Brown Bridge Pond Comprehensive Initial Drawdown Plan
Boardman River Dam Removal Project
Grand Traverse County, Michigan

Prepared for:
Grand Traverse Band of Ottawa and Chippewa Indians
(MACTEC Project Number: 3310110004)

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1.0 INTRODUCTION

This Comprehensive Initial Drawdown Plan (CIDP) provides background information and several plan elements to complete an initial drawdown of Brown Bridge Pond. It is anticipated that the Brown Bridge dam will be removed during 2012 and a final drawdown will be completed in conjunction with the dam removal. This CIDP includes the following elements:

1. Discharge and Water Level Control Plan (DWLCP),
2. Sediment Management Plan (SMP),
3. Re-vegetation Plan (RP), and

The DWLCP, SMP, and RP are inter-related, as each one influences or is influenced by the others.

Discharge and Water Level Control Plan
The DWLCP is intended to define the general means of using the existing discharge facilities to lower and maintain the Brown Bridge Pond (Figure 1-1) water level as low as practical until the final drawdown and dam removal occurs.

It is important to note that this plan addresses the actual drawdown, during which time the Brown Bridge Pond water level would be lowered to a new controlled (or "hold-down") water level, but also the subsequent period until the anticipated final drawdown and dam removal is implemented. While no activities of specific concern are expected to occur during that hold-down period, activities such as debris removal and erosion control must occur and conditions may be slightly different from those historically observed due to the lower water level. Concerns such as the effect of the new control level on downstream discharge rates during large runoff events are addressed.

Sediment Management Plan
The initial drawdown of the Brown Bridge impoundment is intended to be the first in a series of steps aimed at removing the dam. The initial drawdown will lower the water level a maximum of 13 feet (ft) from the recent normal pool level of 797 ft to approximately 784 ft, utilizing the existing water control structures. This will leave approximately 17 ft of water in Brown Bridge Pond with a water level of 784 ft. It is paramount to note at the outset that sediment transport downstream of the dam is expected to be minimal if at all during the drawdown, as a substantial pond will remain upstream of the dam to trap most mobilized sediment. The drawdown will occur slowly, at a maximum rate of 0.5 ft per day, and the
effects of this drawdown within the impoundment, on sediment transport, will be evaluated throughout
the process. Should undesirable effects be observed, the process may be halted at any point.

Both direct and indirect effects are expected within areas upstream of the impoundment that will change
during the initial drawdown. Indirect changes include different wave patterns, and the decreased
suspended sediment trapping efficiency of the pond as it is drawn down. Direct effects include changes in
the delta deposit on the upper end of the reservoir, the adjacent tributary streams flowing into the
impoundment, and the potential for changes in the north slope of the impoundment. The changes to the
delta and tributaries may appear dramatic as the bed of the river and its tributaries begin to incise and
migrate upstream as the channels adjust to pre-dam levels, mobilizing sediment accumulated during the
post dam period. This mobilized material will re-deposit within the upper end of the impoundment and
likely will not migrate downstream near the dam. The north slope of the impoundment is not expected to
change, though the potential for localized bank failure exists, and has been identified as an area of
concern. Frequent monitoring will allow the magnitude of all changes to be assessed with respect to their
impact on existing conditions and future phases of the project.

Although changes will occur both within and upstream of the impoundment, these will not be transferred
below the dam. Thus, the risk for sediment derived impacts resulting from the initial drawdown to the
Boardman River below the dam structure is minimal.

Re-vegetation Plan
Re-vegetation of the bottomland soils exposed during the drawdown period will not be actively planted
but will re-vegetate through natural recruitment and germination of the existing seed bank. These areas
will be actively monitored in accordance with an Invasive Species Monitoring Plan (ISMP).

Monitoring Plan
Monitoring to be performed during the initial drawdown and hold-down period includes monitoring of
flows and water levels, water quality, erosion, and monitoring of equipment and structures. In addition,
fish rescue, record keeping, reporting, photo documentation, and public notification are discussed.
Section 2.0 of this document contains the primary components of the DWLCP for Brown Bridge Pond.
Section 3.0 addresses the SMP, and Section 4.0 covers the RP. The MP is provided in Section 5.0, and
references are provided in Section 6.0. A series of appendices provide supporting information for the
assessment of effects of implementing the CIDP and for use in the implementation of the CIDP.
2.0 DISCHARGE AND WATER LEVEL CONTROL PLAN

2.1 OBJECTIVES OF BROWN BRIDGE INITIAL DRAWDOWN

The DWLCP defines the conditions that will be imposed on the system that will dictate certain needs for the other plans. Consequently, it is important to clearly define what is to be accomplished by the initial drawdown. The overall goal of the DWLCP is to achieve maximum drawdown of the impoundments using existing water control structures (interim condition) of Brown Bridge Dam. The DWLCP defines how the water level in Brown Bridge Pond will be controlled beginning with implementation of the initial drawdown in the summer of 2011 and extending into 2012 when the final drawdown and dam removal activities are anticipated to be implemented. It also provides statistical information regarding what streamflows and water levels are likely to occur during the initial drawdown period based on historic streamflow characteristics. Flows in the Boardman River will be a result primarily of the natural runoff during the period, with some influence of the release of water stored in Brown Bridge Pond to incrementally increase streamflow rates during the lowering of Brown Bridge Pond. This DWLCP is not intended to be an operations plan, providing mechanical details associated with the manipulation of water control structures to achieve the initial drawdown.

Since the proposed schedule places the actual dam removal in 2012, the DWLCP includes a pond hold-down plan to be implemented following completion of the initial drawdown. Assuming the structures will not be actively managed during high inflows to adjust discharges, the hold-down plan will involve the selection of an appropriate discharge structure setting that will function as safely as possible and not create additional risk in the event of future flood events. In the discussion below, the DWLCP refers to both the initial drawdown procedure as well as the subsequent hold-down scheme which may follow initial lowering by full drawdown.

The DWLCP includes:

- Consideration of:
  - Capacity and configuration of the water control structure
  - Condition of the operable discharge equipment (ability to be safely operated)
  - Pond bathymetric characteristics, including storage
  - Watershed hydrology and streamflow including seasonal characteristics
  - Potential for scour induced by discharge flow at the structure tailwater
  - Consideration of sediment trapping capacity of the remaining impoundment

- Recommended timing for the initial drawdown
  - Example outlet structure settings for the indeterminate post-drawdown period that will:
    - Pass high flows as safely as practical
    - Provide a minimum low flow, to the extent practical, during dry periods
An assessment of overall safety concerns

It is assumed that no equipment (gates, trash racks, turbines, and other equipment) will be removed as part of this drawdown analysis.

The initial drawdown of Brown Bridge Pond is a reversible step in the overall Brown Bridge Dam removal project (i.e., the Brown Bridge Pond could be raised back to its previous pond elevation), as its primary purpose is to reduce the duration of the final drawdown prior to dam removal. It accomplishes objectives related to the safety of the Brown Bridge structure.

Specifically, the objectives of the Brown Bridge Pond initial drawdown can be summarized as follows:

- Use existing discharge facilities to minimize time required to lower Brown Bridge Pond when the final drawdown is implemented (anticipated in 2012).
- Reduce impact magnitude of full drawdown by extending the period over which effects, such as erosion and sediment processes will occur.
- Control and reduce to the extent practical, the erosion and sediment transport processes in the Boardman River, Brown Bridge Pond, and tributaries around Brown Bridge Pond that will be initiated by the water level lowering.

2.2 SUMMARY OF INITIAL DRAWDOWN CONSIDERATIONS

This section of the DWLCP provides an overview of the considerations identified as potentially significant for the initial (partial) lowering of Brown Bridge Pond using the existing water control structures. These include potential effects to natural resources and infrastructure. Additional discussion of the effects is provided in Section 2.3.

2.2.1 Existing Structure Discharge Characteristics

Discharge rating relationships of the existing water control structures at Brown Bridge Dam are an important consideration in drawdown plan formulation and are presented in detail in Appendix A. Characteristics of the structures at the dam as summarized in the most recent Safety Inspection of Brown Bridge Dam (STS, 2008) are presented in Table A-1 (Appendix A) and illustrated in Figure 2-1. The lowest level achievable will depend on the physical control elevations and the actual hydraulic capacity of the discharge structures (Figures A-1 and A-2). Figures A-1 and A-2 illustrate the varying water control features at Brown Bridge and their respective discharge capacities. Figure A-1 illustrates the full discharge capacity assuming the gates are fully functional and fully open. In contrast, Figure A-2 provides rating curves for varying gate functionality, assuming there is no flow through the turbines.
Rating curves for each of the control structures were developed based on basic weir and orifice flow equations for the gates (two upper Tainter gates, two lower Tainter gates, and log chute sluice gate). Storage capacity of the existing pond based on bathymetric data (Table A-2, Figure A-4) was also used in the development of rating curves. Very limited information is available regarding the rating of these structures from earlier work. The most recent Brown Bridge Dam inspection report provides some information regarding the maximum capacity, and the discharge rating for the Brown Bridge Dam removal project compares with that information reasonably well. The rating is slightly lower than the referenced discharge capacity, which is assumed to be design rating curves with all facilities in good condition. For purposes of this initial drawdown plan, the calculated rating relationships developed in support of this plan are believed to be sufficient.

The calculations were done within a spreadsheet. Control is based on the lower discharge estimate from basic weir and orifice equations using a single assumed value for the orifice coefficient and weir coefficient throughout the head range. In the spreadsheet, gate openings and discharge coefficients are assigned to each gate individually to enable calculating the total discharge for any combination of gate settings. Two example discharge rating curve plots are provided in Appendix A, one providing the maximum capacity (gates fully open) and the second provides a series of plots for varying gate openings for an individual upper Tainter gate and a lower Tainter gate.

It is noted that the lower Tainter gates cannot be opened with a pool level above elevation 792.5 ft (STS, 2008). Given the head conditions controlling flow through the upper Tainter gates and the lower Tainter gates, this condition creates an unusual apparent rating curve where discharge capacity drops to zero for pool elevations in that transition range.

The discharge rating also includes flow through the two turbines. The flow capacity of the turbines was estimated based on the stated power generation capacity of the turbines (STS, 2008). Flow through the turbines is controlled by the opening of the turbine wicket gates. It appears that the turbines can be used to discharge water at any pool elevation above the sill elevation to the turbine bays; however, because of operational considerations including debris accumulation on the horizontal trash rack, it is assumed that discharge through the turbines will be used only as needed to maximize drawdown. The inspection report (STS, 2008) indicates that, with the exception of the lower Tainter gates that were not opened due to zebra mussel infestation, all of the structures were operated through at least a portion of their range during the 2008 inspection and determined to be in working condition. The inspection report (STS, 2008)
indicates that the lower Tainter gates were refurbished in 2002 and should be in working condition if the mussels were to be removed.

2.2.2 Existing Streamflow Characteristics

Existing streamflow characteristics are an important input to the development of a drawdown plan as drawdown rate and duration is not only influenced by control structure rating capacities, but also contributing streamflow to the pond. The flows in the Boardman River at Brown Bridge Dam are unusually steady. Baseflow as calculated by standard methods is greater than 90% of the total average annual discharge. The 100-year return period peak discharge is estimated to be only two times the 2-year flood discharge. Appendix B provides information related to Boardman River streamflows, including:

- mean daily flow duration statistics for each month of the year, and
- high flow frequency data.

Extensive analyses of streamflow data from two U.S. Geological Survey (USGS) long-term stations was completed to characterize historical streamflow statistics including mean daily flow duration for each month and peak discharge information annually and by month (Figure B-1).

The period of record for the station downstream of Brown Bridge Dam is from 1954 to 1989. That station location primarily measures discharge from Brown Bridge Dam, but East Creek also enters the Boardman River just upstream of the station. The statistics indicate a marked difference in runoff characteristics at this station from those at the active station that is upstream of Brown Bridge Pond (Figure B-2). It appears that the East Creek watershed below Brown Bridge Pond has a more rapid response to precipitation events than does the upper Boardman River watershed. The rates of rise and fall for runoff events are more rapid for the lower station than for the upper station. The runoff volume per unit watershed area is slightly higher for the downstream station, which is assumed to reflect the inflow from East Creek.

Because this DWLCP is primarily concerned with inflows to Brown Bridge Pond, the focus of the summarized information is for USGS Station 04126970 Boardman River above Brown Bridge Road (USGS) (Figure 1-2).

2.2.3 Hydrologic Effects of Initial Drawdown

Perhaps the most obvious potential effects are those associated with hydrology. Reasonable concerns include:
• alteration of Boardman River flows downstream of Brown Bridge Pond resulting from the loss of storage in the reservoir,
• changes natural resources due to hydrologic alteration,
• risk of potential damage to infrastructure, and
• alteration in groundwater levels due to changes in pond water levels.

It is not the intent to identify and assess every potential effect; however, potentially significant concerns and effects are addressed.

Downstream River Discharge

The lowering of the Brown Bridge Pond water level through changed discharge structure operations alters the temporary storage volume and release rates from the structure for a runoff event. The effects of this initial drawdown are distinguished from effects of the dam removal with return to an open river system. Only the effects of the initial drawdown are addressed here. Streamflow effects of the final drawdown phase and dam removal will be addressed in subsequent project studies and plans.

There are no direct observations to quantify the existing effects of the Brown Bridge Pond on Boardman River streamflow. For example, there are no known records of measured inflows to the reservoir coincident with measured releases during the course of a runoff event. Additionally, long-term streamflow records are available from an active USGS streamflow station upstream of the structure (USGS Station 04126970) and from an inactive USGS streamflow station (USGS Station 0412700) downstream of the structure, but these monitoring periods do not overlap. In order to overcome this gap in the available streamflow records, the influence of Brown Bridge Pond effects on discharges has been estimated using hydrologic routing methods that consider the available storage in the reservoir, the settings of the gates and discharge structures, and the characteristics of the inflow hydrograph. Fortunately, inflow hydrograph information is available from the upstream USGS Station 04126970 to provide accurate characterization of inflows.

The analyses completed to evaluate the effects of the Brown Bridge structure on peak discharges are summarized in Appendix C. Five historic high flow events with 15-minute interval flow data from the USGS Station 04126970 record and three events with 60-minute interval flow data were used to perform a standard storage routing procedure using HEC-HMS (Sharffenberg and Flemming, 2010). The April 28, 2011 event is based on preliminary USGS data. The three events with 60-minute data were included in a Brown Bridge Dam hydrologic study (Mead & Hunt, 2001) as observed runoff events preceding the establishment of USGS Station 04126970. These nine hydrographs are plotted on Figure C-1 such that
the peak discharge occurs at the same time to illustrate variations in hydrographs. The HEC-HMS graphic results for the routings are included in Appendix C as Figures C-2 through C-19. Figures C-2 through C-10 show results for historic conditions with a controlled water level of 797 ft and discharge represented as weir flow over the two 12-ft wide Tainter gates. Note that these results are not intended to replicate those historic event results, as the actual Brown Bridge spillway gate openings during those events are not known. Figures C-11 through C-19 show results for the same nine storm events assuming the initial drawdown conditions with an assumed moderate discharge through the turbines (approximately 100 cubic ft per second [cfs] at pool level 785 ft) and flow over the two lower Tainter gates when the water pool level rises above 786.7 ft, (overflow elevation for the lower Tainter gates when fully open).

The results of the routing analyses are summarized in Table C-1 and Figures C-20 and C-21. For these nine hydrographs, flow through Brown Bridge Pond reduces the peak discharge from inflow to outflow by amounts ranging from approximately 3% to 16% based on historic conditions and from approximately 2.5% to 14% for the initial drawdown condition. Comparing the two pond conditions, the releases are increased by the initial drawdown condition by approximately 0.3% to 2.7%.

It is noted, however, that the largest storage effects are for the three historic events included in the Mead & Hunt (2001) report. The increase in release rates from those three hydrographs average 2.7% with a maximum of 3.2%. However, the average increase for the six highest flow events measured at the USGS Station 04126970 in its 13-year period of record, average only 0.8% with a maximum of 1.9%.

From Figure C-1, differences in hydrograph characteristic rates of rise and recession are apparent and these cause the differences in storage effect on release rates. The means and methods of measuring and estimating the hourly flow rates for those three hydrographs are not readily available, but the location is believed to be approximately the same as USGS Station 04126970. Two of those three events have higher peaks than any of the events recorded at the USGS Station 04126970 while the third has a peak flow similar to those recorded by the USGS Station 04126970. Based on the consistent difference from the USGS Station 04126970 measured events, the accuracy of those three hydrographs is questionable. Differences may be a result of intentional bias for the purpose of the study being performed or may be the result of an inaccurate discharge rating curve. Regardless, even assuming those three hydrographs are representative hydrographs, the effects are increases that are less than 3%, which is a relatively small increase. It is believed that the actual differences are better characterized as less than 1%.
Reservoir Area

The water level in Brown Bridge Pond will be lowered through changing the settings of existing discharge structures. As previously, however, the reservoir level will continue to rise and fall with the conveyance of runoff from precipitation and snow melt events. The hydrologic effects in the reservoir area of interest include:

Surface Water:
- The shoreline zone subject to wave erosion is reduced in elevation and diminished in length (perimeter).
- The lowered water level results in altered surface runoff erosion potential in the zone between historic pool elevation to the lowered pool elevation.

Groundwater:
- Alteration in hydrology for wetlands that have developed as a result of the Brown Bridge Dam construction.
- Changes in water levels in any water supply wells within the area potentially affected.
- Changes in soil moisture, potential soil strength changes, and changes in slope stability characteristics.

The potential surface water erosion effects are addressed in Section 3.0; however, because the initial drawdown will hold the pond elevation at a reduced pool elevation, any coarse sediment (fine sand and larger) eroded at specific locations within the exposed impoundment will continue to be deposited behind the dam and will not move downstream.

The effects of a lowered groundwater table are difficult to quantify, in general, due to limited data on the stratigraphy and aquifer characteristics around the Brown Bridge Pond. However, because there is very limited infrastructure, potential infrastructure effects are assumed to be limited. The only known potable drinking water well potentially affected is a well at the Brown Bridge Dam Keeper’s residence located adjacent to Brown Bridge Pond (Figure 1-1). There are no known structures of significance around the Brown Bridge shoreline that would be of concern with regard to erosion by either wave action or surface flow. Effects to wetlands have been evaluated during the Boardman River Feasibility Study (ECT, 2008). It is expected however, that new wetlands will become established in the historic restored floodplain and shoreline zone as a part of bottomland restoration.

When Brown Bridge Dam is removed and a riverine reach is restored, groundwater levels will return to approximately the historic condition prior to dam construction. The topography of the surrounding slopes and valley has generally not been changed by the construction and existence of the structure. However, there has been some sedimentation in the valley bottom (ponded area) and some shoreline erosion along the pond perimeter (water level fluctuation zone). It is believed that fill material for construction of the
dam was removed from the hillside north of the dam, but that area and whatever topographic changes resulted from the soil borrow is not known to be subject to effects by water table change, as long as the change occurs slowly. Rapid drawdown (not proposed here) can have a destabilizing effect on these adjacent slopes. As a result, there does not appear to be significant detrimental effects of water table lowering that are not recognized and acceptable as an effect of restoring the river.

Brown Bridge Structures and Dam Embankment

The water levels in Brown Bridge Pond and discharges through the outlet structures will be within the ranges of operation of these structures. It is, therefore, assumed that initial lowering will not adversely affect the structure itself. While discharges will be routed through different facilities, the total discharge during drawdown will not differ from flow rates normally observed in the Boardman River as it flows through the Brown Bridge Valley Section. Visual inspections of the flow control structures in support of the initial drawdown will be conducted (1) prior to initiation of the initial drawdown, (2) during the drawdown, and (3) regularly during the subsequent hold-down period until final drawdown.

The potential effect on the embankment is related to rapid drawdown resulting in slope failure and shoreline erosion caused by easterly long-shore wave action, though westerly winds prevail in this region. The drawdown rate will be made at a safe, controlled rate to avoid rapid drawdown conditions that might cause slope instability at the embankment or along the reservoir rim. Regular inspections as described above will look for embankment erosion at the new and former shorelines. The embankment is expected to be subject to this condition for a period of approximately one year or less and erosion controls can be implemented if needed.

2.2.4 Sediment Transport and Water Quality Effects

The initial drawdown will lower the Brown Bridge Pond water level by approximately 13 ft or less (current water level of approximately elevation 797 ft to lowest expected level of approximately elevation 784 ft). The lowest level achievable will depend on the actual hydraulic capacity of the flow control structures (Section 2.2.2). The lowering will expose approximately 100 acres of previously inundated bottomlands. It will also change the hydraulic conditions and sediment transport capacity of the Boardman River inflow channel, causing erosion of the channel as it adjusts to the new hydraulic conditions. Similar erosion of stream channels will occur at any other small tributaries into the reservoir that have deposited deltas during the life of the reservoir.
An assessment of the erosion, sediment transport, settling characteristics, and observations from a recently conducted on-site geomorphological assessment for the Boardman River delta area and Brown Bridge Pond is more fully discussed in Section 3.0 of this report.

### 2.2.5 Fishery Effects

Fish communities that would potentially be affected by the drawdown of Brown Bridge Pond include those within the pond itself and those immediately downstream of the dam. The minimum pond level that can be achieved using only the existing discharge facilities will provide a reduction in the surface area of the pond to approximately 70 acres, leaving previously inundated near-shore areas dry. A drawdown occurring in the spring or early summer could affect generally warm water lentic species that utilize these shallow, often vegetated, littoral areas as spawning and nursery habitat. The reduced water volume in the pond could also affect the resident community, which presumably consists of a mixture of warm-coolwater lentic and lotic species. The warm-cool water lentic species will likely be affected by the reduced habitat size, but the decision to carry out this project implies that the overall ecologic value gained from the anticipated system restoration outweighs the impact on these species that are found in abundance in naturally lotic systems found elsewhere in the watershed. Further, given the absence of upstream barriers, the lotic species will migrate upstream into the existing system, and the fish community there should equilibrate quickly.

The fish community in the Boardman River downstream of the Brown Bridge Dam could potentially be stressed by the drawdown if the incoming water was extremely turbid (suspended solids heavily dominated by fines <0.62 millimeters (mm) comprised of organics and clay), or if substantial amounts of entrained sediments (0.062 – 2 mm) were released. But assuming these conditions can be prevented through appropriate management practices, the downstream fish community should not be adversely affected. As discussed in Section 2.2.4, the Brown Bridge Pond remains a large water body that will provide an estimated 90 to 95% removal of inflowing suspended solids. Other sediment management practices will be implemented as needed around the pond perimeter to control those potential sediment sources. These controls are expected to provide discharges that will not cause significant adverse effects for fish in the river downstream of Brown Bridge Dam; particularly if drawdown timing occurs outside of sensitive life stages of the dominant fish community.

From a seasonal perspective, the least effect on fisheries from the initial drawdown would be to perform it in mid-summer to early autumn. In the spring and summer, many species use the shallow, littoral areas as spawning and/or nursery habitat. A drawdown during this period would likely increase mortality and
inhibit recruitment success for that year’s cohort for warm-cool water lentic species. However, as stated above, such a loss in recruitment is not considered to be a significant issue, given the overall objectives of restoring the existing lentic system to a lotic environment.

2.3 SUMMARY OF ANALYSES AND FINDINGS FOR PLAN FORMULATION

The capability to drawdown the Brown Bridge Pond over a short time interval at any time of the year, even the very regular high flow period of April, exists as long as the lower Tainter gates and the turbines can be used. Therefore, the drawdown plan as described in Section 2.4, is primarily one of (1) selecting the timing for the drawdown to avoid or minimize any seasonally related adverse effects and take advantage of any seasonally related benefits, and (2) establishing the desired rate(s) of water level lowering to avoid or minimize adverse effects of a particular rate of water level lowering.

2.3.1 Seasonal Considerations

The seasonal variation in streamflow is summarized in flow duration data provided in Appendix B, Figures B-1, B-2 and B-3, and Tables B-1 and B-2. The mid- to late-summer drawdown offers the advantage of lowest streamflows, least risk of large runoff event, lowest wind speeds affecting wind generated wave turbidity, establishment of vegetation in newly exposed areas for erosion control, and fastest drying and consolidation of newly exposed sediments. From a seasonal perspective, therefore, the drawdown should ideally begin in late June or early July.

2.3.2 Drawdown Rates

Aside from contributing to slope instability and creating higher potential for fish stranding, a faster rate of drawdown appears beneficial compared to slower rates. This will minimize the potential turbidity from wind generated waves as the water level fluctuation zone passes through the expected 10 to 12 ft drawdown range. If sediment re-suspension is observed to be a persistent problem, then it may be that after allowing a period for exposed sediments to dry and allowed to consolidate and rooted vegetation to become established, a slight rise in the controlled water level would reduce sediment re-suspension.

A faster rate of drawdown may subject some steep slopes, including the earthen embankment, to instability and increase potential fish stranding problems. The Michigan Department of Environmental Quality (MDEQ) (2008) established a maximum rate of 0.5 ft per day in a temporary drawdown permit for Brown Bridge Pond. At that rate, the increased downstream flow associated with the release of water from storage is minor and would occur during the low flow season if the drawdown is implemented in July through August. A drawdown rate of 0.5 ft per day contributes an equivalent discharge rate of only
approximately 45 cfs (high water level) to 20 cfs (low water level) to the Boardman River flow rate. These rates are based on estimated pond storage volumes and do not account for any incremental flow generated by discharge of groundwater storage created by a falling water table. While seepage to a lake from a water table is generally difficult to predict, it is anticipated that additional seepage contributions induced by lowering the pond level are likely to be on the order of a few cfs and discharges as large as 15 to 20 cfs would be unexpected for the lowering rate anticipated.

2.4 DISCHARGE AND WATER LEVEL CONTROL PLAN

2.4.1 Schedule
Based on the seasonal flow patterns described in Section 2.3, the recommended period of initial drawdown is during the months of July and August (Figure 2-2). The initial drawdown is recommended as beginning in the end of June, assuming that unusually high flow conditions do not exist on that date and the appropriate permits are received. Should high flows exist on that date, the drawdown will be initiated when the flow at USGS Station 04126970 falls below 250 cfs. During the initial drawdown, the Brown Bridge Pond water level will be lowered at an average rate of approximately 0.5 ft per day. Recognizing uncertainties in inflow rates, discharge ratings for the gates, and other factors, the upper limit of 0.5 ft per day is considered to be an average over a three day time period with reasonable efforts to not exceed that rate on any single day. The spillway gates (upper and lower Tainter gates and log chute sluice gate) will be used to lower the water level to an elevation of approximately 787 ft with discharge for further lowering occurring through the turbines by opening the wicket gates.

If a runoff event occurs during the drawdown, gates may be temporarily opened wider to maintain a falling pond level if considered appropriate based on the conditions at that time. Alternatively, the increased flows and resulting temporary rise in pool level can be allowed to pass through Brown Bridge Pond without adjusting the gates. Flow records indicate a low risk of having a significant increase in flow during July and August (refer to Tables B-1 and B-2 and Figures B-1, B-2 and B-3). After drawdown to the maximum level achievable at baseflow has been achieved and maintained for one week or more, the gate openings may be maintained at that opening to allow pond levels to subsequently rise and fall based on pond inflows and the gates (including turbine wicket gates) fully open. This will allow water levels to fall at a rate that may exceed 0.5 ft per day. This would be associated with a brief, temporary rise in water levels rather than the initial lowering, and slope stability concerns would not be expected. Stranding of fish in isolated depressions following a temporary rise may potentially occur and would need to be monitored and actions taken as appropriate.
The pond water levels and control may be adjusted to avoid use of flow through the turbines if excessive debris accumulation on the horizontal trash rack occurs and creates an excessive maintenance effort, reverting to use of the lower Tainter gates as the lowest outlet control or potentially with only a reduced flow through the turbine(s).

### 2.4.2 Drawdown Implementation Logistics

To implement the drawdown on this schedule, maintenance and testing of the discharge facilities are required prior to the beginning of drawdown. Figure 2-3 presents a decision tree that illustrates logistical issues that should be considered in support of the drawdown plan implementation.

Zebra mussel infestation and operability of the gates and turbines are central to the previously identified issues. While it is possible to effect some pool reduction without performing maintenance, the outcome of such an approach is less certain as it is dependent on the functionality of existing controls. At a minimum, the pool can be reduced to elevation 793 ft (Scenario D) or even lower, depending on control functionality (Scenario C).

Implementing pool drawdown following maintenance and zebra mussel removal provides advantages by increasing certainty regarding control functionality, but such scenarios require additional steps which may delay the initiation of drawdown. For example, Scenarios A and B both provide for greater certainty in achieving a lower pool level, but the timeline for procurement and completion of maintenance measures is unknown.

Should either Scenario A or B be used, it is recommended that:

1. **Coincide Maintenance with Low Flow.** Maintenance be done during a time with flows as low as practical (i.e., just prior to the start of the initial drawdown, or late May/early June).
2. **Implement Partial Drawdown Prior to Maintenance Activities.** While the log chute should be capable of passing flow with the head gate closed for an extended period, it may be desirable to implement a maintenance drawdown prior to the scheduled maintenance activities to minimize potential problems associated with reliance on discharge through the log chute. This could be done using the upper Tainter gates. Lowering the pool level by 2 ft, for example, and then allowing the pool to rise while discharging through the log chute would reduce the discharge through the log chute for one or two days. Flow records indicate that during late May/early June, flows have only about a 20% chance of exceeding 150 cfs while the log chute has an estimated hydraulic capacity of approximately 170 cfs at pool level 797 ft.
3. **Schedule Flexibility.** It is recommended that the schedule for the mussel removal and maintenance be held as flexible as practical to allow for completion during a low flow period, as required.

In support of the implementation of this initial drawdown, a spreadsheet has been developed that can be used by the City of Traverse City (City) to effect the desired drawdown rate and level. This spreadsheet
uses the discharge rating curves of the control structures coupled with operator inputs to achieve drawdown. Examples of the rating curves for two specific gate opening Scenarios B, maximum drawdown, and D, minimal drawdown, are presented in Figures 2-4 and 2-5. Additional curves to support actual drawdown can be generated by the City based on needs for the range of conditions that may be encountered.

2.4.3 Project Criteria and Requirements

**Regulatory Requirements**
An MDEQ Joint Permit Application (JPA) permit pursuant to Part 315 of the Natural Resources and Environmental Protection Act (NREPA) is required to support the initial drawdown of Brown Bridge Pond. The City submitted the JPA to the MDEQ on May 11, 2011.

MDEQ requirements included in a prior temporary drawdown permit for Brown Bridge included two primary criteria, a maximum rate of water level lowering of 0.5 ft per day and a requirement to provide response for cases of stranding of fish in isolated depressions. These are criteria that are appropriate for this initial drawdown project as well.

**Project Criteria**
In addition to the regulatory requirements, project criteria for this CIDP include needs for monitoring of structures and guidance for responding to the range of potential hydrologic conditions. Provided that the equipment functions as intended, nearly any runoff event with a reasonable risk of occurring during the one-year period of the initial drawdown can be passed through Brown Bridge Dam without increased risk. Comparing the estimated discharge capacity (Figure A-1) with the flood discharge - frequency data (Table B-3), the Brown Bridge spillway capacity appears to be sufficient to pass even the highest estimate of the 500-year peak discharge, even with a low pool level controlled by the lower Tainter gates.
3.0 SEDIMENT MANAGEMENT PLAN

3.1 INDIRECT EFFECTS
The impoundment behind Brown Bridge Dam is elongated and angled northeast to southwest (Figure 3-1). Both indirect and direct changes to sediment related processes as a result of the initial drawdown have been identified. Indirect effects are those changes induced by natural floods or wind action that may impact the pond differently in a drawn down condition. Direct changes are those induced specifically in response to drawdown. Waves either induced by boat traffic or wind have had some effect on the impoundment in the past. The impoundment is nestled within a confined valley, sheltering it from all but those winds blowing parallel to the valley orientation and opposite of regional prevailing wind direction. Most of the material within the impoundment appears to be coarse and less susceptible to wave induced suspension. However the possibility of wave induced turbidity does exist, though the project will not affect the frequency of such occurrences.

A second indirect effect is related to the size of the pond. Larger ponds and longer residence time allows particles in suspension to fall out, or be trapped within the pond, sending less turbid water downstream. As the pond is drawn down the residence time is decreased, as is the trapping efficiency. Eventually in a removed state, sediment particles will pass completely through the area as sediment continuity is restored. Still, it is important to note this as a change, though a change moving toward the end goal of restored water and sediment regimes on the river.

3.2 DIRECT EFFECTS
Direct effects are related directly to the drawdown of the impoundment. These include changes that will occur as well as changes that have the potential to occur. Three direct effects have been identified. First, a pronounced delta has formed at the upper end of the reservoir since construction of the dam in 1921. This delta actively migrates and grows in response to floods and changes in water surface elevation associated with operation of the dam. Second, two defined tributaries and a number of seeps were identified within the extended impoundment area. Since each tributary and seep transports flowing water into the impoundment or river, the lowering of the water level will institute a physical change in the tributary channel as well. The final concern is the north slope of the impoundment. When the dam was constructed, much of the fill utilized in the earthen embankment was excavated from the north shore of the valley wall nearest the dam. Each of these issues is discussed in more detail below.
3.2.1 Delta

A 3-ft drawdown occurred in 2008, dewatering a large portion of the impoundment and initializing adjustments in the Boardman river channel well above the impoundment. A comparison of aerial photographs taken in 2005 and 2010 shows this change, which is likely due to a combination of water level change exposing existing delta surfaces and an influx of sediment caused by the new channel that formed in response to the drawdown (Figure 3-2). During the field investigation, these changes first became apparent in tiered depositional surfaces along the banks, about two miles upstream of the dam on the river, just above Grasshopper Creek (Photo 1). This location indicates an approximate upstream boundary or zone where channel changes associated with further drawdown may become diffuse or less obvious.

Photo 1: Inset bank surface showing channel narrowing and incision associated with the 2008 drawdown of 3 ft.
As the initial drawdown progresses, the changes noted in both the channel upstream of the delta and in the delta itself during the 3-ft drawdown of 2008 will again be evident (Photo 2). Moving closer to and through the delta, bank heights will increase beyond the current elevations as the sand in the channel is mobilized downstream. Incision is the primary mechanism of adjustment, followed by widening of the existing channel as bank heights become unstable and fall into the channel. Finally, horizontal adjustment of the planform of the channel might be expected. Specific times for these adjustments are difficult to predict. Scales for incision may be on the order of days following a change in water surface elevation, widening likely on the order of weeks to months depending on the cohesion of the bank material, and horizontal or lateral adjustments are likely controlled by the magnitude and frequency of flood events in a given season. Sand that is mobilized will re-deposit at the end of the delta where the active flow enters the static water of the pond, migrating this feature in a downstream direction. Estimating the extent of this downstream migration is difficult, though based on the comparison between the aerial photographs in Figure 3-2, the bulk of the delta should remain confined to the upper third of the impoundment.
3.2.2 Tributaries
Two significant tributaries were noted within the project area, Grasshopper Creek approximately 2 miles upstream of the dam (Station 116+000) and Century Creek approximately 1,500 ft upstream of the dam. Both tributaries flow into the Boardman River (or Brown Bridge impoundment) from the south. Grasshopper Creek emanates from several sand seeps noted in the bed of the channel along its entire length. The visible stream ends about 1,200 ft (straight line distance) from its confluence with the Boardman River. This creek is within the influence of the 3-ft drawdown from 2008 and will likely see minor adjustments from continued drawdown. The presence of mature cedar stumps within the channel near its confluence (Photo 3) indicates a pre-dam base level is likely very near the surface of this tributary.

![Photo 3](image)

**Photo 3:** Near the outlet of Grasshopper Creek, note the old stumps present indicating conditions associated with a pre-dam elevation.

Century Creek is a newly exposed tributary since the 2008 drawdown. The creek is composed of an array of channels and subsurface flows that form a single, shallow channel within a few hundred ft of the edge of the impoundment. As the channel nears the edge of the impoundment the form changes and channel narrowing and incision are apparent in response to the 2008 drawdown (Photos 4 and 5). Again, based on associated stumps and vegetation, it appears the channel has always flowed through a lower gradient wetland in its upper reaches then increased in slope down to meet what was the former Boardman River.
elevation. A small delta of fine, unconsolidated material is present at the interface of Century Creek and the current impoundment level. This delta will likely re-establish downstream as water levels in the impoundment drop.

Photo 4: Upper portion of Century Creek, low bank heights and diffuse flow.

Photo 5: Lower portion of Century Creek, note channel narrowing and increased bank heights in response to the 2008 drawdown.
A few diffuse seeps were noted along the Boardman River. Adjustments to these are expected as well, though the extent of adjustment will likely stop at the valley toe, where the groundwater daylights. Photo 6 illustrates one such seep that adjusted in response to the 2008 drawdown by incising. The adjustment stopped when the stream reached the valley toe less than 50 ft away (seen in the background of Photo 6).

![Photo 6](image)

**Photo 6:** Incision from a seep coming out of the valley toe upstream of the impoundment. The valley wall is in the background.

### 3.2.3 North Slope

A formal analysis of slope stability along the north slope was not conducted. As mentioned, most of the material for the considerable earthen embankment of the Brown Bridge Dam is thought to have been excavated from this shore of the impoundment. The result of this effort on the topography seen today is unknown. The north slope consists of three parts, the upper visible slope containing mature trees, the bench that is located at the elevation of the impoundment, and the lower terrace slope, located below the existing water line which is not visible. The upper slope appears fairly stable, evidenced by the mature trees, standing vertical on the hill. Near the toe of the upper slope, some areas of erosion are apparent, known to be caused by wave action at pre-2008 water levels which eroded the sand slope. Trees in this area have exposed roots and can be seen leaning slightly toward the water (Photo 7). The bench of sand that has been revealed since the 2008 drawdown appears to have provided protection from wave action and this toe area is likely no longer eroding via this mechanism. The bench of sand proceeds out into the
existing water at a gradual slope before steepening to intercept the historic Boardman River floodplain or channel bank at some depth below the water surface. Two locations of concern along this slope are the lower end nearest the dam, and the upper end, near the delta where the Boardman River is expected to flow in close proximity to the toe of this slope. Photo 7 shows these locations and the average slope of the upper and lower portions based on the ACOE HEC-RAS cross-sections and geometry data.

Photo 7: North slope of Brown Bridge Pond just downstream of the delta. Note the toe erosion that occurred on the upper slope, and the exposed bench of sand.

The mechanism for failure of the upper slope would likely be the failure of the lower slope, effectively causing the upper slope to slide down. Again, formal analysis was not performed on these slopes, but logic can be used to assess the potential for this occurrence. Most bank failures occur in response to toe instability. The inability of adjacent ground to dewater as fast as the impoundment can create hydraulic pressure pushing out against the exposed slope (e.g., piping) is a common mechanism of failure. Assuming that the lower slope is composed largely of sandy, (porous) material, as is most of the watershed; the ability to store water and thus build head through pore water pressure within the slope may be minimized. Sand has an angle of repose of about 35 degrees when dry and only the upper and middle portions of the slope exceed or come close to this angle (Figure 3-3). Further, the slow rate of drawdown should allow reasonable time for the groundwater level within the lower slope to adjust to the new surface level of the impoundment. Once the impoundment is dewatered, wave action may be a second
mechanism for toe erosion, as noted above. Observations in the field (May 2011) reveal little evidence of this during the interim since the 2008 drawdown. However, the lower slope revealed with continued dewatering may reside on a steeper angle and be susceptible to such forces in specific areas. An assessment of the consequences of failure is an important part of this discussion.

Though the risk appears low based on the observations and assumptions above, a failure of both the upper slope and lower slope will deposit this material in the bed of the existing impoundment at a stable angle that can be managed during the final drawdown process. The shallow layer of organic material that has developed on the upper slope would likely create a short-term, turbid condition within the impoundment that would be transported downstream, though levels would likely be consistent with turbidity from a large flood event. No municipal infrastructure exists at the top of the upper slope (roads, bridges, etc.) but several trails and lookout platforms are present that may be affected, depending on the extent of a slope failure. If the apparent risk and perceived consequences of failure are unacceptable, a formal assessment of risk and stability should be conducted by a geotechnical engineer.

3.3 IMPOUNDMENT AND DELTA SEDIMENT CHEMICAL CHARACTERISTICS

Sediment samples have been collected by the U.S. Environmental Protection Agency (USEPA) (June 2005) and by Great Lakes Environmental Center (GLEC) (2010) (Appendix E) as summarized below.

Core sampling was performed in Brown Bridge Pond in June 2005 by the USEPA and representative samples were analyzed by the MDEQ Environmental Laboratory for the presence of pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs) and 10 metals (arsenic, barium, cadmium, chromium, copper, lead, selenium, and zinc). It was reported that while the methods used and the Reporting Levels (RLs) were appropriate, the samples were analyzed outside the USEPA’s maximum allowable holding time for pesticides, PCBs, PAHs, and mercury. Six core samples were collected and identified as BBP1 through BBP6. The approximate location of the core sampling points is identified on Figure 3-4: Brown Bridge Pond Sediment Sample Location Map. It was reported that arsenic, barium, lead, selenium, and zinc were reported at levels that exceeded the USEPA Ecological Screening Levels for these metals in some or all of the core samples. The core lengths ranged in depth from 13 inches to 73 inches. The sediment cores were divided into 24-inch subsections (or less) and mixed. No sediment samples were collected upstream or downstream of the impoundment to compare the contamination levels of the impounded sediments with locally-derived background sediments.
Additional sediment sampling was performed in Brown Bridge Pond in 2010 based upon a review of the previous sampling performed by the USEPA and the MDEQ. The sampling consisted of collecting eight core samples identified as BBGLEC1 through BBGLEC5 along with three sample points identified as Delta 1 through Delta 3 (Figure 3-4). Sediment samples were collected using a 4-inch diameter vibracore tube. The core lengths ranged from 10 to 46 inches. Representative core samples were analyzed for PCBs, semi-volatile organic compounds (SVOCs), organochlorine pesticides, the 10 metals, nickel, manganese and total organic carbon (TOC).

The 2010 sample locations included the same locations as in 2005 in addition to eight new samples. A total of 14 cores were collected in the Brown Bridge Pond. GLEC reported that results from the 2005 and 2010 investigations showed similar magnitudes in concentration for most metals, with the exception of cadmium, mercury, and silver. It was noted that the discrepancies between these three metals concentrations between the two sampling events can be explained by a difference in RLs. The contamination levels were compared with the Threshold Effect Concentration (TEC) and the Probable Effect Concentration (PEC). None of the sediment samples exceeded the PEC levels, but many exceeded the TEC thresholds and background levels for this area of Michigan (Appendix E). The MDEQ does not consider the PEC as regulatory criteria; neither do they typically consider them as action levels.
4.0 RE-VEGETATION PLAN

Dam removal will create opportunities for invasive species to become established. In particular, dam removal will create large expanses of previously inundated and un-vegetated soils that may be colonized by invasive plant species which may out-compete desirable native plant species. Furthermore, the change in aquatic habitat type from reservoir to free-flowing river may also provide opportunities for aquatic invasive species to become established or spread. An ISMP identifies and prioritizes species to be controlled and provides the methods and procedures for control of invasive species during dam removal and subsequent river/floodplain restoration.

Nearly 100 acres of previously inundated bottomlands will be exposed following the 13-ft interim drawdown of Brown Bridge Pond. Newly exposed soils will not be actively planted but will re-vegetate through natural recruitment and germination of the existing seed bank. These areas will be actively monitored in accordance with the ISMP. If erosion or invasive species become problematic, erosion control measures will be implemented along with targeted herbicide treatment as deemed necessary.
5.0 MONITORING AND REPORTING

Monitoring to be performed during the initial drawdown and hold-down period falls into various types, including monitoring of flows and water levels, water quality, erosion, and monitoring of equipment and structures. In addition, fish rescue, record keeping, reporting, photo documentation, and public notifications are discussed below.

5.1 STREAMFLOW AND RESERVOIR LEVEL

During the initial drawdown phase, gate settings will need to be adjusted to accomplish the water level lowering at rates not exceeding the maximum rate. Discharge rate versus pool elevation relationships have been developed for all the gated discharge structures. While uncertainties in these discharge ratings exist, they provide a guide to estimate gate openings needed based on the inflow to Brown Bridge Pond. Inflow rates will be available from the USGS real-time station located approximately one mile upstream of the pond: Station 04126970 Boardman River above Brown Bridge Road near Mayfield (http://waterdata.usgs.gov/mi/nwis/uv?site_no=04126970).

After the initial minimum drawdown elevation has been achieved and held for at least one week, the discharge gate settings are not expected to require further changes except for specific needs that may arise; it is not anticipated that discharge gate settings will be changed in response to runoff events.

Pond levels will be monitored and levels recorded not less than once per day. The water level, gate settings, and other information will be recorded as described in Section 2.4.4.

5.2 EROSION, SEDIMENTATION AND WATER QUALITY

An inspection of reservoir erosion and sedimentation conditions and field water quality measurements will be made as described in Section 3.0.

5.3 MONITORING DELTA CHANGES

The delta will undergo the most obvious changes during drawdown, and will likely not require any mitigation measures. The majority of the delta appears to be sand, though a layer of alluvial flood deposits (silt mixed with large pieces of wood and detritus) are apparent in the south “lobe” of the upper impoundment that the channel now occupies. Extensive coring and analysis has not been performed to detail the extents of various layers. Channel adjustment through these layers is part of the evolution from a pond back to a fluvial system. Since the transport of sediment will be controlled by the remaining
Brown Bridge Pond, and not allowed to move into reaches below the dam, all adjustments that occur in this initial drawdown phase can be attended to in later phases that deal with remediating the unnatural deposits of sediment in this section of the river.

The one caveat that may bear on the extent of initial drawdown is the distance the delta migrates downstream. Although not confirmed, it is believed that the pond below the delta is relatively free of deposited sediment, and may represent an intact river channel and floodplain. Recognizing that allowing sand to migrate into this area in large quantities will only complicate restorative efforts in later phases, the extent of sand transport into this area is of interest. Should the delta move considerably further downstream than the upper third of the impoundment, prior to reaching the full drawdown elevation of 784 ft, discussions will likely occur about the efficacy, from both a cost and logistics standpoint, of continuing to draw down the impoundment without managing the transport of this material preemptively; as generally being the ideal approach.

5.4 MONITORING TRIBUTARY CHANGES
As the drawdown progresses, if either Century Creek or Grasshopper Creek do not stabilize at their original base levels and proceed to cut deeper into their channels, steps may be taken to mitigate the rate of change. In particular, the addition of logs, found or cut on site, into the channels at strategic locations can help provide grade control, limiting the gullying effect. These measures can be accomplished by hand and will provide temporary control of incision until more permanent efforts, if deemed necessary, can be examined. Emphasis should be placed on controlling the rate of change, not forcing the streams to stop adjusting. Tenuous action to halt adjustment is contrary to the overall momentum and trajectory toward restoration of the pattern, profile and dimensions of the stable condition and thus will have questionable, long term, persistence in the channel; or in worse case, could potentially contribute to channel degradation/aggradation and a corresponding increase in time to reach channel stability.

5.5 MONITORING THE NORTH SLOPE
Monitoring the situation on the north slope should focus on revealed areas on the lower slope during drawdown. Localized areas of failure at the toe of the slope are expected, caused by wave action. Instituting a no wake policy along the shore may help to curb some boat induced wave action. Further, consideration should be given to the relative position of the boat launch slabs and the bottom composition beyond them; as it may be prudent to employ a non-motorized policy while informing and educating the public the purpose for such is to maintain bank stability during the drawdown. Proportionately larger areas of failure, more closely associated with large slumps or calving into the impoundment are serious
signs of instability and should illicit immediate action. During the growing season, the development of vegetation will add further protection to exposed surfaces.

5.6 **Fish Rescue**
The applicant (under the guidance and supervision of the MDNR Fisheries Division and Grand Traverse Band of Ottawa and Chippewa Indians) will monitor the drawdown for fish stranding and rescue. Appropriate fish transfers will occur through all applicable permits, guidance, and supervision of the MDNR Fisheries Division and Grand Traverse Band of Ottawa and Chippewa Indians. A report documenting this activity will be prepared and made available to the MDEQ within ten days of the conclusion of the drawdown for review and inclusion into the subject file. The applicant will not transfer any fish species from isolated pools (resulting from the drawdown) to the Boardman River or Brown Bridge Pond that will negatively affect the fish community of the Boardman River or Brown Bridge Pond.

5.7 **Brown Bridge Structure**
An inspection of the discharge gates, discharge apron and banks, trash racks, log boom, and earthen embankment will be made not less than once each day during the initial lowering phase. Inspections will be made not less than twice each week during the hold-down phase. The inspection will be documented on a standard inspection form.

5.8 **Record-Keeping**
Records of conditions existing during the drawdown and inspection observations will be maintained. Inspection observations related to the facility structures, including the discharge gates, turbines, dam, and spillway will be maintained on the inspection form presented in Appendix D. Inspections related to sediment management are addressed in Section 3.0.

5.9 **Project Reporting**
A brief status report will be submitted to the Implementation Team once each week during the initial drawdown phase and monthly during the hold-down phase.

5.10 **Drawdown Plan Modifications**
This drawdown plan is a dynamic document and will be modified as appropriate based on different conditions.
5.11 Emergency Preparedness
The existing Brown Bridge Dam Emergency Action Plan (City, 2011) provides information appropriate for use should any emergency conditions develop during the drawdown and hold-down period.

5.12 Photo Documentation
At least four photo documentation stations will be established at key vantage points adjacent to Brown Bridge Pond and the Boardman River in the drawdown area of concern. At least two of these will be at elevated locations such as the scenic overlook platforms located on the north side of Brown Bridge Pond. Station stakes or markers will be fixed in place with arrows indicating the direction the photo will be taken. At least three photos at each location will be taken from the same vantage point as indicated by the station marker and arrows, using the camera’s wide angle setting. Each photo will be overlapped to some extent to allow creation of a panoramic encompassing scene. Photos will be time and date stamped and photo file identifications recorded in a log book.

Photos at the stations will be recorded on a daily basis starting the day prior to initiating the drawdown. Select series of photos will be reviewed and posted weekly on one of the Boardman River Web site for public access.

5.13 Public Notifications and Communications
It is important to make information regarding the drawdown available to the interested public and stakeholders. This will occur through regular project reporting to the City, press releases and pertinent information will be posted on the Boardman River Web page (www.theboardman.org).

In addition, the City will create and place as appropriate, signage along areas around Brown Bridge Pond and the adjacent Boardman River that have steep slopes, erosion, soft bottom, etc.
6.0 REFERENCES


STS, September 17, 2008. Safety Inspection of Brown Bridge Dam. Performed for City of Traverse City, MI.


FIGURES
Figure 1-1.
Brown Bridge Pond
Boardman River
Grand Traverse County, MI

Legend
Brown Bridge Pond

Image Source: NAPI, 2010

Scale: 0 500 1,000 Feet
Figure 2-1. Brown Bridge Dam Power House Water Control Features
Figure 2-2. Exceedance Flows (1%, 10%, 50%, and 90%) by Month for USGS Stations above and below Brown Bridge Pond
Brown Bridge Initial Drawdown Plan

**Figure 2-3**
Brown Bridge Dam Initial Drawdown Plan (IDP) Decision Tree
Figure 2-4. Discharge Rating Curves Based on Initial Drawdown Scenario D

Assumptions:
- Use only Upper Tainter Gates - equal openings
- No Trash Rack Head Losses Included
- No Flow through Turbines
- Head Gate raised
Brown Bridge Discharge Capacity

Figure 2-5. Discharge Rating Curves Based on Initial Drawdown Scenario B
Figure 3-2. Delta Comparison (2005 vs. 2010)
Boardman River
Grand Traverse County, MI

Legend
Brown Bridge Pond

Image Source: NAP, 2009 & 2010
Brown Bridge Initial Drawdown Plan

Figure 3-3.
Percent Slope
(North Slope of Brown Bridge)
Boardman River
Grand Traverse County, MI

Legend
▲ 1,000 ft Stations
● Boardman River

Image Source: NAR, 2010
Data Source: Interfluve, 2011

Created by: ISRA
Checked by: SPS
Approved by: WJE
Date: 5/19/2011
**APPENDIX A**

**Brown Bridge Structure Hydraulic Information**

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<th>Table A-1</th>
<th>Brown Bridge Dam Discharge Facility Data</th>
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</thead>
<tbody>
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<td>Table A-2</td>
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</tr>
<tr>
<td>Figure A-1</td>
<td>Brown Bridge Discharge Rating Curves (Maximum Capacity Each Gate)</td>
</tr>
<tr>
<td>Figure A-2</td>
<td>Brown Bridge Discharge Rating Curves; Upper and Lower Tainter Gates - Varying Opening Heights</td>
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<tr>
<td>Figure A-3</td>
<td>Brown Bridge Pond Elevation – Area and Elevation – Storage Curves</td>
</tr>
<tr>
<td>Figure A-4</td>
<td>Brown Bridge Bathymetric Map/Aerial Image (2010)</td>
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Appendix A provides a summary of basic hydraulic information for the Brown Bridge discharge facilities and the impoundment relevant to development of the Initial Drawdown Plan. This information includes:

- Summary of discharge facilities data
- Estimated discharge rating relationships for the discharge facilities
- Brown Bridge Pond elevation – area – storage relationships
- Brown Bridge Pond bathymetric map
Discharge Rating Relationships

Discharge rating relationships were developed based on basic weir and orifice flow equations for the gates (two upper Tainter gates, two lower Tainter gates, and log chute sluice gate). Characteristics of the structures at the dam are summarized in Table A-1. Very limited information is available regarding the rating of these structures from earlier work. The most recent Brown Bridge Dam inspection report provides some information regarding the maximum capacity, and the discharge rating for the Brown Bridge Dam removal project compares with that information reasonably well. The rating is slightly lower than the referenced discharge capacity, which is assumed to be design rating curves with all facilities in good condition. For purposes of this initial drawdown plan, these calculated rating relationships are believed sufficient.

The calculations were done within a spreadsheet. Control is based on the lower discharge estimate from basic weir and orifice equations using a single assumed value for the orifice coefficient and weir coefficient throughout the head range. In the spreadsheet, gate openings and discharge coefficients are assigned to each gate individually to enable calculating the total discharge for any combination of gate settings. Two example discharge rating curve plots follow, one providing the maximum capacity (gates fully open) and the second provides a series of plots for varying gate opening.

It is noted that the Dam Inspection Report states that the lower Tainter gates cannot be opened with a pool level above elevation 792.5 ft. Given the head conditions controlling flow through the upper Tainter gates and the lower Tainter gates, this condition creates an unusual appearing rating curve where discharge capacity drops to zero for pool elevations in that transition range.

The discharge rating also includes flow through the two turbines. The flow capacity of the turbines was estimated based on the stated power generation capacity of the turbines. Flow through the turbines is controlled by the opening of the turbine wicket gates. It appears that the turbines can be used to discharge water at any pool elevation above the sill elevation to the turbine bays; however, because of operational considerations including debris accumulation on the horizontal trash rack, it is assumed that discharge through the turbines will be used only as needed to maximize drawdown.
## Table A-1. Brown Bridge Dam Discharge Facility Data

<table>
<thead>
<tr>
<th>Facility Attribute/Element</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Gate</td>
<td>15 feet (ft) high x 27 ft wide gate</td>
</tr>
<tr>
<td>Inclined Trash rack</td>
<td>Approximately 384 square ft (sq ft)</td>
</tr>
<tr>
<td></td>
<td>Bottom elevation = 782.0 ft (approx)</td>
</tr>
<tr>
<td>Horizontal Trash rack</td>
<td>Located above turbine bays at elevation 792.5 ft (top)</td>
</tr>
<tr>
<td></td>
<td>Assume four racks at 12 ft x 8 ft each or 384 sq ft</td>
</tr>
<tr>
<td>Upper Tainter Gates (2)</td>
<td>12 ft wide x 5.5 ft high</td>
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<tr>
<td></td>
<td>Sill Elevation = 792.5 ft; lift to open</td>
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<tr>
<td></td>
<td>Left gate - manual lift; Right gate – motorized lift</td>
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<tr>
<td>Lower Tainter Gates (2)</td>
<td>12 ft wide x 5.5 ft high</td>
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<td>Sill Elevation = 786.7 ft; lower to open</td>
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<tr>
<td></td>
<td>Manual lift</td>
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<tr>
<td></td>
<td>Cannot be used for pool levels higher than approximately 792 ft</td>
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<tr>
<td>Turbines (2) – Vertical Shaft Francis</td>
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<tr>
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<td>• 690 horsepower (HP)</td>
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<td>• Flow capacity approximately 230 cubic ft per second (cfs)</td>
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<tr>
<td></td>
<td>Leffel Type F</td>
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<td>• 375 HP</td>
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<td>• Flow capacity approximately 115 cfs</td>
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<td>Log Chute</td>
<td>6.0 ft wide x 6.0 ft high sluice gate (manual hoist)</td>
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<td>Log Boom</td>
<td>Deployed in advance of head gate</td>
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Figure A-1. Brown Bridge Discharge Rating Curves (Maximum Capacity Each Gate)

Assumptions:
- Lower Tainter gates are operable for pool level <791 ft
- No trash rack head losses included
- Maximum flow through turbines is 115 cfs (Type F) and 220 cfs (Type Z) (controlled by headgate and/or wicket operation)
- No flow through turbines for headwater > 795 ft
- All equipment set for maximum discharge
Figure A-2. Brown Bridge Discharge Rating Curves: Upper and Lower Tainter Gates - Varying Opening Heights
Figure A-3. Brown Bridge Pond Elevation – Area and Elevation – Storage Curves
Table A-2. Brown Bridge Pond Elevation – Area and Elevation Storage Data

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<th>Elevation (ft)</th>
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<th>Shoreline Area (acres)</th>
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<th>Cumulative Storage Volume (bottom up)</th>
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Figure A-4. Brown Bridge Bathymetric Map/Aerial Image (2010)
APPENDIX B

Existing Condition Streamflow Characteristics

Table B-1 Daily Mean Flow Duration Curves; USGS Station 04126970 Boardman River above Brown Bridge Road
Table B-2 Maximum Mean Daily Discharge Data by Month
Table B-3 Peak Discharge Frequency Estimates; USGS Station 04126970 Boardman River above Brown Bridge Road
Figure B-1 Daily Mean Flow Duration Curves; USGS Station 04126970 Boardman River above Brown Bridge Road
Figure B-2 Exceedance Flows (1%, 10%, 50%, and 90%) by Month for USGS Stations above and below Brown Bridge Pond
Figure B-3 USGS Annual Peak Discharge Series Plot USGS 04126970, Boardman River above Brown Bridge Road near Mayfield
Existing Condition Streamflow Characteristics

Appendix B provides information related to Boardman River streamflows, including:

- mean daily flow duration statistics for each month of the year, and
- high flow frequency data.

Extensive analyses of streamflow data from two USGS long-term stations was completed to characterize historical streamflow statistics including mean daily flow duration for each month and peak discharge information annually and by month.

The period of record for the Station downstream of Brown Bridge Dam is from 1954 through 1989. That station location is primarily discharge from Brown Bridge Dam, but East Creek also enters the Boardman River just upstream of the station. The statistics indicate a marked difference in runoff characteristics at this station from those at the active station that is upstream of Brown Bridge Pond. It appears that the East Creek watershed has a more rapid response to precipitation events than does the upper Boardman River watershed. The rates of rise and fall for runoff events are more rapid for the lower station than for the upper station. The runoff volume per unit watershed area is slightly higher for the downstream station, which is assumed to reflect the inflow from East Creek.

Because this Initial Drawdown Plan is primarily concerned with inflows to Brown Bridge Pond, the focus of the summarized information is for USGS Station 04126970 - Boardman River above Brown Bridge Road.
Figure B-1. Daily Mean Flow Duration Curves; USGS Station 04126970 Boardman River above Brown Bridge Road
Figure B-2. Exceedance Flows (1%, 10%, 50%, and 90%) by Month for USGS Stations above and below Brown Bridge Pond
## Table B-1. Daily Mean Flow Duration Curves; USGS Station 04126970 Boardman River above Brown Bridge Road

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## Table B-2. Maximum Mean Discharge Data by Month

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\(^1\)(USGS Station 04126970 Boardman River above Brown Bridge Road; September 1997 – December 2010)

\(^2\)(based on Annual Maximum Series)
Figure B-3. USGS Annual Peak Discharge Series Plot USGS 04126970, Boardman River above Brown Bridge Road near Mayfield
## Table B-3. Peak Discharge Frequency Estimates; USGS Station 04126970 Boardman River above Brown Bridge Road

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APPENDIX C

Analysis of Runoff Event Hydrologic Effects

Table C-1  Effect of Smaller Pond on Peak Flow Reduction
Figure C-1 Historic High Flow Events at Brown Bridge Road above Brown Bridge Pond
Figure C-2 Flow and Storage within Brown Bridge Pond, June 18, 1986 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-3 Flow and Storage within Brown Bridge Pond, April 2, 1988 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-4 Flow and Storage within Brown Bridge Pond, April 2001 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-5 Flow and Storage within Brown Bridge Pond, March 30, 2004 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-6 Flow and Storage within Brown Bridge Pond, March 23, 2007 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-7 Flow and Storage within Brown Bridge Pond, September 8, 1985 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-8 Flow and Storage within Brown Bridge Pond, September 18, 1985 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-9 Flow and Storage within Brown Bridge Pond, April 9, 2008 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-10 Flow and Storage within Brown Bridge Pond, June 18, 1996 Event, with Initial Drawdown Control
Figure C-11 Flow and Storage within Brown Bridge Pond, April 2, 1998 Event, with Initial Drawdown Control
Figure C-12 Flow and Storage within Brown Bridge Pond, April 2001 Event, with Initial Drawdown Control
Figure C-13 Flow and Storage within Brown Bridge Pond, March 30, 2004 Event, with Initial Drawdown Control
Figure C-14 Flow and Storage within Brown Bridge Pond, March 23, 2007 Event, with Initial Drawdown Control
Figure C-15 Flow and Storage within Brown Bridge Pond, September 8, 1985 Event, with Initial Drawdown Control
Figure C-16 Flow and Storage within Brown Bridge Pond, September 18, 1985 Event, with Initial Drawdown Control
Figure C-17 Flow and Storage within Brown Bridge Pond, April 9, 2008 Event, with Initial Drawdown Control
Figure C-18 Effect of Smaller Pond on Peak Flow Reduction (Percent Reduction of Peak Inflows)
Figure C-19 Effect of Smaller Pond on Peak Flow Reduction (Percent Increase Due to Lower Pond Level)
Analysis of Runoff Event Hydrologic Effects

Appendix C provides information used to assess the effects of the historic Brown Bridge Pond and the Initial Drawdown pool condition on peak discharge rates of runoff rates. This assessment was accomplished by accessing 15-minute discharge records for USGS Station 04126970 Boardman River above Brown Bridge Road near Mayfield from the USGS archives. Four historic high flow events were routed through storage in Brown Bridge Pond using HEC-HMS to assess the attenuation provided by the temporary storage. HEC-HMS graphics showing inflow and outflow discharge hydrographs and pool elevation and storage volume hydrographs are provided. The results are summarized in tabular and graph form.
Figure C-1. Historic High Flow Events at Brown Bridge Road above Brown Bridge Pond
Figure C-2. Flow and Storage within Brown Bridge Pond, June 18, 1986 Event, with 24 ft Spillway Crest at 797.0 ft

Figure C-3. Flow and Storage within Brown Bridge Pond, April 2, 1998 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-4. Flow and Storage within Brown Bridge Pond, April 2001 Event, with 24 ft Spillway Crest at 797.0 ft

Figure C-5. Flow and Storage within Brown Bridge Pond, March 30, 2004 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-6. Flow and Storage within Brown Bridge Pond, March 23, 2007 Event, with 24 ft Spillway Crest at 797.0 ft

Figure C-7. Flow and Storage within Brown Bridge Pond, September 8, 1985 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-8. Flow and Storage within Brown Bridge Pond, September 18, 1985 Event, with 24 ft Spillway Crest at 797.0 ft

Figure C-9. Flow and Storage within Brown Bridge Pond, April 9, 2008 Event, with 24 ft Spillway Crest at 797.0 ft
Figure C-10. Flow and Storage within Brown Bridge Pond, April 28, 2011 Event, with 24 ft Spillway Crest at 797.0 ft

Figure C-11. Flow and Storage within Brown Bridge Pond, June 18, 1996 Event, with Initial Drawdown Control
Figure C-12. Flow and Storage within Brown Bridge Pond, April 2, 1998 Event, with Initial Drawdown Control

Figure C-13. Flow and Storage within Brown Bridge Pond, April 2001 Event, with Initial Drawdown Control
Figure C-14. Flow and Storage within Brown Bridge Pond, March 30, 2004 Event, with Initial Drawdown Control

Figure C-15. Flow and Storage within Brown Bridge Pond, March 23, 2007 Event, with Initial Drawdown Control
Figure C-16. Flow and Storage within Brown Bridge Pond, September 8, 1985 Event, with Initial Drawdown Control

Figure C-17. Flow and Storage within Brown Bridge Pond, September 18, 1985 Event, with Initial Drawdown Control
Figure C-18. Flow and Storage within Brown Bridge Pond, April 9, 2008 Event, with Initial Drawdown Control

Figure C-19. Flow and Storage within Brown Bridge Pond, April 28, 2011 Event, with Initial Drawdown Control
Figure C-20. Effect of Smaller Pond on Peak Flow Reduction (Percent Reduction of Peak Inflows)

Figure C-21. Effect of Smaller Pond on Peak Flow Reduction

(Percent Increase Due to Lower Pond Level)
<table>
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<th>Storm Event</th>
<th>Peak Inflow (cfs)</th>
<th>Bull 17B</th>
<th>MDRNR</th>
<th>Peak Discharge (cfs)</th>
<th>Peak Reduction (%)</th>
<th>Initial Drawdown Condition (NWL - 784 ft)</th>
<th>Peak Discharge (cfs)</th>
<th>Peak Reduction (%)</th>
<th>Reduction in Peak Attenuation (%)</th>
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<sup>a</sup> Hydrograph data from PMF study HEC-1 model input data (Mead & Hunt, 2001)
APPENDIX D

Structures Inspection Form
Brown Bridge Structure Daily Report

Date: _________________   Time Arrival: __________ am pm   Time depart: __________ am pm

Personnel:
___________________________________________________________________________________

Wind:  Calm □  Mild □  Moderate □  Strong □  Steady □  Gusty □  Direction (from) __________

Speed: ______ mph

Temperature: _______ °F   Precipitation: ______ inches   Time: __________ am   pm

Headpond Elevation: _________ ft   Time: _________ am   pm   Change since last reading: _________ ft

Tailwater Elevation: _________ ft   Time: _________ am   pm

USGS Station 04126970: Flow: _______ cfs   Time: ________ am   pm   Steady □  Increasing □  Decreasing □

Discharge Rate Needed: _________ cfs

Discharge Controls:

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<th>Debris</th>
<th>Comments</th>
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Other comments:

Gate change Notifications Completed:  Y   N

Debris Controls:

Inclined Trash Rack: Inspected:  Y   N   Removed debris:  Y   N   Type:  ______________

Comments:
___________________________________________________________________________________

Horizontal Trash Rack: Inspected:  Y   N   Removed debris:  Y   N   Type:  ______________

Comments:
___________________________________________________________________________________

Log Boom:  Inspected:  Y   N   Removed debris:  Y   N   Type:  ______________

Comments:
___________________________________________________________________________________

Embankment:

Inspected:  Y   N   Erosion  Y   N   Seepage  Y   N   Sloughing  Y   N   If yes, explain (location and details):
___________________________________________________________________________________
Comments:

______________________________

Tailrace:
Inspected: Y N Debris Y N Erosion Y N Sedimentation Y N
Comments:

______________________________

Other Observations:

______________________________

Attach sketches or other information as needed: Attachments: Y N Photographs taken: Y N
Unscheduled Follow Up Required: Y N Urgent: Y N Responsible Person:

______________________________

If yes, explain:

______________________________
APPENDIX E

Sediment Quality Data Summary
## 2005 Brown Bridge Impoundment Samples

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The Ecological screening levels were taken from USEPA Region V RCRA Guidance (2003); for barium and selenium the value given is the Apparent Effects Threshold (AET).

**Units:** µg/kg
## 2010 Brown Bridge Impoundment Samples

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<th>Chromium</th>
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<th>Nickel</th>
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1 North Central Hardwood Forest Region
2 Statewide Average

- One to two times background
- Two to three times background
- Three to five times background
- Five to ten times background
- Over ten times background levels