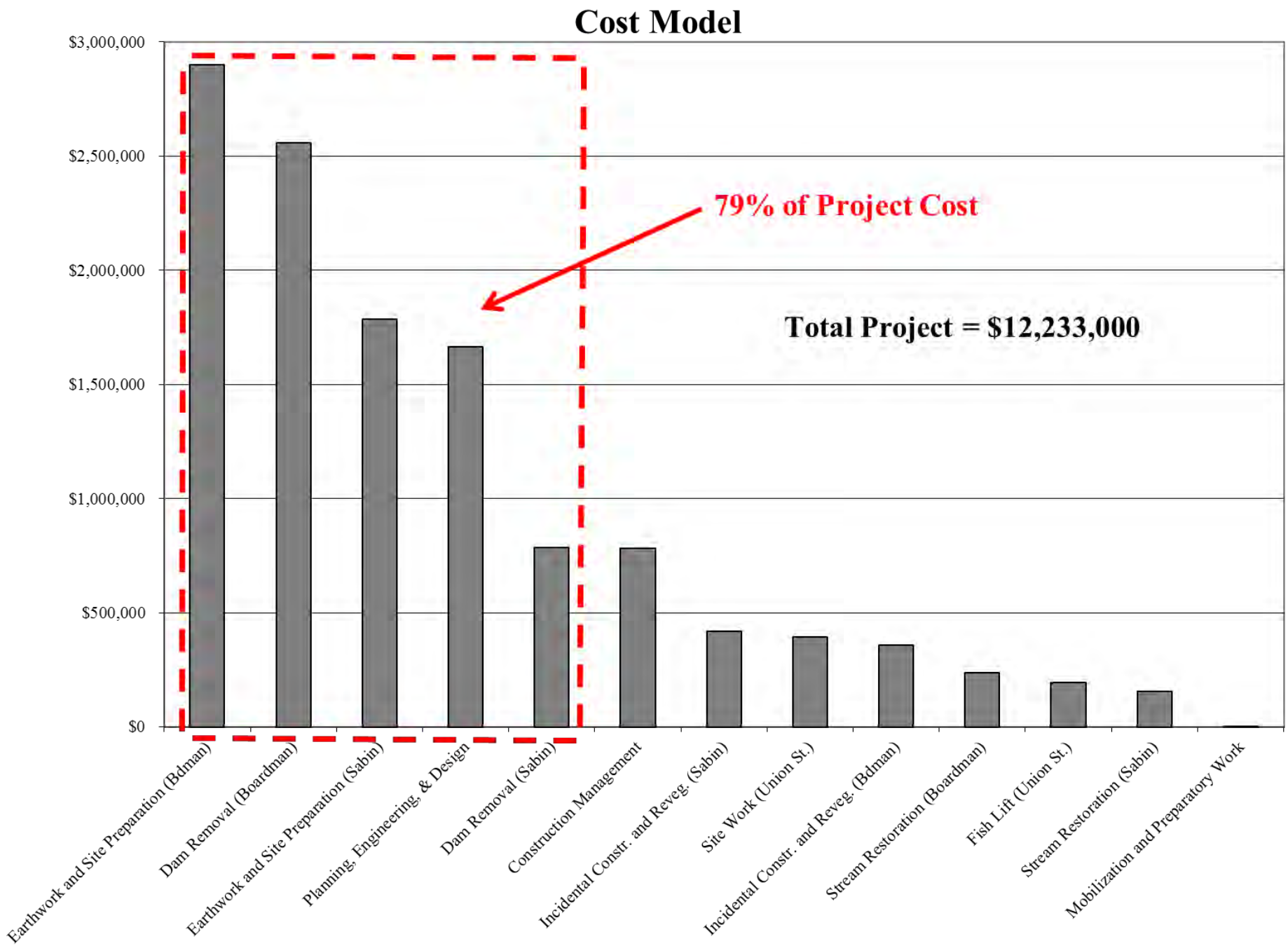
Attendees				Participation					
				Meetings			Study Sessions		
Name	**Organization and Address (Organization first, with complete address underneath)**	**Tel # and Email (Tel first with Email underneath)**	**Role in Workshop**	**Intro**	**Out Brief**	**Implem**	**Day 1**	**Day 2**	**Day 3**
Mark Allen	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	Mark.S.Allen@usace.army.mil	USACE Representative		X				
Paul Allerding	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	Paul.H.Allerding@usace.army.mil	USACE Representative		X				
Frank Dituri	Grand Traverse Band of Ottawa & Chippewa Indians 2605 N West Bay Shore Drive Peshawbestown, MI 49682	231-534-7358 Frank.Dituri@gtbindians.com	Non-Federal Sponsor Representative	Via Phone					
Mike Donahue	URS Corporation 27777 Franklin Road, Suite 2000 Southfield, MI 48034	248-204-4953 Michael.Donahue@urs.com	Joint Venture Project Manager	X	X	Via Phone	X	X	X
Brett Fessell	Grand Traverse Band of Ottawa & Chippewa Indians 2605 N West Bay Shore Drive Peshawbestown, MI 49682	231-534-7655 Brett.fessell@gtbindians.com	Non-Federal Sponsor Representative	Via Phone					
Hal Harrington	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	313-226-5043 Hal.f.harrington@usace.army.mil	Biologist	X		X	X	X	X
John Love	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	John.B.Love@usace.army.mil	USACE Representative			X			
Bill Merte	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	William.D.Merte@usace.army.mil	USACE Representative		X				
Troy Naperala	URS Corporation 27777 Franklin Road, Suite 2000 Southfield, MI 48034	231-922-4301 Troy.Naperala@urs.com	Deputy Project Manager/Lead Engineer	X	Via Phone	Via Phone	X	X	X
Tom O'Brien	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226		USACE Representative		X				
Carl Platz	USACE Detroit District P.O. Box 629 Grand Haven, MI 49417	616-842-5510x25521 Carl.a.platz@usace.army.mil	USACE Project Manager	X	X	X	X	X	X
Leigh Ann Ryckeghem	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	313-226-6371 Leigh.a.ryckeghem@usace.army.mil	Civil Engineer/VEO	X	X	X	X	X	X

Workshop Attendance

Attendees				Participation					
				Meetings			Study Sessions		
Name	**Organization and Address (Organization first, with complete address underneath)**	**Tel # and Email (Tel first with Email underneath)**	**Role in Workshop**	**Intro**	**Out Brief**	**Implem**	**Day 1**	**Day 2**	**Day 3**
Nancy Salisbury	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	313-226-6070 Nancy.S.Salisbury@usace.army.mil	USACE Representative			X			
Kyle Schafersman	URS Corporation 8300 College Boulevard, Suite 200 Overland Park, KS 66210	913-579-4286 Kyle.Schafersman@urs.com	VE Team Leader	X	Via Phone	Via Phone	X	X	X
Eric Taurianinen	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	Eric.C.Tauriainen@usace.army.mil	USACE Representative		X				
Scott Thieme	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	Scott.J.Thieme@usace.army.mil	USACE Representative		X				
Shelley Tule	USACE Detroit District 477 Michigan Avenue Detroit, MI 48226	313-226-3403 Shelley.j.tule@usace.army.mil	Hydraulic Engineer	X		X	X	X	X
Terry Woodward	URS Corporation 27777 Franklin Road, Suite 2000 Southfield, MI 48034	248-204-5900 Terry.Woodward@urs.com	Cost Estimator	X			X	X	X

APPENDIX B
Cost Information

APPENDIX B – Cost Information


Cost Model
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
79% of Project Cost
Total Project = $12,233,000
Earthwork and Site Preparation (Bdman)
Dam Removal (Boardman)
Earthwork and Site Preparation (Sabin)
Planning, Engineering, & Design
Dam Removal (Sabin)
Construction Management
Incidental Constr. and Reveg. (Sabin)
Site Work (Union St.)
Incidental Constr. and Reveg. (Bdman)
Stream Restoration (Boardman)
Fish Lift (Union St.)
Stream Restoration (Sabin)
Mobilization and Preparatory Work

APPENDIX C
Function Analysis

APPENDIX C – Function Analysis

Function Model

Item	Cost	Function
Total Construction	$12,233,000	Restore cold water habitat Improve aquatic habitat Restore connectivity of river segments Permit flow of woody debris Pass sturgeon from Lake Michigan Increase Biomass density of brook trout/dace
Earthwork and Site Preparation (Boardman)	$2,900,000	Restore historic stream profile Minimize habitat damage Maintain traffic connectivity
Dam Removal (Boardman)	$2,559,000	Minimize habitat damage Free space for sediment disposal Restore historic stream profile Allow fish passage Restore cold water habitat
Earthwork and Site Preparation (Sabin)	$1,786,000	Restore historic stream profile Minimize habitat damage
Planning, Engineering, & Design	$1,665,000	Determine/ensure viable project Develop detailed design Finalize cost estimate Gather field data Coordinate stakeholders Prepare project for construction
Dam Removal (Sabin)	$784,000	Minimize habitat damage Free space for sediment disposal Restore historic stream profile Allow fish passage Restore cold water habitat
Construction Management	$783,000	Ensure project built as designed Control quality/cost/schedule Ensure regulatory compliance Support construction with engineering
Incidental Construction and Revegetate (Sabin)	$418,000	Manage erosion Supply construction access Restore ecosystem
Site Work (Union St.)	$394,000	Allow fish passage Preserve sea lamprey control Increase spillway capacity Allow adult sturgeon downstream passage Maintain public safety
Incidental Constr. and Revegetate (Boardman)	$358,000	Manage erosion Supply construction access Restore ecosystem

Item	Cost	Function
Stream Restoration (Boardman)	$235,000	Control grade Enhance aquatic habitat Stabilize channel
Fish Lift (Union St.)	$193,000	Lift fish Allow sturgeon passage Sort fish
Stream Restoration (Sabin)	$155,000	Control grade Enhance aquatic habitat Stabilize channel
Mobilization and Preparatory Work	$3,000	Move equipment and people

APPENDIX D
Creative Idea List and Evaluation

APPENDIX D – Creative Idea List and Evaluation

List of Creative Ideas			
ID #	**Name of Idea / Description**	**Develop Status**	**Team Member Responsible**
1	Utilize higher piles of sediment disposal to improve the efficiency of material movement	1	T. Naperala & H. Harrington
2	Elevate the profile downstream of Sabin Dam to reduce the amount of sediment removed during construction	2	T. Naperala & H. Harrington
3	Elevate the profile downstream of Boardman Dam to reduce the amount of sediment removed during construction	DC	T. Naperala
4	Retain Sabin Dam Powerhouse in lieu of removal	1	C. Platz
5	Retain Boardman Dam Powerhouse in lieu of removal	1	C. Platz
6	Eliminate the requirement for woody debris to flow down the river	4	
7	Utilize Sabin spillway alignment in lieu of the historical channel alignment	1	H. Harrington
8	Allow the Sabin Dam spillway concrete basin to remain as the new alignment in lieu of removing the concrete and returning the channel to a natural base	3	
9	Utilize a narrower excavated floodplain bench than the original design for the Sabin impoundment	2	S. Tule
10	Utilize a narrower excavated floodplain bench than the original design for the Boardman impoundment	2	S. Tule
11	Allow sediment to travel down the river in the amount that will not degrade riffle pool habitat in lieu of not allowing sediment travel	DC	H. Harrington
12	Allow hydraulic methods of dredging in lieu of specifying only mechanical dredging	DC	T. Woodward
13	Utilize flexible pipes in conjunction with flex blocks to reduce the cost of breaching the dams in lieu of only using flex blocks	2	T. Naperala & H. Harrington
14	Minimize the labor necessary associated with the fish elevator at Union Street Dam	DC	M. Donahue
15	Secure a long-term operation and maintenance agreement with a non-federal entity for the trap-transport operation	DC	C. Platz
16	Modify the existing downstream fish ladder at Union Street Dam in lieu of replacement	4	
17	Reduce the cost of the fish elevator by shopping multiple vendors	DC	M. Donahue
18	Consider alternative locations of the fish ladder at Union Street Dam	2	M. Donahue
19	Utilize a performance specification for the fish elevator in lieu of a proprietary system	DC	L. Ryckeghem
20	Evaluate the real estate implications throughout the project to reduce total project cost	DC	C. Platz
21	Utilize targeted active restoration on stream banks and steep slopes in lieu of passive restoration	2	L. Ryckeghem & H. Harrington
22	Utilize Sabin Dam as a sediment trap for the Boardman Dam drawn down in lieu of capturing and removing sediment at both Sabin and Boardman Dams	3	

List of Creative Ideas			
ID #	**Name of Idea / Description**	**Develop Status**	**Team Member Responsible**
23	Conduct full channel restoration and then construct the new bridge over Cass Road last in lieu of constructing the bridge in an early phase	4	
24	Allow the bridge to be designed and constructed by the county as an in-kind effort in lieu of integrating into USACE construction contract	DC	C. Platz
25	Create an interpretative center at the Boardman River Dams Powerhouses if it remains	4	
26	Utilize temporary cofferdams (i.e. Hesco Baskets) to dry out work zones where applicable in lieu of working in the wet	DC	L. Ryckeghem
27	Conduct an all-hands meeting of regulators at all levels to review the project and verify regulatory requirements early in the process	DC	M. Donahue
28	Utilize turbidity curtains to manage sediment	4	
29	Realign county line road around Boardman Powerhouse in lieu of demolishing the powerhouse and reconstructing a new roadway on fill	4	
30	Utilize large corrugated metal pipe culverts in lieu of a bridge at Boardman Dam	4	
31	Conduct further analysis of alternatives for the Cass Road Bridge over the Boardman River during the detailed design phase	3	
32	Utilize 1:3 side slopes for the bank full sides under the bridge in lieu of 1:6 side slopes to reduce the bridge span	2	T. Woodward
33	Reduce the width of the wildlife corridors below the bridge to the minimal width possible to reduce the length of the bridge	2	M. Donahue
34	Create a separate wildlife passage system independent of the bridge crossing	4	
35	Utilize multiple contracts in lieu of only one contract to improve the project schedule	DC	C. Platz
36	Encourage Michigan Department of Natural Resources (MDNR) to begin a sturgeon monitoring program and initiate a rearing operation (if necessary) when the dams have been removed	DC	H. Harrington
37	Utilize the existing fish crane to at the processing center in lieu of constructing a new fish elevator	DC	T. Woodward

Development Status Legend:

1: Idea is considered by the VE Team to be the best value enhancement possibility and is currently being developed as a VE recommendation
2: Idea is considered by the VE Team to be a good value enhancement possibility and will be developed as a VE recommendation after all the “1s” have been developed
3: Idea is considered by the VE Team to be of marginal value enhancement possibility and may be developed as a VE recommendation after all the “1s” and “2s” have been developed
4: Idea was not considered to enhance the value of the project and has been eliminated from further consideration by the VE Team
DC: Idea is being developed as a Value Engineering Design Comment to the designers with no easily quantifiable cost associated

APPENDIX E
VE Agenda

APPENDIX E – VE Agenda

AGENDA

Tuesday, July 24

10:00 am **Welcome and Introductions**

10:10 am **Workshop Goals and Objectives**

10:15 am **Overview of Value Engineering Study Process**

10:30 am **Overview: Boardman River Feasibility Study and Environmental Assessment**

A. Authority and Purpose
B. Scope of Work and Methodology
C. Current Status (95% Draft)
D. Major Design Elements (e.g., H&H, biology, cost)
E. Special Criteria (e.g., codes, constraints, requirements)
F. Major Project Design Benchmarks/ Decisions

11:00 am **Information Gathering**

A. Review/Discuss Current Design documents
B. Review/Discuss Baseline Cost Estimate and VE Cost Model
C. Determine Additional Information Requirements
D. Capture and Assign Action Items
E. Contact A/E Team Members/ Project Stakeholders for Additional Information

12:30 pm **Lunch Break**

1:15 pm **Information Gathering (continued)**

2:30 pm **Break**

2:45 pm **Function Analysis of Project Components**

A. Determine Value and Worth of Functions
B. Identify High Cost, Low Value Areas

4:45 pm **Wrap-up/ Day Two Preview**

5:00 pm **Adjourn for Day**

AGENDA (CONTINUED)

Wednesday, July 25

8:30 am **Review Agenda and Day One Progress and Outcomes**

9:00 am **Brainstorming: Alternative Approaches to Identified Functions**

10:30 am **Break**

10:45 am **Analysis and Evaluation**

A. Develop List of Evaluation Criteria
B. Evaluate Brainstormed Ideas
C. Select Ideas for Continued Analysis and Development
D. Assign Selected Ideas to Team Members for Development

12:00 pm **Lunch Break**

12:45 pm **Analysis and Evaluation (continued)**

2:00 pm **Developing VE Recommendations**

A. Develop Selected Proposed Concepts into VE Recommendations
B. Develop Estimates of Cost Savings for Each VE Recommendation

3:30 pm **Break**

3:45 pm **Developing VE Recommendations (continued)**

4:45 pm **Wrap-up/ Day Three Preview**

5:00 pm **Adjourn for Day**

AGENDA (CONTINUED)

Thursday, July 26

8:30 am **Review Agenda and Day Two Progress and Outcomes**

9:00 am **Finish Development of All VE Recommendations**

A. Original Design Sketches
B. Recommended Design Sketches
C. Calculations
D. Initial Cost Saving Estimates
E. Life-cycle Cost Saving Estimates

10:30 pm **Break**

10:45 am **Finish Development of All VE Recommendations (continued)**

12:00 pm **Lunch Break**

12:45 pm **Develop Selected Combinations of VE Recommendations**

2:00 pm **Prepare for Presentation of VE Study Results**

2:45 pm **Break**

3:00 pm **Review All VE Recommendations Presented by Fellow Team Members**

3:45 pm **Wrap-up and Next Steps**

4:00 pm **Adjourn**

APPENDIX F
Action Summary Sheet

APPENDIX F – Action Summary Sheet

SUMMARY OF RECOMMENDATIONS/ACTION

Rec #	Recommendation Title / Description	1st cost savings (or cost)	Recommended Action
VE-1	Retain Boardman Dam Powerhouse in lieu of removal	$720,000	Accepted for implementation
VE-2	Retain Sabin Dam Powerhouse in lieu of removal	$534,000	Accepted for implementation
VE-3	Utilize Sabin spillway alignment in lieu of the historical channel alignment	$147,000	Accepted for implementation
VE-4	Utilize a partial removal of Sabin Dam spillway resulting in a higher profile alignment achieving 30% reduction in sediment disposal volumes	$662,000	Rejected for implementation because this deviates from the project goal of a natural channel design, and the project team felt this will reduce the habitat benefits of fish passage
VE-5	Utilize a narrower excavated floodplain bench than the original design for the Sabin impoundment	$72,000	Accepted for implementation pending results of additional hydraulic modeling
VE-6	Utilize a narrower excavated floodplain bench than the original design for the Boardman impoundment	$89,000	Accepted for implementation pending results of additional hydraulic modeling
VE-7	Utilize higher piles of sediment disposal to improve the efficiency of material movement	$313,000	Accepted for implementation
VE-8	Utilize flexible pipes in conjunction with flex blocks to reduce the cost of breaching the dams in lieu of only using flex blocks	$82,000	Rejected for implementation because of the additional erosion risk and challenges to get water through the pipes and the engineering implementation would be extremely difficult
VE-9	Repurpose existing Union Street Dam auxiliary spillway/gates in lieu of constructing a new downstream fish passage	$372,000	Accepted for implementation pending further engineering design and verification of sea lamprey barrier
VE-10	Reduce the width of the wildlife corridors below the bridge to the minimal width possible to reduce the length of the bridge	$72,000	Rejected for implementation because project team desires to maximize the wildlife corridor to assure connectivity
VE-11	Utilize 1v:3h side slopes for the bank full sides under the bridge in lieu of 1v:6h side slopes to reduce the total bridge span	$142,000	Rejected for implementation because this requires additional hard engineering analysis and it may lead to stability issues
VE-12	Utilize targeted active restoration on stream banks and steep slopes in lieu of passive restoration	($24,000)	Accepted for implementation

Implementing Recommendations VE-1, 2, 3, 5, 6, 7, 9, and 12 will result in a cumulative cost savings of $2,160,000.

The above Recommended Action(s) were provided by the Detroit District Project Manage, Carl Platz, at the implementation meeting held on Monday, September 17, 2012.

END OF REPORT

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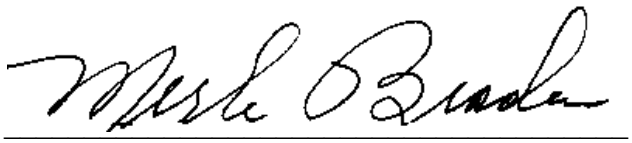
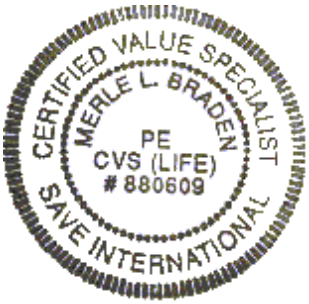


Approved by Merle Braden, PE, CVS-Life (URS)



US Army Corps
of Engineers
Detroit District

FEASIBILITY STUDY FOR THE BOARDMAN RIVER

GRAND TRAVERSE COUNTY, MICHIGAN

ATTACHMENT 6
CITY OF TRAVERSE CITY PROPOSED MODIFICATIONS TO THE SELECTED ALTERNATIVE

GREAT LAKES FISHERIES AND ECOSYSTEM RESTORATION PROGRAM

US Army Engineer District, Detroit
477 Michigan Avenue
Detroit, MI 48226-2523

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1.3 Flood Risk Evaluation 4
1.4 Habitat Outputs 4
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1.6 Design Refinements Evaluation Summary 5

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Figure 4: Public property (shaded) at Union Street Dam 4

1 Proposed Design Refinements to the Selected Alternative

Following the identification of a selected alternative, the City of Traverse City requested the evaluation of design refinements to the measures proposed for modifying the Union Street Dam. The existing Union Street Dam operates by passing flow through a series of large conduits under the earthen structure. The City of Traverse City requested consideration of having the dam modified to a flow over structure, rather than the proposed modifications to the existing fish ladder. A flow-over structure would allow for uninhibited fish passage, and result in lower maintenance costs. A secondary benefit would be the ability to pass recreational craft, such as canoes and kayaks. A constraint associated with this alternative is that the Union Street Dam currently blocks sea lamprey passage upstream. Modifying the Union Street Dam to a flow-over structure would require that a barrier be constructed downstream at a location that provides greater sea lamprey protection.

Design modifications to the proposed measure were developed and evaluated. These modifications and the results of the evaluation are documented in the following sections.

1.1 Union Street Dam Flow-Over Modification Measure Description

The Union Street Dam is used to provide stable water level control to Boardman Lake, which is raised approximately 7 to 9 feet as a result of the dam; to block the passage of aquatic nuisance species (ANS); to provide a pedestrian crossing point; and to support a 12-inch water main. In addition, there are fishing platforms above and below the dam and the site is part of a city park. Significant infrastructure is dependent on the water level in Boardman Lake, including discharge of the regional wastewater treatment plant and road crossings. For these reasons, full removal of the Union Street Dam was not considered. Any modification alternatives must maintain the existing Boardman Lake level and provide sufficient barrier to invasive species.

The proposed design refinement would involve converting the dam from a gate-controlled, flow-through dam to a free-flowing, flow-over dam. To accomplish this, a new concrete core wall would be installed upstream of the current dam. This wall would be supported upstream and downstream with fill and would feature a rock ramp, with engineered riffle or step pool features downstream. The flow-over structure would be constructed at a shallow enough gradient to accommodate the passage of all desired fish species common to the area.

The proposed Union Street Dam flow over modification measure would consist of a 600-foot engineered slope comprising large rocks and cobble to small gravel. The slope of the engineered structure would vary along its length and have a maximum slope of 2 percent. Approximately 10,000 cubic yards of fill material and 100 cubic yards of structural concrete would be needed to construct the engineered riffle. A plan view and elevation of the proposed design refinements are shown in Figures 1 and 2.

Figure 1: Plan view of proposed Union Street modifications

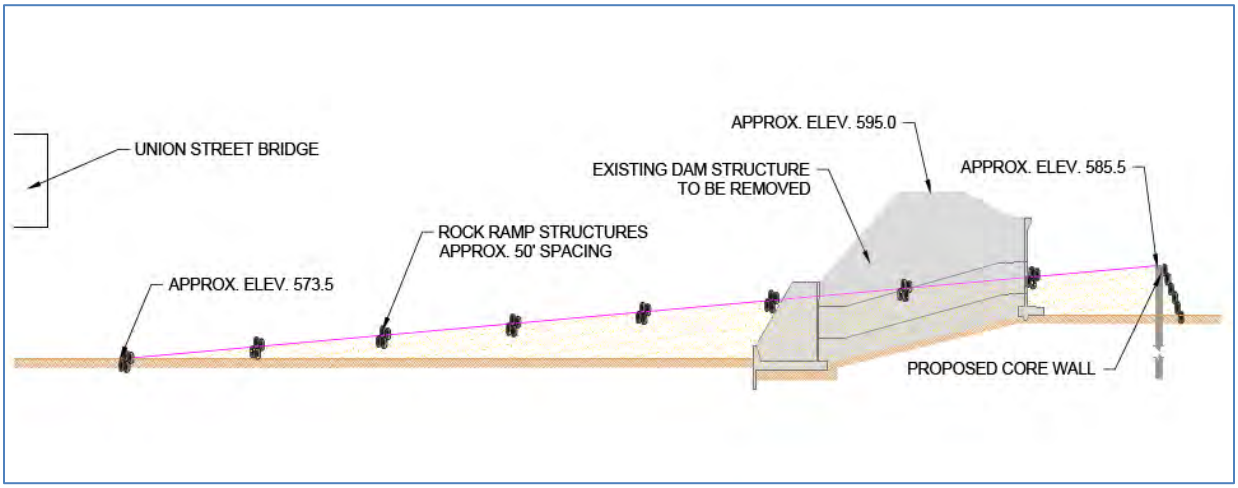

Figure 2: Profile view of proposed Union Street modifications

Because the modified dam would no longer prevent the upstream passage of ANS, a new sea lamprey barrier would be installed at the location of the current MDNR trap-and-transport facility between Front Street and the northern Union Street crossing. This location would provide a barrier for Kids Creek as well as the Boardman River mainstem and would allow for use of the MDNR's existing trap-and-transfer facility. The trap-and-transfer facility would be modified to accommodate the passage of the sturgeon past the barrier. The barrier is proposed as a permanent structure with stop logs that allow for seasonal variations of barrier heights. The barrier would be

operated to maintain a minimum 18-inch drop in water surface elevation. During large storms capable of causing structure flooding, stop logs would be removed to reduce the probability of flood damage.

1.2 Construction Access and Property Constraints

Under the modification plans for the Union Street Dam, both the dam site and the MDNR trap-and-transfer facility may be impacted by construction activities. Impacts at each site are discussed in relation to site access and property acquisition. Parcel information is based on data provided by Grand Traverse County.

Lamprey Barrier. As shown in Figure 3, ample access and public property (shaded in red) is available along the west bank of the river at the MDNR facility. This would accommodate improvements at the facility. If a new barrier is placed in the river at this facility, a construction easement may be necessary along the east bank from the private property. Geotechnical investigations would be necessary to properly design the proposed barrier.

Figure 3: Public property (shaded) at MDNR trap-and-transfer facility

Union Street Dam. At the Union Street Dam, access to the dam and adjacent work areas is sufficient, as shown in Figure 4. Access to the river could be difficult as a result of the grades and utilities along the north side of the river if the rock ramp, engineered riffle, and step-pool features are to be constructed. Geotechnical investigations would be necessary to properly design the proposed core wall for the rock ramp feature as well as for the foundations of the trap-and-transfer feature.

Figure 4: Public property (shaded) at Union Street Dam

1.3 Flood Risk Evaluation

An evaluation of the proposed barrier was conducted using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) to evaluate the rise of the water surface elevation. The design criterion of the lamprey barrier is to provide an 18-inch drop from the top of the barrier to the downstream water surface during a 10-percent-chance (10-year) flood event. Additionally, a minimum 4-inch ledge is required on the downstream face of the barrier to prevent lamprey from climbing over the barrier. The results of the preliminary analysis indicate that the flood elevations between the proposed barrier and the Union Street Dam would increase approximately 5 feet during the 1-percent-chance (100-year) flood event. Based on these increases, new Letters of Map Revision (LOMRs) and structure survey would be needed.

1.4 Habitat Outputs

The design refinements include modifying the Union Street Dam for downstream passage of sturgeon to coincide with the manual transfer of sturgeon upstream and construction of a sea lamprey barrier downstream of the confluence of the Boardman River and Kids Creek. This would prohibit sea lamprey from migrating into Kids Creek and a large portion the Boardman River between the Union Street Dam and Grand Traverse Bay. Accordingly, Average Annual

Habitat Units (AAHUs) modeling for sea lamprey control was undertaken to account for this additional protection. The proposed modifications add 514 AAHUs to the habitat output of the selected alternative. Details on the evaluation are included in **Appendix E: Habitat Analysis**.

1.5 Cost

The cost to construct the rock ramp at the existing Union Street Dam is estimated to be $2.5 million. The lamprey barrier is expected to cost $436,000 to construct. Total construction cost for the proposed design refinements is approximately $2.9 million.

1.6 Design Refinements Evaluation Summary

The proposed design refinements would have considerable habitat benefits in that a lamprey barrier downstream of Kids Creek would have the effect of protecting the tributary from access by ANS. However, the refinements would also engender the potential for flooding of structures upstream of the lamprey barrier, even during a 10-percent-chance flood event. Costs to mitigate this increased risk of flooding are likely to be considerable. Additionally, real estate impacts and easements necessary for construction could be difficult to obtain, disruptive, and costly. These findings were presented to the City of Traverse City, and a decision was made that the design refinements were not worth pursuing further. Based on the above considerations, the design refinements proposed for the selected alternative were not carried forward.