# Leading Small Dam Removal

A Guidebook for Understanding the Natural and Social Characteristics

Huron Pines

*Conserving the Forests, Lakes and Streams of Northeast Michigan*

www.huronpines.org

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**Acknowledgments**

Huron Pines would like to thank the organizations and individuals that supported the development of this guidebook and the workshop, both financially and through the contribution of volunteers, expertise and advice. The level of support and participation during the whole process really exemplifies the desire to and need for increasing collaboration, which in turn will lead to more effective projects being completed. In a time when organizations and agencies are highly interested in on-the-ground results, their support for a guidebook and education campaign displays both understanding and foresight. Special thanks to photographer David M. Smith.

Partial funding for this program is supported by a Cooperative Agreement from the U.S. Department of Interior – Fish & Wildlife Service and The Carls Foundation. This guidebook was also supported by generous funding from the Challenge Chapter of Trout Unlimited and the Paul H. Young Chapter of Trout Unlimited. Additional support was provided by the Kalamazoo Valley Chapter of Trout Unlimited, Tip of the Mitt Watershed Council, Michigan Environmental Council, Michigan United Conservation Clubs and Michigan Trout Unlimited.

With more dam failures, the impacts that result, and the lawsuits that have ensued, Huron Pines continues to evolve its role in the field of actively treating dams and restoring stream habitats. Part of that evolution is to rely on the guidance of the Resource Advisors. This is a group of resource professionals active in restoration and habitat protection throughout Michigan and the Great Lakes Region. As part of their quarterly meetings, they dissect the details of each project and program that Huron Pines is considering for future work and interpret the overall value each project will lend to its broader ecosystem. The whole process enables Huron Pines to adopt projects that most effectively and efficiently improve the natural resources in comparison to the effort and funding it would take to do so. Their analysis of the most appropriate role Huron Pines should fill in Northeast Michigan is that Huron Pines should further the field of dam removal by focusing on education, knowledge dissemination, and hands-on implementation. As a direct result of those recommendations, Huron Pines applied for and received a grant from the U.S. Fish & Wildlife Service – Fish Passage Program.

The purpose of the grant was two-fold. The first goal was to bring together resource professionals that have an active role in dam removal, to teach and learn from each other in a workshop forum. In July, 2010, over 30 participants representing that conglomerate attended a two-day workshop to help evolve the collective direction of dam removal practices in Michigan. The second goal was to build on that workshop and create a guidance document that would lead project managers and landowners through future dam removals. The idea was to outline the steps involved, based on the breadth of knowledge and experience present at the workshop, in the process of designing a well-rounded dam removal project. This guidebook is the result of that effort.

Every dam removal is different and there will be anomalies that do not fit into the general framework of project design. Those projects, and the detailed questions that arise, need to be addressed specifically by the partnership leading the decision making. This document does not provide the answers to each situation that may exist. Rather, it is focused on highlighting the steps that will lead the group through the process of deciding. The onus of decision-making remains on the partners vested in each project. This guidebook is intended to be a tool to streamline the process of determining the questions that need to be asked for each project and considerations to incorporate when arriving at the answers.

With the knowledge and expertise of dam removal constantly growing, there are continually new case study examples and information being made available. This guidebook works to set the tone of communication between dam removal experts and practitioners within the Great Lakes region. Though references from scientific journals and other published studies are made available at the end of each pertinent section as a resource, it was not planned for this document to serve as an exhaustive bibliography review.

Finally, this guidebook was written with the intent of facilitating project design and implementation for dam removals that are voluntary, where the landowner is a willing participant. In no way should information set forth in this guidebook replace the specific detailed decisions of partners involved, or the requirements set forth in legal documents, court settlements, or court-ordered mitigation or restoration. The information in this document is focused on managing dam removals and does not cover details regarding the installation of dams or those impoundments that may not be directly connected to true streams.

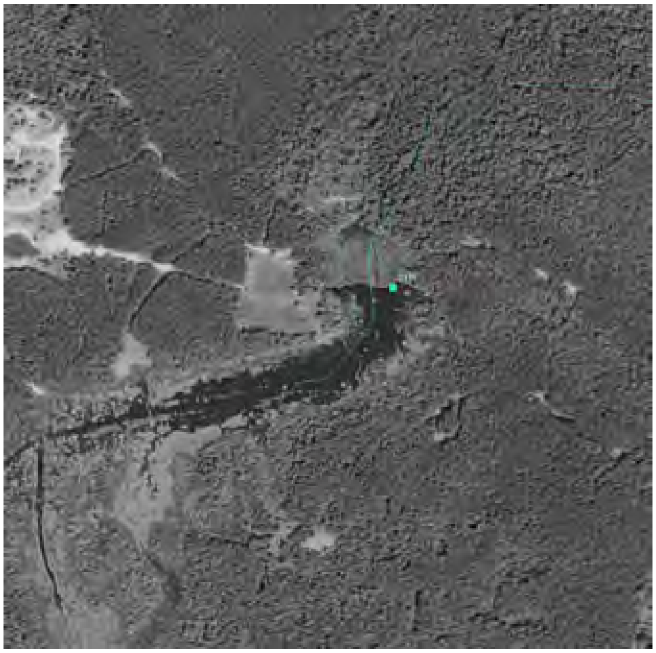
# Contents

## 1. Overview: Understanding the Impacts and Oversight of Dams

Natural resource professionals in Michigan have long realized that the total number of dams in the state is unknown. There are, however, some agreed-upon estimates that drive the direction of how dams are treated currently and in the future in Michigan. Over 2,500 dams exist in Michigan, yet those are the accepted estimates for dams larger than 6 feet in height. There are no concrete numbers that would represent all of the dams in Michigan, from the large hydropower dams to smaller impoundments that may serve only to create a recreation pond. Though we know the 2,500 estimate, it has proven difficult to properly assess the quantity of dams that do not make the 6-foot height threshold. It is believed that there are far more dams throughout Michigan below this 6-foot limit that continue to be undocumented. What is more concerning is that by the year 2020, it is estimated that over 80% of all of these dams will be older than their design life.

### a. The Situation of Dams in Michigan

Aging dams present a new and growing opportunity for the conservation community to reevaluate each dam and determine if a change in the management of each would bring benefits to the natural ecosystem. That evaluation is underway with the majority of known dams in Michigan. However, there is a broad understanding that many of the small dams that could pose significant threats to the streams in Michigan may not even be known to resource professionals. Dams are continually being discovered and added to databases maintained by either the State of Michigan or the U.S. Fish & Wildlife Service.



*Air photo of a suspected dam. Notice the widening and change in channel pattern.*

Many of the dams being added to existing databases are those previously unknown small dams on tributary or headwater streams. Often they have been unnoticed because they were constructed generations ago by private landowners in areas that may be relatively remote. The dams may have been built before regulations were in place or in disregard of existing laws. The intentions behind dam construction and the intended purpose of the dam or pond are numerous. Many small dams recently added to the knowledge base include those constructed to serve as wildlife ponds, to improve the aesthetic beauty of a property, to increase property values of neighboring properties, etc.

These dams are creating worry among the conservation community and several dam owners, as they were not built with the science and engineering of many larger dams. As concern over the larger dams reaching the end of their design life grows, there is equal alarm about the risk of failure of these landowner- created structures. These dams may have outlived their original purpose or they may have been fully abandoned. Furthermore, it is unclear if any regular inspection or maintenance has occurred, making the idea of their failure more disconcerting.

### b. What is a Stream?

The term “stream,” for the purpose of this document, refers to any stretch of flowing water that exhibits features of a defined channel and is part of a broader drainage system, or watershed.

All streams, as part of their natural function, have the ability to move sediment. Regardless of the stream’s size, location, or distribution within the watershed, this sediment movement is directly related to the amount and velocity of water flowing in the stream and what sediment types and sizes are available for the stream to move.

Sediment movement, stream velocity, and volume of water flowing through the channel are three major factors that control the overall condition of the stream.

In a stable stream, each characteristic (sediment movement, velocity, volume) would properly react to changes in the other features to maintain an overall equilibrium. That is not to say that erosion or deposition would not be occurring in a specific reach of stream. It means that the overall amount of sediment movement results in no net loss or gain.

As water velocity increases, the stream has the ability to move larger particles and higher quantities of sediment and erosion results. When velocity slows, the larger particles and increased quantities can no longer be transported by the stream and they will settle out in depositional features. Even when there aren't large fluctuations in water velocity, the stream is continually eroding and depositing sediment in respective areas.

*Sediment filling in at a point bar typical of the inside bend in a stream.*

For example, on the outside bend of the stream, where the water exerts its greatest force, sediment is eroded, creating a feature known as a cut bank. On the inside of the bend, water typically flows more slowly and this becomes a location of deposition, known as a point bar. The development of cut banks and point bars helps lead a stream to meander, or wind back and forth within the landscape. As the stream meanders, it increases the horizontal distance it has to travel to cover a certain drop in elevation (vertical distance). Thus the stream changes its slope. As slope changes, so does velocity of the water, which then changes the amount of sediment the stream can move. This continually occurs until a general balance is reached.

Whether on the inside or outside of a bend, or in the center of a stream, the overall amount of sediment being moved along the bottom is referred to as the stream's bedload. Again, the velocity (controlled by the stream slope), the volume of water and the movement of the bedload are constantly working against one another to reach equilibrium in the stream.

When a dam is put into any stream, this equilibrium is interrupted. The balance between velocity, volume and sediment transport responds accordingly and changes to the stream begin. Each characteristic of the stream adjusts in an effort to reestablish the equilibrium.

### c. What is a Dam?

A dam, in the simplest sense, is a structure that restricts flowing water. Dams can be composed of all sorts of materials, constructed by many different mechanisms and created for numerous purposes. Both natural and human-made structures can behave as a dam. They can last for very brief periods of time or be built with the intention of lasting generations.

*A typical small dam with stop logs to control water level.*

The word "dam," or more often "damming," is readily used to describe anything that may be interrupting natural water flows. However, the image the word "dam" conjures up in most people's minds is that of a large hydropower dam. Those images are typically of big concrete structures with large ponds upstream. Pontoon and fishing boats cut through the impoundment for a good day's recreation. On the downstream side, white frothy water rushes through the spillway and perhaps even a desperate fish attempts to jump unsuccessfully as it obeys its instinct to migrate.

That image, by all means, depicts what would be classified as a dam. Yet, there are exponentially more structures acting as dams than those that would fit the description given above. There are small tributary streams dammed for the purpose of simply creating a pond on someone's property. Bigger tributaries have been dammed to increase the appeal of the land as it is developed. Communities have maintained dams to create recreational opportunities for its members. Larger streams have had dams and mill ponds installed during the logging boom of the late 1800s. Several mill dams have been removed, yet many remain as communities were built around the dam and the industry it may have supported.

Features do not have to be created by humans to function as a dam. Many natural phenomena interrupt stream dynamics as well. They can be ice jams in the winter, beaver dams, windstorms that cause blow downs and tree falls may lead to log jams. Even large landslides can interrupt stream flow. Not including these natural features, it is commonly estimated that there are over 2,500 dams in Michigan alone. It is also readily admitted that no one organization or agency has complete knowledge of existing dams. Particularly, those low-head, private or abandoned, unregulated structures are difficult to incorporate into totals of existing dams.

### d. General Stream Impacts Caused by Dams

#### i. Sediment Transport

The most immediate impact a dam causes to a stream is that the dam changes the vertical distance a stream drops in the reach upstream of the structure. The dam acts as the new elevation control by raising the elevation of the "stream bottom" by creating an obstacle that water must flow over or through. By raising the elevation downstream, the dam creates a situation in which the stream is, in essence, flowing down a less steeply sloped hill. The less vertical drop a stream covers over a given amount of horizontal distance, the less steep the slope of the stream is. Decreasing the stream's slope causes a reduction in the velocity of the water. In short, dams decrease slope, forcing the upstream water to slow down.

When you consider the equilibrium of the stream before the presence of the dam, the conditions in the stream, such as velocity, volume of water and bed load, were in balance. By decreasing the slope of the stream, the velocity slows down. As the water slows down, its ability to carry sediment also decreases and the previous bedload amount is forced to decrease. However, right where the stream enters the water impounded behind

*Deposition occurs at the upstream end of the impoundment as demonstrated in the Huron Pines River Model.*

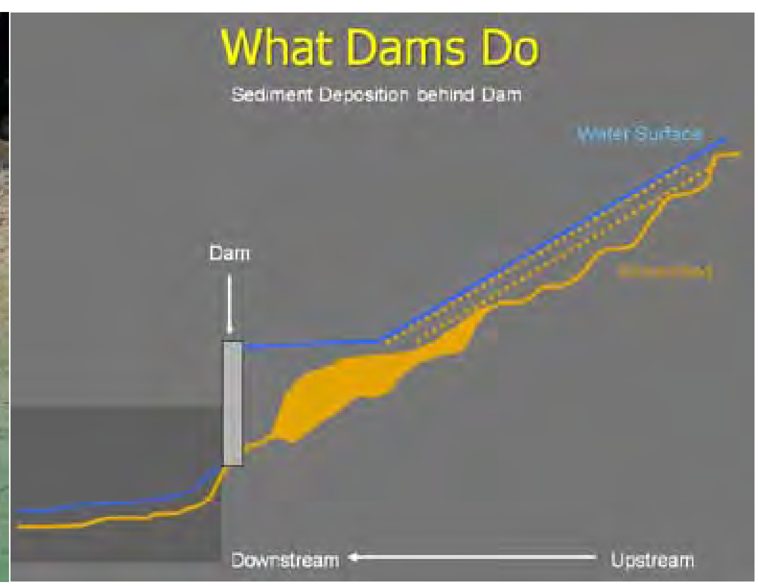



**Figure 1.** *A cross-section of deposition where the stream enters the impoundment (adapted from Bryan Burroughs presentation).*

the dam, it is still carrying the larger amount of sediment. At the location where the faster water enters the slower water of the impoundment, the stream is no longer capable of carrying the larger amounts of sediment associated with the faster water (figure 1). Deposition occurs at the upstream end of the impoundment as the water slows down and is forced to drop the sediment it was previously transporting.

As the deposition continues, new stream features cause the stream channel to migrate within the upstream portion of the impoundment as the stream attempts to adjust its slope to the new bedload capacity. The deposition will occur along the banks on the slower side of the channel, just like in a natural meandering stream. As that occurs, the stream will wind more and more in the upstream part of the impoundment. This is the stream's attempt to balance its new sediment load capacity by adjusting its slope.

The longer the dam is in place, the more profound the impact of sediment deposition becomes and the stream channel exhibits physical features of change in slope. For example, the series of photos on the right depicts the changes in stream channel that occurred as sediment deposited in the Lansing Club Pond after installation of the dam. Notice how the channel meanders, widens and the radius of curvature increases. There is also a greater likelihood of braiding that occurs as the stream adjusts slope and develops a new channel.

A little further down in the impoundment, sediment continues to build up. What was initially deeper water when the dam was created will continue to get shallower as the stream continuously brings new sediment. Behind many dams, the water is moving so slowly that not just the sand and larger-sized particles drop out and deposit. Very fine particles of organic matter are also being transported by streams. This material is commonly referred to as muck or silt. It is very light in terms of weight and is generally not difficult for streams to move.

*Aerial photos of the same dam in 1938, 1963 and 2005 show how the sediment deposition in the impoundment causes subsequent braiding of the channel.*

This organic matter can originate from numerous sources in a stream system, including the decomposition of leaves and trees that fall into the water, the breakdown of aquatic plants, waste from aquatic organisms in the stream, particles within soil that has been eroded by the stream, etc. It comes from many origins, but it can be thought of as one of the major sources of nutrients in the stream ecosystem. Organic matter is the dark brown or black material that settles out of water in the very slow moving sections. Water in many impoundments is moving so slowly that it can no longer even transport the majority of the organic matter.

### ii. Water Temperature

As water is backed up behind a dam it typically causes the stream to widen. With the new water elevations created by the dam, the stream is able to fill in the valley through which it used to flow. The boundaries of the new impoundment are created by the former valley walls. The water will inundate any upstream lands below the elevation of the dam. In this stretch of stream, with the increased width, the surface area of water exposed to sunlight is also greatly increased. There is also a loss of shade as the vegetation along the stream begins to perish as it is inundated.

Increasing the amount of exposure to the sun on the stream, the water absorbs more solar energy. Additionally, the slower water in the impoundment increases the "residency time" of the water. This means water spends a longer amount of time flowing through the impoundment than it would have if this stretch were still a natural stream channel.

*A beaver dam has raised the elevation of the water in the stream behind it. The impounded water absorbs sunlight and warms, decreasing the amount of dissolved oxygen it can hold and altering the fish habitat.*

Both of these impacts cause water in the impoundment to warm at rates higher than if it were still a natural stream. The temperature impacts become more pronounced as the impoundment becomes wider. Impoundments that are narrow will tend to have less of a thermal impact. Changes in temperature will ultimately lead to shifts in the ecology of the impoundment.

### iii. Dissolved Oxygen

Water temperature plays a critical role in determining the amount of dissolved oxygen that can be stored in any body of water. The colder water is, the better its ability to hold dissolved oxygen. If the dam is impounding colder water and the exposure to the sun leads to warming, the water's ability to store dissolved oxygen decreases. Ultimately, this can lead to a shift in the ecosystem, from a cold-water to a warm-water fishery, as an example. What may have once been a thriving trout fishery may switch to more of a cool-water fishery dominated by pike and perch, or even a warm-water fishery, where largemouth bass and bluegill would be more abundant. That shift is primarily due to long-term changes in the water temperature.

The dissolved oxygen issues do not stop with water temperature either. With greater amounts of the organic matter settling out in the impoundment, the demand for dissolved oxygen is increased as more organisms work to decompose those organic materials. Impoundments are receiving more organic matter than the natural stream would because of the settling with slow water. Therefore, there is more decomposition occurring, thus using greater amounts of dissolved oxygen. That increased oxygen use, in combination with the effect of warming water, contributes to lower and lower dissolved oxygen levels, leading to changes in the biological community inhabiting the impoundment and downstream waters.

### iv. Barrier and Blockage

Perhaps the most obvious impact of a dam in a stream ecosystem is that it creates a physical obstacle in the waterway. Though some dams have more of an impact in this sense than others, all dams produce obstacles to the movement of aquatic organisms, nutrients and sediment. Many fish and other aquatic organisms, whether resident or migratory, need to move through large stretches of water to fulfill activities integral to their life cycle (Groot, and Margolis, 1991, Powers, 1980, Winston, Taylor, and Pigg, 1991).

Every organism in the stream has different capabilities when it comes to swimming speeds, endurance and jumping ability. When thinking back to the original image of a dam with the fish jumping from the frothy spillway, that fish would likely exemplify one of the stronger migratory species. The fish in this stereotypical dam image could be a salmon or steelhead as it attempts to migrate upstream to reach good spawning gravel. However, those are both very strong jumping fish. Many fish that need to migrate are poor jumpers, if they can even jump at all (Bell, 1986, Kondratieff and Myrick, 2006).

The same goes for swimming speeds. Each species has different abilities when it comes to both: how fast they can swim over short distances and if they can maintain fast swimming speeds over long distances of stream. This also weighs into consideration when evaluating a dam as an obstacle to passage of aquatic organisms. If dams and their spillways cause water velocities to be greater than those in the non-impacted reach of the stream, aquatic organisms will begin to have difficulty traversing the obstruction. Similar difficulty passing the dam is realized when the dam or spillway begins to disconnect the stream vertically as well, creating a situation in which aquatic organisms must be able to jump to pass over the dam. The faster the water is and/or higher the dam is leads to greater separation between upstream and downstream habitats.

The distribution of once prevalent species across the watershed also suffers with persistence of a dam. Every year the dam is in place is another year that individuals of a divided population cannot interact. As the individuals in that population, both upstream and downstream of the dam, are continually stressed by the changing physical, chemical and biological conditions, the population continues to divide geographically and becomes weaker overall. Those in the downstream reach may be prevented from accessing upstream spawning or rearing habitats. This not only means that there are fewer individuals in the population reproducing, but there are fewer individuals reproducing with each other, which may ultimately lead to a genetic isolation of the population and weaken the overall gene pool.

There are also numerous non-fish species that require the ability to access upstream waters during their lifecycle. Freshwater mussels, for example, depend on the migration of host fish species to sustain and expand their populations (Haag and Warren, 1997, Waters, 1996). Mussel larvae briefly parasitize the gills and skin of certain fish species for a few weeks or more before falling off and settling to the streambed. During this time, juvenile mussels can be transported by the fish to new or under-populated habitats (Pennack, 1978). Successful colonization of new habitats by mussels depends on their host fish being able to migrate. This process enables mussel populations to maintain a healthy degree of genetic variability and to maintain larger populations by colonizing all suitable habitats.

The obstacles to the passage of aquatic organisms created by dams, in certain cases, can provide a benefit to ecosystems by also blocking the migration of non-native, invasive species. For example, dams that are considered the “first barrier” to migration from the Great Lakes into inland waterways may be helping to prevent the prevalence of the invasive sea lamprey. In these cases however, using dams as the management strategy against an invasive species is done at the expense of many native species.

Movement of nutrients and organisms isn’t just blocked for those going upstream. Materials that would typically bring nutrients down the stream, such as leaves and woody material like branches and tree falls, are blocked by the dam and have difficulty floating through the slow water. Not only does each of those materials provide

***The Franklin Dam Story***

*To help provide a better description of “real life” issues involved in removing a small dam, we’ve developed the Franklin Dam Story. Using events that have happened in ours and our partners’ experiences, the story gives examples of events you might encounter as you move through the dam removal process.*

For many years, landowners along Franklin Creek have enjoyed the recreation opportunities and solitude provided by impounded water behind a small dam. They often went fishing, swimming, or paddled their boats and canoes for an evening adventure. Several would talk about and photograph some of the common wildlife that would skirt the banks or fly over the pond. These activities have been taking place on Franklin Creek for nearly 70 years.

The pond resulted from the construction of a driveway, built so one landowner could access his family property on the south side of Franklin Creek, just before it joins the Liberty River. Franklin Creek was once home to brook and brown trout and exhibited numerous other characteristics of a typical northern Michigan, groundwater driven stream. Cold water from groundwater seeps help maintain constant temperatures in Franklin Creek, which in turn, created a stable coldwater ecosystem that provided several miles of tributary and nursery habitat to fish and wildlife in both Franklin Creek and the Liberty River. Where the driveway crossed Franklin Creek, a small dam was created as a means of controlling water levels in the pond.

In recent years, landowners along the pond have become increasingly unhappy with their typical a unique instream habitat type, but as they decompose, they replenish nutrients throughout the stream. However, as discussed above, that organic material gets trapped in the impoundment. Without the natural, even distribution of the organic material throughout the stream, an imbalance in resources and nutrients occurs, with the basis of the food chain being sequestered in the impounded water.

So too it is for sediment transport, which has been well described. Yet, the impacts of interrupting sediment flow don't stop in the impoundment. Downstream of the dam, the impact of not having continuous sediment supply is realized in another manner.

### v. Downstream Erosion

Once the water in an impoundment makes its way past the dam, it has typically returned to flowing freely. However, when the water passes the dam it has a significantly steeper slope over which it travels as it begins to flow in the downstream channel again. Just as the dam changed the slope of the upstream reach, the slope immediately downstream of the dam has also been altered. Upstream, the impact was a lower slope. Downstream is the opposite, where the slope has been increased or steepened. When the water flows over the dam, it drops drastically in a vertical direction, while only traveling a minimal distance horizontally. This motion causes the water to rapidly speed up and to flow at faster velocities than in the impoundment, often even faster than if the impoundment didn't exist on the stream.

The same dominant stream forces, discussed above, that are constantly trying to achieve equilibrium in the stream system are just as important downstream of a dam: speed of the water, quantity of water, and amount and size of sediment being moved by the stream.

*An overhead view of a river "mining" sediment downstream from a dam as the river incises. The red arrow depicts the streambank before the dam. The green arrow shows the development of the new streambank, or terrace.*

recreation activities along the pond. It seems that weed growth is really inhibiting the canoeing because with every stroke of the paddle, up comes a big chunk of aquatic plants that need to be cleaned off before continuing. People are no longer catching the brook and brown trout that they used to find and actually haven't been catching any fish for the last 5 or 6 years. In addition to the weed growth, the depth of the water has begun limiting the swimming opportunity.

It seems the pond continued to get shallower and shallower until it crossed a point that swimming is no longer enjoyable, causing further heartache with the landowners. Unfortunately, residents on the very upstream portion of the pond began taking it upon themselves to go down to the dam and add boards, or stop logs, to increase the water levels. Much to the dismay of the owner of the driveway dam, Mr. Snoop, more of the residents continued to manipulate the dam and the water level. Residents on the pond wanted to be able to engage in the activities that brought them joy for many years and they felt that by increasing the water levels, they could recapture some of that fun.

The boards placed in the dam by the upstream residents accomplished their goal of deeper water for a short time. What the residents did not understand was that the dam needed to be managed much more regularly based on water level and inputs from changes in weather. In 2009, with the extra boards in the dam, Franklin Creek received a large influx of water from spring snow melt, combined with a heavy precipitation event. The dam could not pass the amount of water that was coming downstream and water began to

When flowing water enters the impoundment, it slows down and is forced to deposit the sediment it was transporting. So when the water is released over the dam, it is again flowing with good speed, which increases its ability to move sediment. Yet as the water worked its way through the impoundment, it deposited any sediment it had been carrying. When it flows over the dam and regains its energy, the stream has no bedload to transport as a way to use its energy to do work.

This creates a situation where the water has increased velocity yet no sediment moving with it. The stream will then “find” or “harvest” sediment as part of its natural function, as it tries to reestablish equilibrium (figure 2). This is a case in which the water now has the energy required to move sediment, but it is not currently moving sediment. The result is that the flowing water will begin to pick up sediment from wherever it is available. That often means the stream begins to erode both the stream bottom and the streambanks. As long as the velocity, slope and sediment load continue to try and balance each other, erosion within the stream reach downstream from the dam will continue. That results directly from the fact that there is a constant supply of new water leaving the impoundment that has no sediment load, but has again achieved the ability to “harvest” and move sediment.

This leads to an ongoing state of erosion downstream of most dams. As the stream erodes the streambed and streambanks, the whole system will begin to cut downward. This process, called incision, can lead to instability in the streambanks. What once was a stable

*Erosion can occur downstream from a dam due to blockage of natural sediment and the higher water velocity.*

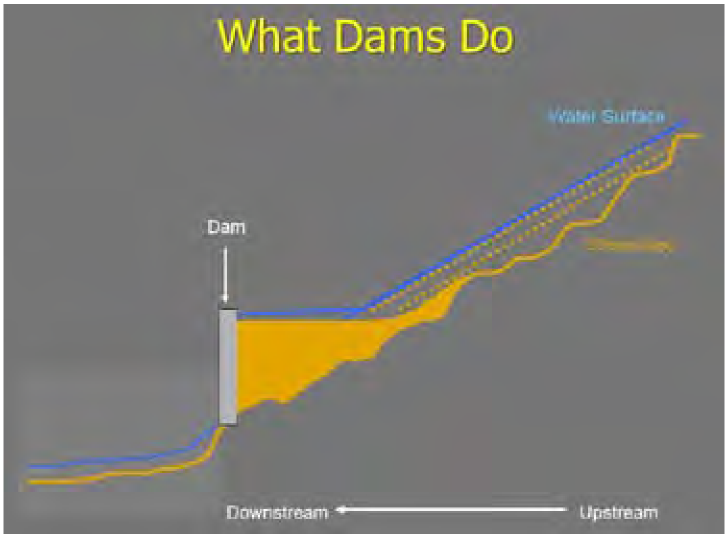



**Figure 2.** *In the downstream section (left of the dam), sediment is exported from the site and the stream incises.*

breach the driveway, which was made worse by the extra boards that the upstream residents had placed in the dam. There was an emergency spillway pipe in the pond that drained directly into the Liberty River, but the culvert was undersized and Franklin Creek continued to flow over the driveway. The flooding caused the driveway to badly erode on both sides of the dam, carrying large amounts of sediment downstream and compromising the integrity of both the dam and the driveway. Ultimately, the dam failed.

Franklin Creek Dam could no longer impound water similar to past levels and any water pressure threatened to further erode the driveway, wash out the dam, and cause sediment from behind the dam to wash downstream.

streambank that was 3 feet high may now be 5 feet high as the stream incises deeper and deeper into its bed. The new, higher banks may not be nearly as stable as they were before any incision, especially as they are exposed to more erosion forces from the stream. Banks that become unstable, can begin sloughing off into the stream, leading to more instability in the overall system.

### vi. Feedback Cycles

The example of channel erosion downstream of a dam is a good one to highlight how impacts to the stream caused by a dam create positive feedback cycles, meaning the situation is perpetuated. The longer the dam is in the stream, the more pronounced the impacts become. The more intense the impacts get, the more they lead to an increase in the related effects. The cycle continues while the situation gets worse and worse. A good example of this is the discussion about organic matter and increased heat in the impoundment, which encourages the growth of aquatic plants. As the new plants complete their annual growth and die back cycle, there is even more organic matter that needs to be decomposed. Throughout the increased plant growth, die back and decomposition of organic matter, the quantity of dissolved oxygen decreases more and more, while nutrients for more plant growth continue to increase.

With sediment transport, the disconnection the dam causes in the stream leads to two starkly opposite impacts. Upstream, the sediment, which would normally pass through the system, deposits. With that deposition, the stream is forced to meander more and more, further decreasing its slope, causing more sediment deposition. Downstream of the dam, water that is “starved” of sediment is again capable of moving bedloads typical of that stream, so the stream harvests sediment from anywhere in the channel it can. This leads to instability of the streambed and banks. As the bed and banks become unstable, erosion rates increase even further.

The ecology of the impoundment and downstream habitats undergoes similar trajectories of change. Coldwater systems that once held trout may shift to cool water communities that favor pike and perch. As the water continues to warm, the shift will trend towards supporting bluegill and largemouth bass. That warmer water with less dissolved oxygen eventually makes its way past the dam. As it does, the shifts in ecosystem parameters also occur downstream of the dam, leading to changes in species abundance and composition in downstream reaches as well.

## e. Oversight and Concern

Failure of any dam presents numerous threats to both the upstream and downstream environments in the stream. Initially, the release of a large quantity of water can do physical damage to downstream development that has occurred in or near the floodplain. Damage can also be done to other structures downstream of the failure as the rush of water brings much higher forces than typical of the downstream reaches. As that rush of water enters the next impoundment, the rapid increase in water levels may even compromise the integrity of the next dam. An example of this occurred in 2003 in Michigan’s Upper Peninsula, when the Silver Lake Dam, on the Dead River, failed. Water rushed downstream, into a series of impoundments and over several other dams. The dam in Tourist Park was not able to withstand the increase in water from the upstream failure. Shortly after receiving the floodwaters from upstream, the Tourist Park dam also failed.

Biologically, the impacts from a dam failure can have detrimental impacts on downstream communities. With the large release of water, sediments that have been depositing in the impoundment can rapidly mobilize. Both the larger sediments such as sand and the organic matter can lead to downstream habitats being inundated, while the organic matter can choke or suffocate organisms. This was the case after an incident at a dam on the Pigeon River in 2008, near Vanderbilt, Michigan. When the dam experienced an uncontrolled release of water, organic material behind the dam mobilized and led to fish kills for several miles downstream (Nuhfer et al., 2009).

It is feared that the frequency of these types of failures is going to increase and biological impacts around the state are going to worsen. Fortunately, for dams known to the state or federal agencies, there is a well-established framework for oversight and regulation. Based on the characteristics of each dam such as structure height and impoundment size, whether it produces hydroelectric power, or the purpose of its creation, the regulatory agency will be different. All but a few of the hydroelectric dams in Michigan are regulated under the Federal Energy Regulatory Commission (FERC).

Each FERC regulated dam must adhere to predetermined schedules of inspection and maintenance and many have formalized contributions to the restoration of stream habitat caused by the presence of the dam. Dams that do not meet the criteria for regulation and oversight by FERC are then divided into two major categories in the state of Michigan. Dams from both categories, which are determined by size of dam and impoundment, are regulated by the Department of Environmental Quality's Water Resources Division. However, if the height of the dam is over 6 feet and the impoundment encompasses over 5 acres, then the structure would *also* be regulated by the Dam Safety Program. Each level of oversight carries with it different requirements in terms of doing repair, maintenance or removal.

For specific Michigan Department of Environmental Quality staff contact information for dam removal projects across the state, see Appendix A for Inland Lakes and Streams Program and Appendix B for Dam Safety Program.

### f. Inventory Efforts

Throughout the Great Lakes region, the regulation and oversight of dams is becoming a better understood and more recognized process. Whether communities and resource professionals want to learn more about dams or not, the issue of aging dams and the risk of their failure are forcing the progress of education. The number of examples of dam removals or alterations is consistently growing and this builds the knowledge base from which lessons are learned and better projects are designed. As more dams need attention and the impacts of dams become better understood, strategies to determine how to better target dams are developing as well.

More and more landowners are beginning to realize the liability and danger that accompany aging dams. That is how many dam removal projects have come to fruition. Though there are many benefits to the stream that will be realized as these dam removal projects are implemented, the urgency and the willingness of the landowner is usually what moves the project forward.

Simultaneous to the ongoing responsive nature of the more urgent projects, several resource agencies are partnering to refine ideas to inventory and assess dams across entire watersheds. This process is similar to inventory processes outlined for other watershed impacts. For small dams, Huron Pines has led the development of a method to locate and collect data about small dams that may have previous been unknown to resource professionals. With a more accurate understanding of dams across a watershed, Huron Pines, and partner agencies, can better prioritize sites and develop projects for the removal of dams having the greatest amount of impact on the stream.

The inventory starts with Geographic Information Systems (GIS) and air photo or satellite imagery analysis. By following a chosen stream, the user can investigate changes in details such as channel shape, width and direction to find locations that appear to be exhibiting impacts from a dam. The locations of these "suspected" dams are captured in a GIS and then compared to the state and federal databases of known dams.

If the locations of suspected dams do not coincide with points from the databases on existing dams, a site visit to the dam is planned. For the site visit, there is a standard inventory form used to collect data pertinent to the location and potential stream impacts of each dam. Field work for collection of data about small suspect dams requires a GPS, survey rod, measuring tape and/or range finder, data forms and a camera.

Once collected, the data will be entered into a spreadsheet and provided to both state and federal biologists for inclusion in each of their existing databases. There have been efforts, like that of the Great Lakes Connectivity Workgroup, to better model stream connectivity, to help prioritize dams for removal. Locations of known dams and other barriers in the stream, such as improperly designed road/stream crossings, will be used to calculate which barrier is having the greatest impact on stream connectivity. This provides another technique used to prioritize which barrier is in greatest need of improvement as it relates to increasing connectivity of the river habitats.

## Case Study: Hersey Dam Removal – Hersey River

Gary Noble, Muskegon River Watershed Assembly

### Background

The Hersey River, a major tributary to the Muskegon River, had been dammed in one form or another since 1858. The original dam failed in 1941 and it was patched with poured concrete over a pile of boulders. Since that time, the Hersey Dam and auxiliary spillway structures had become more of an annoyance than an asset, although village residents were accustom to having a small impoundment (pond) for many years as part of a village park. More recently the pond was lowered substantially (by state order) and the surrounding village park was closed due to public safety concerns associated with the dam structures. Upstream of the dam structures, the Hersey River is a designated trout stream, its fishery considered in the top 15% among Michigan's high-quality coldwater streams.

### The Problem

State-mandated Dam Safety Reports in 1994 and 2004 found the Hersey Dam and auxiliary structures to be in poor, deteriorating condition. Warm impounded water behind the dam exceeded water quality standards during summers and slower water movement also depleted dissolved oxygen levels. The dam structures were also barriers to fish movement between the Hersey and Muskegon Rivers. The state listed Hersey Dam as a high priority target (one of the top four dams) for removal.

### Managing the Problem

The Village of Hersey (pop. 500+) owned the dam structures and was responsible for maintaining them, but didn't have the funds to do so. Initially, the village considered replacing the structures, but estimated costs were far too prohibitive as were subsequent estimates by their consulting engineer to remove the structures. Also, some village officials and residents were reluctant to remove the dam for historical and aesthetic reasons and resisted prior attempts by the MI Dept. of Natural Resources-Fisheries Division (MDNR) to initiate dam removal proceedings. In 2001, the Muskegon River Watershed Assembly (MRWA) and MDNR teamed up to hold meetings with village officials and their hired engineer. These meetings focused on public safety concerns, lost access to their village park and the environmental benefits of dam removal. Eventually, the village agreed on removal as the proper course of action and the MRWA and MDNR agreed to help the village find funds to remove the dam. During 2004, the MRWA sought and received a small state grant and matching foundation grant initially to obtain competitive feasibility studies on removing Hersey Dam along with estimated costs. In 2005, project partners (Village, MRWA, MDNR) selected Prein & Newhof Engineer's proposed "controlled drawdown" approach with an estimated $275,000 cost. Acting as the village's agent, the MRWA secured nearly 100% grant funding during 2005-2006 for dam removal and river restoration efforts from multiple sources after several years of effort.

### Funding Partners ($281,160 in Total Grant Awards)

- National Fish & Wildlife Foundation - $75,000
- U.S. Fish & Wildlife Service - $50,000
- MDNR-Consumers Energy Habitat Improvement Account - $9,580
- Trout Unlimited (2 chapters) - $5,000
- Village of Hersey - $1,000 contribution
- Wege Foundation (match) - $140,580

### Results

Dam removal and initial restoration work were completed during fall 2006. A favorable bidding climate helped reduce project costs by 22% less than budgeted. The village re-opened their park to the public and eliminated substantial liability concerns. Removal of Hersey Dam restored coldwater habitat and freed over seven miles of pristine stream, allowing the migration of fish and aquatic organisms between the lower Hersey and Muskegon Rivers. During spring/summer 2007, additional streambank adjustments were needed (costing $14,000) to address stability/erosion concerns as the river established its new equilibrium. Leftover Wege Foundation matching funds covered these additional costs, resulting in a revised total project cost of $233,200.

**Lessons Learned**

1. Promote clarity of purpose and communicate openly with all partners to build trust.
2. Apply for more grant funds (simultaneously) than actually needed because you may not receive every grant.
3. Budget 5-10% contingency funds for post project completion follow up river restoration work (after dam removal area has stabilized some), if needed, and build this follow up work component into project timeline and grant timeline, if possible.
4. Planting new river bank areas with native seedlings to help stabilize soils and reduce erosion may not be needed with exposure of dormant native plant seeds/root structures present in soils.

The likelihood of success of any project lies in the composition and strength of the partnership guiding the project decisions. In a project that has to do with modification or removal of a dam, there are logical parties that have a clear role in shaping the outcome. However, there are other aspects to the project that can demand involvement of numerous other groups or organizations. Each project and the partnership that guides it will be unique. The composition of that partnership will follow an analysis of conditions at the project site and the expected issues that will demand attention.

### a. Defining and Determining a Change in Management of a Selected Dam

With projects relating to dams, their management and their impacts, the focus of the discussion can quickly turn into *what* is going to be done. However, before getting to the details of what is going to be done, it is more important to thoroughly understand *why* any changes need to be implemented at the dam in question. How did this dam come to be the center of that discussion? Was it discovered during an inventory and if so, what details made this one stand out against other dams in the watershed? Perhaps this dam was brought to your attention by a landowner who is concerned about the dam's condition and no longer wants to have or operate the dam. Another case may be that the dam is showing signs of age and is in desperate need of repair.

Carefully outlining what the goal of the project is and continually revisiting that goal will provide the proper guidance to project planning and implementation activities. Many decisions throughout the project, such as which Best Management Practices to install, types of monitoring or data collection that may need to be done, which parties should be involved in the project, and potential funding sources, all relate back to the initial purpose and goal. Therefore the planning and implementation, guided by your overall goal, is tailored to your specific project and will best accomplish the tasks you set out to do. A list of potential guidance questions for each project can be found in Appendix A.

### b. Developing a Project Partnership

When it comes to planning a dam removal project, there is usually a long list of items to incorporate or factors that need to be considered. Who will benefit from this project? Will anyone or anything be harmed? Will erosion occur upstream? How far will erosion occur? What is the target species? Will non-native invasive species benefit from this project? Are there social implications to completing this work? Does the water release pose a risk to anything downstream? Is this considered a Great Lakes "first barrier?" Each of these is an example of a factor that will be incorporated into the project plan and guide the design of the overall project. Another benefit arises from contemplating these questions as the project gets started.

Determining the people that have the ability to answer these questions, and which conservation or community interest they represent, helps outline the development of a proper partnership for the whole effort. There is no one person that has all of the answers needed to complete every dam removal project and there does not need to be. By assembling a well-designed partnership for the project, the majority of questions that arise can be easily answered by a select handful of professionals. Additionally, by involving several agency partners throughout the project, there is more support across the conservation community in that region. This also increases the likelihood of being able to diversify potential funding sources.

Once the proper group of people is assembled it is best to develop a partnership agreement. Likely partners include:

- A project manager to coordinate the overall project and keep tasks and budgets on schedule
- State and federal biologists to provide guidance on the ecological questions that may arise
- Hydrologists to offer advice on the expected response of flow, velocity and stream features
- An expert in non-native, invasive species to address potential issues
- A representative from permitting agencies to suggest designs that may make permitting easier

- The landowner (or landowner group) who have the ultimate say on what happens in a voluntary project
- Other watershed based volunteer groups to help bring local knowledge and facilitate with communication
- Individuals from the dominant user groups found on that particular river
- Tribal representation when applicable

A partnership agreement, which will be signed by all of the partners, is a document used to guide the project. It does so by outlining each partner's role and what is expected of them while fulfilling that role. Also described in the partnership agreement is the overall project, why it was chosen, what the goals are and what the expected outcomes will be. Therefore the partnership agreement can be revisited anytime during the project to clarify gaps or overlaps of tasks in the project and better guide the group if it begins to skew from the originally agreed upon purpose. It also serves as a reference to which each partner can always refer back to in order to be sure activities and/or plans are still on task with the agreed upon goals. Huron Pines uses partnership agreements to build further support for the project by pointing to the document to highlight the collaboration on each project.


**Figure 3.**

***The Franklin Dam Story - Part 2***

The large release of water and sediment that occurred during the dam failure caught the attention of more than just the residents around the pond. The local permitting officer from the Michigan Department of Environmental Quality (MDEQ) was also informed of the deteriorating condition of Franklin Creek Dam. The MDEQ visited the dam several times and informed Mr. Snoop that he would be in violation of state law if any other releases of water or sediment were to occur from his dam. Mr. Snoop also learned that, as the owner of the dam and adjacent property, he was the only person legally responsible for management of the dam, water levels, and releases of water or sediment.

Concurrent with receiving notification from MDEQ, Mr. Snoop had been following the status of a dam failure on the Pigeon River and the potential lawsuits that were developing. He decided that he did not want the same to occur on his property and face the same scrutiny and liability. At that point, Mr. Snoop decided he did not have the financial means to rebuild the dam and he began searching for opportunities for help in removing the dam. The MDEQ suggested that Mr. Snoop contact the U.S. Fish and Wildlife Service and the Michigan Department of Natural Resources (MDNR) because reconnecting rivers through dam removal is an activity they would likely fund.

The U.S. Fish and Wildlife Service visited the site and determined that the benefits to the natural stream habitat upon removal of Franklin Creek Dam were valuable enough to develop a proposal for funding. USFWS then contacted Huron Pines to bring in a project manager that would be responsible

## c. Scope and Goals of a Project

When developing the goal, or intent, of a project focusing on changes to a dam or its management, it is important to assess what the existing condition of the overall site is, including state of the dam, current impacts to the stream, and what habitats are present and/or being impacted. By outlining the whole situation that currently exists at the site, as well as uses of the impoundment or dam, other people impacted by any decisions, and any potential influence on existing infrastructure, a baseline is created from which decisions about potential changes can be made. This provides a custom view of how features or conditions at the project site interact with each other.

Starting with the idea that each factor in the decision has equal influence on the design (figure 3), the solution is sure to consider all of the issues that may arise, including aquatic organism needs, physical characteristics like erosion, community uses or involvement, landowner participation, permitting, and fundraising. While assessing each facet, it may become evident that particular factors could influence design or BMP selection more heavily than others. Once the complete assessment is finished (figure 4), the most prominent characteristics or considerations will outline what limitations there are to the design.


**Figure 4.**

for overseeing and organizing the project. Huron Pines would coordinate the fundraising, financial management, project design, permitting and oversight of the project while balancing the goals of reconnecting Franklin Creek to the Liberty River and maintaining access across the creek for Mr. Snoop.

During the winter of 2009, a Huron Pines Project Manager visited the site with USFWS and MDNR to complete an initial site survey. After the site visit, Huron Pines researched the tax records to find contact information for each resident on the impoundment and the nearest landowners downstream of the dam. A letter was sent to each resident to describe the condition of the dam, the natural stream processes at work in the impoundment and downstream, and what the dam removal project would entail. Each landowner was invited to a meeting on-site to be able to ask questions, voice concerns, but most importantly, to be able to meet the project manager, who would be the single point of contact about the project. It is integral to clear communication that all of the interested parties have one person that is able to represent and describe all sides of the project. That person, for the Franklin Creek Dam removal, was the Huron Pines Project Manager.

The next step for the project was to coordinate the USFWS, MDNR and Huron Pines to spend a day in June 2010 surveying Franklin Creek from where it joins the Liberty River upstream to where you could no longer interpret influences from the impoundment, which turned out to be just less than one mile of stream. Depths and widths of the stream were captured to be used in the design and plans for the new driveway crossing that will replace the old dam.

As an example, the goal of the project could be to improve fish passage, but the owner of the dam may be concerned about losing the habitat for waterfowl. In that case, there will need to be a balance struck between the competing wishes of the project partners. The goal of passing fish could involve removal of the dam. However, removing the dam would eliminate the impoundment and the landowner may be left with no waterfowl. By addressing both goals as part of the overall project plan, the selection of a treatment will best suit everyone's needs. A fish ladder, bypass or step pool system may be the best solution in this example.

When addressing all of the considerations that need to be involved in project design, the scope of work required to accomplish the goal begins to take shape. A project that has nothing but public land for miles upstream and downstream of the dam may treat erosion differently than a removal site that has a bridge that crosses the impoundment. Design for the former example can allow for more freedom of sediment movement, while the latter has to protect existing infrastructure and may call for more stabilization of sediments. Neither project design may be better than the other, because the situations at each site are not the same. Yet by properly outlining and understanding all of the features that will help shape the project design as a decision-making strategy, the best solution for each respective project will be developed. Designs that accurately incorporate all of the limiting factors at each site lead to a better selection of strategies to implement the project.

At this point in the project development, the partners and their roles were beginning to evolve and it was time to properly outline who was going to do what, as well as the common goal that bound each party to the project on Franklin Creek. Huron Pines developed a partnership agreement that clearly outlined what was expected from each identified partner. The partnership agreement document (Appendix B) provided a clear outline of the goal of the project, who was responsible for tasks that work towards that goal, and was utilized to prevent the project from drifting away from its original purpose.

The goals of the Franklin Creek Dam removal were:

- Eliminate the possibility of a dam failure and the associated potential environmental impacts.
- Reconnect Franklin Creek to the Liberty River for the purpose of restoring stream function and natural stream habitat connectivity.
- Maintain access across Franklin Creek for the Snoop family.

By describing the project based on its goals and responsible parties, partners were able to maintain a clear direction towards the end product as problems arose. Each goal represented a different set of circumstances that had to be outlined and factored into each step of the project. Though several of the residents on the former impoundment voiced displeasure that the pond would no longer be maintained, the project was able to move forward because Mr. Snoop owned both sides of the dam, therefore any decisions were solely his to make. Funding through the USFWS – Fish Passage Program

## Case Study: The Boardman—A River Reborn?

Jim Pawloski, Michigan Department of Environmental Quality, information taken from www.theboardman.org

The Boardman River is located in Grand Traverse and Kalkaska Counties in Northwest Michigan and includes 160 miles of river and tributary streams. There are a total of 287-square miles in the watershed, producing one-third of the water volume of Grand Traverse Bay in Traverse City and draining 182,800 acres of land. An estimated 2 million user days are logged on the Boardman River annually for recreation purposes. Many of these visitors come to the river to fish since the river is one of the top ten trout streams in Michigan and 36 river miles are designated as Blue Ribbon river sections.

### History

In 2005, Traverse City Light and Power determined that it is not economically feasible to produce hydropower at the Sabin, Boardman and Brown Bridge dams. Dam owners – the City of Traverse City and the Grand Traverse County – organized the Boardman River Dams Committee to gather community feedback, encourage community involvement and manage an engineering and feasibility study to assess the environmental, economical and social benefits and detriments of retaining, modifying and removing the Boardman River dams. After thorough review and discussion the dam owners decided to remove the Sabin, Boardman and Brown Bridge dams and modify the Union Street dam.

### Project Facts at a Glance

### Funding

Rebirthing the Boardman is not an inexpensive proposition. But, it's a long-term investment in a priceless community asset. The initial cost estimate to complete the project is $5 million - $8 million, not including transportation system costs. Funding is being pursued through federal, state, tribal, local government and private sources.

### Benefits

In addition to the environmental benefits, the rebirth of the Boardman is also a community development project with many long-term benefits.

- Environmental

was granted for this project, contingent upon the reconnection of Franklin Creek to the Liberty River. With no funding to build a new dam, yet partners willing to help with dam removal, the choice Mr. Snoop made was to eliminate the dam and have a culvert installed so he still could use the driveway. All project development details were communicated to landowners on the pond and they were made aware of the intended removal through a second letter.

- Enhance and restore habitat for native and naturalized fish species and organisms preferring cold water.
- Restore over 3.4 miles and reconnect 160 miles of high-quality river habitat.
- Restore more than 250 acres of wetlands and nearly 60 acres of upland habitat.
- Community
- Impact the local economy by an estimated $3 million from increased recreation, tourism and property values.
- Promote business growth and new opportunities from increased interest in water-related activities, including fishing, kayaking and canoeing.
- Support the long-term goals of the Grand Vision guiding principle of “protecting and preserving the water resources, forests, natural areas and the scenic beauty of the region.”
- Regional/Collaboration
- Engage all interests, cultivating a sense of ownership in the project and outcome, and ensure that the process is sensitive to community needs and concerns.
- Secure unparalleled cooperation among federal, tribal, state and local government agencies and nonprofit entities.
- Document and archive the process in detail as it unfolds, and initiate the development of a model that will be transferable for use by other communities faced with similar issues.
- Continue to involve a diverse group of individuals and organizations throughout the process, and into the future, to ensure the long-term health of the Boardman River.
- Educational
- Create an on-the-ground laboratory for local schools. Support a variety of scientific research initiatives to assess the impacts of dam removal.

## Where Do We Go From Here?

The Great Lake Fishery Trust has recently awarded over $1,000,000 for the planning, design and removal of the Brown Bridge Dam. A consultant team has been secured and is currently developing an action plan and engineering plan for the removal of the dam. The Brown Bridge Dam impoundment was drawn down during 2011 and removal of the dam and restoration of the stream is expected to be completed in 2012. Throughout 2012 and 2013, each of the three dams slated for removal will follow approved plans for deconstruction as engineering plans are finalized and funds are secured. The Union Street dam will follow approved plans for modification.

## Contributions to Future Projects

To say this project is multi-faceted is an understatement. Dam removal on the Boardman is funded by numerous sources. The dams are owned by different entities. Use of the existing resource by the community is well established and the whole project is adjacent to a large population center. When undertaking a project of this complexity, never take for granted that the effort your team is putting forth to inform and educate stakeholders about how and why the project is occurring to be nearly sufficient. Be proactive, creative and thoughtful in disseminating information so when the inevitable criticism arises that there wasn’t enough done to inform the public, your team can truthfully say they’ve done the best job possible.

Any team undertaking a large scale dam removal project is encouraged to keep the focus on the immediate task at hand: removal of the dam and associated channel restoration activities. There likely will be efforts to advance other agendas associated with the dam removal on a more macro-scale but those need to be segregated from the actual removal. Elements such as recreational development or longer term habitat enhancement, while important, can tend to make the project (or its budget) bog down and potentially, the dam in question remains in place if we haven’t focused all resources first on the dam removal. There is an artful balance needed between thinking “big picture” with a holistic vision, and carrying out the project in a practical, phased approach.

To keep current with the progress of the project, visit www.theboardman.org.

## 1. Understanding the Expected Changes

Similar to when the process for planning a dam modification or removal began, an assessment of stream features impacted by the dam needs to occur, though this time it will be to predict changes to those features or conditions that will happen when the alterations to the dam are made. Discussions with the partners about what is likely to happen with things such as sediment movement, revegetation of the exposed soils, erosion, etc. will provide a baseline of expected results. As the project moves forward, comparing the changes that are occurring to what was expected lends an opportunity for validation and for adaptive management if changes need to be made.

Lowering or removing a dam will launch a series of physical changes in the stream that begin the process of restoration. In an almost opposite fashion of the impairments that the dam caused, the stream will begin to undo those impacts. The system will begin to return to more natural stream conditions. This does not automatically mean that the stream will return to pre-dam conditions. Unique to each project, the returning stream may be quite different in character than the stream before the dam existed. However, as this takes place, there should be significant oversight of the project while letting the new system stabilize. Knowing the stream functions at work and the expected results of those processes will better enable the project partners to assess the accuracy of their planned work as the project progresses.

### a. Slope and Velocity

When a dam is removed or lowered, the downstream control of the stream gradient changes. By lowering this control, the water that was formerly impounded is again able to flow unimpeded. The structure that was limiting the downstream water flow did so by creating a permanent control point in the stream bottom. That caused a lasting reduction in stream slope. Again, slope is determined by how much vertical change there is in a stream in comparison to how far the stream flows to accomplish the vertical change.

As that control point is removed, the effect is a steepening of stream slope. The stream no longer has an artificial high point in the vertical limitations of water flow, meaning the stream will experience more of an elevation change in the same horizontal distance. Without the dam, the control points in stream slope should return to being natural features, such as riffles, both up and downstream of where the former dam was located (figure 5). The slope then, returns to values similar to the natural slope found in that stream reach before any structure was created.

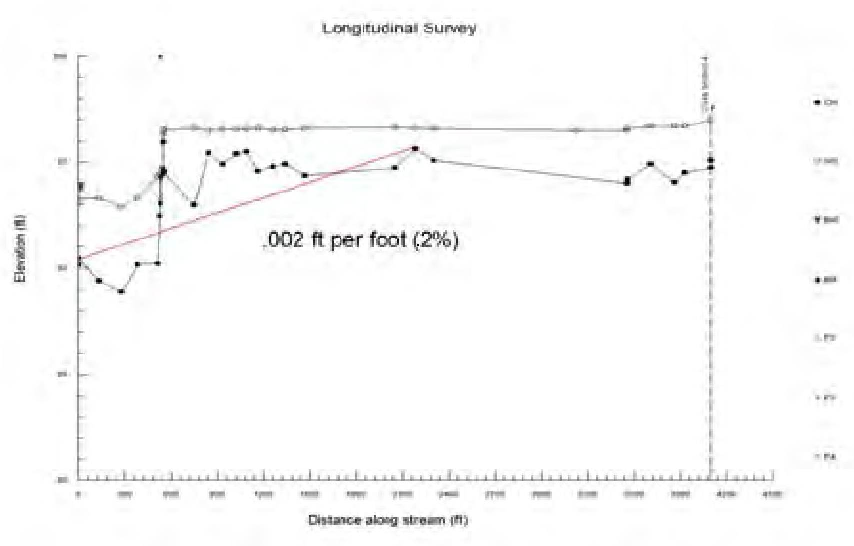



***Figure 5.*** *After removal of the dam (located at distance 600 on the X axis), the slope of the stream is expected to return to connect the two riffles at each end of the red line.*

With slope returning back to values similar to those of the stream reaches that were not impacted by the dam, the velocity of the water will respond accordingly, and speed up. Again, the water is flowing over a similar horizontal distance while accomplishing more of a vertical drop. This means the water is flowing down a steeper gradient. With all else being equal, the water will flow faster down steeper slopes.

### b. Sediment Movement

Just as in any stream, under any number of conditions, the amount of sediment that can be moved by the stream is related to the amount of water and the velocity or speed of that water. With the dam removed, the water is now able to flow at greater velocities and the ability of the stream to move more sediment increases.


*Headcutting in a stream after a dam removal.*

While the dam was in place, sediment had been depositing in the impoundment at higher rates than would have normally occurred in the free-flowing stream. After removal of the dam, the increased velocity of the water enables the stream to begin moving higher amounts of sediment than had occurred during the life of the dam. Though a return to natural sediment transport is the targeted condition, the initial situation is more volatile: large amounts of sediments are exposed. The sediment that has deposited in the impoundment has not had an opportunity to consolidate in a manner that streambanks and channel bars do, with fluctuating water levels, settling and vegetation growth. There is not a well established root structure that would help to stabilize the deposits. The deposited sediment in the impoundment then, has a greater risk of mobilizing and being transported.

One phenomenon that can occur in situations when the downstream grade control is removed is called a head cut. Head-cutting is when the downstream end of the deposited sediment is eroded rapidly and transported away. The erosion of the sediment continues at the downstream end of the old deposits. However, as that steep “edge” of the old deposits is eroded, and the sediment is transported downstream, the eroding “edge” actually “migrates” upstream.

As the stream moves sediment out of the impoundment, it is capable of cutting down to the elevation of the former streambed. During this process there may be signs of head-cutting and, depending on the depth or thickness of the layer of deposited sediment, there could be cause for concern. When cutting is too deep, the concern becomes that the new streambanks created in the deposits will be too unstable and will begin failing and sloughing into the stream. If this occurs, the amount of sediment being transported by the stream may inundate the downstream sections that have had very little, if any, incoming sediments since the time the dam was installed.

***The Franklin Dam Story - Part 3***

What the residents on the pond were unaware of is that the impacts they were witnessing had actually begun the day the dam was installed. By creating the dam, the natural state of the stream was interrupted and Franklin Creek began trying to reestablish a balance between the sediment movement and the velocity of the water. The dam created an artificial high point in the stream bottom, causing the water in Franklin Creek to flow much more slowly. To balance velocity and sediment movement, the natural response of the stream is to begin to deposit sediment. Franklin Creek did just that: deposited sediment right where it entered the newly formed impoundment. That deposition of sand and organic matter is what began the changes in the conditions that the landowners were witnessing nearly 70 years later. In recent years, Franklin Creek had finally crossed certain thresholds where changes were increasingly more noticeable. The fishing was poor, the depth of water was too shallow for swimming and boating, aquatic plants dominated the water column, etc. With the removal of Franklin Creek Dam, the upstream conditions would change drastically yet again, though this time the changes will be realized quite quickly.

Initially, the project partners began to approach the project from a broader scope. This started with a survey of the stream through the project area which would enable partners to conceptualize what changes a potential removal would initiate on the stream and impoundment. According to the survey data, if Franklin Dam were to be completely removed and the stream bottom was restored to historic elevations, the resulting slope of the creek would be 0.2%, meaning the stream

*A stream erodes and deposits sediment while creating new banks and deposition areas. Photo courtesy of Conservation Resource Alliance.*

Not only would the habitats be buried, so too would the organisms that inhabit them.

### c. Channel Redefinition

The initial movement of sediment that is once again exposed to erosive forces can create a scene that looks quite unstable, with fresh erosional and depositional features dominating the landscape of the former impoundment. Analysis the amount of erosion and deposition is going to dictate what is within the realm of acceptable for each specific dam removal and stream restoration project. However, every project will experience at least mild erosion and deposition of sediments in the impoundment as the stream begins to reestablish the necessary landforms and instream features that enable it to function properly.

In the previously impounded area, the stream will again work to reach equilibrium between velocity, volume of water and amount of sediment being moved. There are several natural features in a stream system that enable this equilibrium to be more easily achieved, including cut banks and point bars, a flood plain, riffles, etc. Each of these features, given enough time, will be recreated by stream dynamics in the former impoundment (Burroughs 2007, Doyle, Stanley and Harbor, 2003). During the establishment of these features, it may appear that there is too much instability, due to the high amounts of fresh sediment being exposed and relocated. Therefore, there needs to be close scrutiny of the rates of erosion and deposition to determine if they are beyond the threshold of the partnership and a contingency plan needs to be in place to deal with that instability if/when it arises.

However, if the partnership is comfortable with rates of erosion and deposition, the processes should be allowed to continue. The redistribution of sediments will lead to the creation of those stream features needed for proper stream function. As the stream incises into the sediment, most of the flow will concentrate into the new channel. By doing so, the stream leaves the majority of sediments exposed to air and they will begin to dry.

would drop 2 vertical feet over 1000 horizontal feet. With this bit of knowledge, the partners believed that the restored slope would not cause stream velocities to be cause for concern. Therefore, the threat of upstream erosion was not enough to worry any of the partners. Additionally, the survey data suggested that there were two riffle features in the former impoundment that would provide resistance to any head-cutting. The partners all felt comfortable that grade control structures would not be needed.

The erosion and deposition of impounded sediments was not to be ignored however. Partners believed that by slowly lowering the water behind Franklin Creek Dam, sediments would be exposed to air and sunlight, initiating and promoting plant growth throughout the growing season. As the roots get stronger and more plants grow, that stability also becomes better established. This would create a natural resistance to movement of sediment. Meanwhile, the flowing water would find a path to follow and begin to cut a new channel, while mobilizing only a small portion of the impounded sediment. Based on the early survey data, partners expected Franklin Creek to reestablish a channel that would be approximately 15 feet in width and between 1 and 2 feet in depth.

The vegetation that establishes on the newly exposed sediments will likely be wetland plants or those most commonly found in the riparian zone further upstream in Franklin Creek. However, the plant community will be monitored for the presence of invasive plant species. The wildlife in the area will respond accordingly and be more representative of native riparian ecosystems. There will likely be less of the frogs and turtles that many landowners have come to associate with the

The stream will continue to incise into the deposited sediment deeper and deeper until it restores a slope similar to the stream before the dam was built. However, while the stream incises vertically, the edges of the sediment that border the new channel also experience the changes of settling, redistribution and new vegetation growth. Periodically, large chunks of that sediment along the edge of the channel will fall into the flowing water. As this happens throughout the newly carved channel, the flowing water is forced to flow around these obstacles until it can transport that new sediment downstream, or erode the opposite bank.

*A new channel forming through sediment (note plants colonizing the sediment almost immediately after dewatering).*

Within the newly establishing meanders of the new stream channel, there will be locations of slower water and faster water. The slower water will encourage deposition of sediment being transported while the faster water will help concentrate stream energy, leading to more erosion. Over time, this process helps the stream meander, which ultimately maintains the natural stream slope. As the stream continues to migrate back and forth, by continually shifting its meanders, a general zone of activity of the stream will evolve. This zone will begin to act as the new flood plain. With future flooding events, the stream will continue the development of more prominent features and a more functional flood plain.

### d. Establishment of Vegetation

While the stream is actively harvesting, transporting, redistributing and depositing sediment, there is another natural force actively helping to stabilize those exposed sediments. The sediment that is exposed, and particularly the organic matter, provides favorable conditions to support new growth of riparian and wetland vegetation. Often, the organic matter already contains numerous years' worth of seeds that have fallen into the water from plants living along the upstream segments. Once that organic matter is exposed to sunlight and air, the conditions are right for those seeds to germinate and that vegetation to flourish.

pond. However, those organisms will be replaced by species more customary to the coldwater ecosystem that is expected to return. Fish, including brook and brown trout, as well as other aquatic organisms will have the ability to migrate upstream from the Liberty River during spawning events, while water temperatures will remain low enough through the summer that coldwater species should be able to inhabit the former impoundment year round.

The growth of vegetation on the newly exposed sediments plays an integral part in several processes. First the vegetation will begin to shade the organic matter and absorb solar energy before it reaches the water's surface, helping to restore natural temperatures. Secondly, as the plants grow, the development of root systems throughout the sediments and streambanks act to stabilize the soil and help to slow erosion of the deposited sediment. The network of roots that establishes as these plants continue to grow will be a natural source of resistance to future erosion (Auble 2007, Shafroth et al. 2002, Orr 2002). By slowing the rates of sediment erosion, the plant roots provide a buffering effect to the erosive energy of the flowing stream.

*The same Huron Pines project site immediately after dewatering and later in the same growing season.*

Vegetation also plays a key role in helping to restore instream habitat types that have been depleted or covered by sediment while the stream was impounded. Through natural succession, the early sprouting annuals and herbaceous perennials will give way to shrubby woody species and ultimately larger trees. The branches and leaves of these woody species provide shade to the stream and overhead habitat for aquatic organisms when they grow tall and over the surface of the water. When branches and leaves fall into the stream, even more diversity of habitats is achieved. Finally, the root mass that continues to grow and strengthen soil against erosion will play a part in establishing undercuts or overhanging banks. To watch a time-lapse video of the revegetation of the impoundment shown on the right, please visit http://www.huronpines.org/projectinfo.asp?pjt=pv&pid=30.

### e. Responses of Aquatic Organisms

Just as when the conditions began to deteriorate and cross certain thresholds while water was impounded and the ecosystem shifted, the same holds true when the dam is removed, only with a trajectory towards becoming a healthy stream again. With changes in all of the stream characteristics after a dam removal that have been described, the ecosystem is set to shift again. The organisms that have benefited from the conditions in the *impoundment* will be forced to adapt, relocate, or be replaced by those more capable of surviving in *stream* systems.

One of the biggest concerns that seems to be expressed by the landowners or other residents on the impoundment is in regard to what will happen to all of the wildlife currently living in the impoundment. Many of the species living in a typical impoundment, such as the frogs and turtles, will be forced to relocate. Waterfowl and other avian species that utilize the impoundment have the ability to seek out new habitats in the proximity of the dam or during their migratory routes to and from the area. There is no doubt that individual organisms will suffer because of the activities and stream responses to dam removal. However, most projects focus on improving stream habitat and providing better quality habitats to stream-based aquatic organisms. There may be other organisms yet, that may be uninterrupted by the changes in condition.

The broader point to be made about dam modification or removal projects, and when addressing concerns that have been raised about biodiversity, is that the contribution to diversity and the importance of that stretch of stream is on a regional scale, not just within the site in question. For example, biodiversity associated with the impoundment may increase with the organisms that are able to inhabit the new pond. However, if that impoundment is on a stretch of a high-quality coldwater, the regional diversity may be threatened because of the impacts caused by the dam. The value of that stream is in the fact that it provides high-quality coldwater habitat and though the number of species present may go up with the creation of the pond, it may do so at the expense of organisms that depend on the cold water. The impoundment may have added common waterfowl species for example, yet if the impacts of the dam lead to conditions that no longer favor brook trout, the regional biodiversity has actually decreased. It is important then, when assessing a dam removal project, to analyze the regional impact on the habitats and species that are present and those that will return after the removal.

The result of a dam removal, in terms of habitats available and species that inhabit them, is that there will undoubtedly be change. Change, though people may fear it, is environmentally acceptable and encouraged in these projects. Yet, the people impacted by the project should be made aware of the potential changes expected to result from the dam removal. Each partnership will exhibit a certain comfort level when it comes to causing and realizing the changes to the ecosystem and community. Populations of frogs and turtles, the waterfowl, beaver and muskrat, etc. have the ability to adapt and will prevail. However, without the planned changes, the species dependant on the original stream habitats may not.

## Case Study: Mussel Relocation

Joseph Rathbun, Michigan Department of Environmental Quality

Dams can have a number of negative impacts on mussel populations, including poor water quality and sediment deposition in the reservoir, channel incision downstream of the dam, and inhibition of host fish dispersal. Dam removals can also negatively impact mussels, primarily by mortality due to stranding in the drawn-down reservoir and burial of downstream habitats.

Mussels are sometimes relocated away from dam removal sites, especially if Threatened or Endangered species are known or suspected to occur at the project site. The most important step in conducting a mussel relocation is choosing a suitable relocation site. The relocation site should be as close as possible to the dam site (usually upstream, and preferably in the same subwatershed); have similar water quality, depth, flow, etc.; have stable sediments; and be secure from future disturbances. The presence of reproducing mussels is a strong indicator that a site is suitable. Relocations are best performed in the Spring or Fall when air temperatures are moderate, and mussels should be kept moist and not exposed to the air for more than 4 hours while in transit to the relocation site. Mussels downstream of the dam site are most often relocated, while mussels in the reservoir are usually not, due to the need for collecting by SCUBA diving.

In 2009 an 8-foot tall dam was removed from the Thornapple River, in the village of Nashville in Barry County. Preliminary pre-removal surveys identified an extensive mussel bed directly below the dam, and a relocation was performed at the request of the MDNR Fisheries Division. The reservoir was not checked for mussels. A suitable relocation site upstream of the reservoir could not be found due to extensive channelization of the stream. After consideration of probable sediment transport during and after dam removal, however, an extensive riffle with a sizeable mussel population approximately 1.5 miles downstream of the dam site was selected as the relocation site. The relocation was conducted on July 30, to accommodate the dam removal schedule. In one long day, eight volunteers collected, identified, marked and relocated 1,295 mussels of 11 species, including specimens of two species of "Special Concern" in Michigan; the elktoe (Alasmidonta marginata) and the ellipse (Venustaconcha ellipsiformis). Mussels were collected by wading and "raccooning" the sediments by hand, working along transects (Figure A) in a reach approximately 200 feet downstream of the dam. Additional mussels undoubtedly occurred beyond the collection area, but manpower limitations precluded additional collecting. To date a post-relocation survey has not been conducted.

Note that a Scientific Collectors permit from the MDNR is required to perform a mussel relocation, and the local Fisheries Division staff should always be consulted before mussels are collected or moved.

*Collecting mussels below the Thornapple River dam removal site. Photos courtesy of Joe Rathbun, Michigan DEQ, and Joanne Barnard, Barry Conservation District.*

## Case Study: Wheeler Creek Dam Removal Project

Kim Balke, Conservation Resource Alliance

In 1867 John H. Wheeler built a sawmill and dam on what came to be known as Wheeler Creek, about 500 feet upstream of its Manistee River confluence. In the 1940s a concrete dam with a 24” turbine was built in the same location to provide power to nearby homes in the town of Sherman. In 2005, the landowner of Wheeler Dam contacted the MDNR Fisheries Division regarding its removal. The 18’ high concrete spillway and barrier were cracking and breaking apart, the stop logs were in poor condition, and the risk of failure was looming. MDNR Fisheries Division placed high priority on the removal of the dam with its aging condition, the system of impounded areas behind it that warmed stream water, and the fact that it cut off 7 miles of Wheeler Creek from the rest of the Manistee River Watershed. The Conservation Resource Alliance worked with a variety of partners to pursue and fund dam removal including the MDNR Fisheries Division, MDEQ, US Fish and Wildlife Service, Natural Resources Conservation Service, National Oceanic Atmospheric Administration, and Grand Traverse Band of Ottawa and Chippewa Indians. CRA and partners worked together to draw down the ponds and remove the dam in the fall of 2009.

Wheeler Creek is one of the coldest, highest quality tributaries to the Manistee River; a State designated Natural River and federally designated Wild & Scenic River. The Wheeler Creek riparian corridor is heavily wooded and runs through large tracts of public land with natural springs in its headwaters and near its confluence with the mainstem. The fishery of Wheeler Creek is dominated by a self-sustaining population of brook trout. Some local folks rather liked the dam because it isolated the brook trout population and prevented competition from other fish species. MDNR Fisheries Biologists claim the exceptionally cold water temperatures will not appeal to other trout, and a healthier brook trout population might result from them breeding with other brook trout in the watershed.

The dam removal design, construction, and stream restoration project cost $297,000 during 2008-2010. This included the dam and spillway removal, removal of 1,500 cubic yards of sediment, placement of 310 cubic yards of fieldstone, installation of 800 lineal feet of whole tree revetments and manipulation of existing log jams, grading and sloping of 1,900 lineal feet of newly formed streambanks, and grading and planting warm season grass mix on 2 acres of formerly impounded area.

### Project benefits include the following:

- Eliminated risk of dam failure due to major structural deficiencies.
- Connected ecology of 7 miles of Wheeler Creek to the Manistee River.
- Natural movement of woody debris, substrate, aquatic insects, and fish throughout Wheeler Creek.
- Eliminated scouring of the streambed downstream of the former dam site.

### Biggest Challenge - Sediment

Over 100 years worth of accumulated sediment and debris had collected in the ponds behind the dam. Unfortunately, an ideal sediment removal site was non-existent with the M-37 highway, wetlands, a private residence, and the Manistee River immediately downstream of the dam site. In addition, sediment removal benefits would have been highly limited because of what we had downstream on the Manistee River. Hodenpyl Pond is a 1,680 acre impoundment on the Manistee River that begins less than 2 miles downstream of the Wheeler Creek confluence. Hodenpyl Dam is a hydropower dam built in 1925 and operated by Consumers Energy that produces up to 17,000 kilowatts. Though it was unfortunate to have let the sediment from the Wheeler ponds flush downstream, they inevitably flushed into another impounded area. Since over half of Wheeler Creek meanders through public lands and only 3 road crossings are located upstream, it could be argued that the sediment in the Wheeler ponds was mostly due to the natural transport of sediment in a stream. Visual observations and photos showed that much of the sediment in the ponds was comprised of muck from the decomposition of organic materials, and a significant portion was in fact sawdust from the old sawmill. Currently, the streambed composition upstream of and throughout the former impoundment areas is primarily 1” to 6” gravel.

### What we did well:

1. During the 9 months following the complete removal of the dam, stream channel restoration work was ongoing. In the second and sixth months after dam removal contractors utilized heavy equipment to pull back the slopes of the newly formed, highly unstable, eroding streambanks comprised of muck, sand and sawdust, and stabilized key areas with fieldstone. Creating a 17’ wide or greater bankfull channel width was the target in order to allow the stream to meander and create point bars (as measured in a 200’ long reference reach upstream of the dam impacted area).

2. Throughout the 9-month post-dam removal period a second contractor installed whole tree revetments in sensitive areas and manipulated log jams that were settling and blocking flows in response to the down cutting of the stream channel upstream of the former impoundments.

3. During dam removal a contractor installed 300 lineal feet of whole tree revetments downstream of the dam site to protect streambanks from and prevent aggradation of the channel due to the influx of sediment. This helped better flush out the incoming sediment from the dam removal.

### What we would do better next time:

1. Budget more funds to slope back newly formed streambanks with heavy equipment.
2. Better quantify the amount of accumulated sediment through the former impoundments.
3. Fully assess projected stream gradient through the impoundment once dam removal is fully completed and compare it to the gradient downstream of the dam to help better determine if the stream can handle flushing out sediments naturally. Nine months after dam removal the stream slope through the old impoundments ended up measuring double what the stream slope was downstream of the dam site before reaching Manistee River. It’s no wonder that John Wheeler thought this a good location to harness the energy of a steep, fast flowing stream to power his sawmill. A slower drawdown could’ve avoided inundating the lower stretch with sand and gravel that the channel couldn’t flush out as fast as it was coming in. The caveat is that a slower draw down would have required more funding to cover increased equipment expenses and an earlier start date in the fall so as to avoid winter weather limitations.

CRA and partners will continue to monitor the project site over the next 3-5 years and complete more restoration and instream habitat work as the channel continues to stabilize and funding allows. Just as the construction of the original Wheeler Creek Dam was a historical moment in 1867, so was returning Wheeler Creek to a free-flowing stream in 2009.

*Before and after photos of the Wheeler Creek site courtesy of Conservation Resource Alliance.*

## 1. The Dam Removal Project Plan

The understanding of how best to manage dam removals or modifications and the changes to instream conditions that arise when a dam is removed continues to grow. That being said, there are no exact practices or actions that are recommended for every dam in certain situations. Every dam, the stream it is on, and the factors that go into designing the removal of that dam are unique. No two removals will be exactly the same. This causes difficulty in the development of widely accepted Best Management Practices. However, as natural resource professionals continue to gain knowledge and expertise with dam removal, practices are becoming generally accepted in the professional community. Yet, the specific details of how those practices are implemented still have to be tailored to each dam removal project.

### a. Discussing Best Management Practices

What is understood at this point in the field of dam removal is that there are ranges of intensity in each management practice that will be considered for specific projects. Management practices are being refined as each dam removal project is implemented. Practices continue to evolve for such things as:

- Timing of the construction activities
- Timing and rate of dewatering
- Movement and transport of sediment deposits in the impoundment
- Erosion of the streambed upstream of the removal
- Revegetation of sediment and streambanks in the former impoundment
- Managing the threat of invasive species
- Involving and educating communities to incorporate social factors

By continuing to consider the limiting factors of the overall project (as discussed during the partnership formation), partners for the specific dam removal should define the boundaries and guidelines for each practice. The implementation of management practice must reflect the balance between maximizing benefits to the natural resources and minimizing threats to those conditions that partners deemed to be the limiting factors.

### b. Categories of Removals

After achieving that balance, the broader classification or strategy of the project can be chosen. There are four major categories into which most dam modification projects can be placed: No removal (with modifications), Partial Removal, Full Removal with Grade Control, Full Removal No Grade Control. Each of these categories represents a different suite of practices that accomplish different goals. Based on the limiting factors of a given project, these classifications of projects offer unique benefits and drawbacks.

- **No Removal**
  This would be the case when the project limitations require the structure to be left in the stream as a component of achieving all of the goals set forth in the project planning. The example mentioned earlier of creating fish passage while keeping the impoundment for waterfowl would fit into this category. In that instance, a fish passage structure, such as a fish ladder, bypass channel or rock ramp, might be installed. That would accomplish the goal of lessening the obstacle to fish passage while also keeping some impounded water for waterfowl.
- **Partial Removal**
  There are situations when removing the entire structure would not provide the best solution to impacts addressed during project planning, nor would it enable the accomplishment of project goals. However, removing a portion of the structure may be the best option for completing the tasks set forth and achieving the goals of the project. Situations such as the threat of non-native invasive species or the protection of an historical structure could warrant this course of action. Partial removal can be either a vertical or horizontal modification to the structure. Horizontal modification would be when the sections removed are parallel

to the water surface, such as an entire dam being lowered across the stream. Vertical modifications are when the structure is cut or modified perpendicular to the water surface. This is the case when a section of the dam is removed all the way to the stream bottom, yet not all the way across the stream.

- **Full Removal – with Grade Control**
  One of the biggest concerns with many dam removals is the mobilization of sediment that has built up in the impoundment. There are cases when moving a portion of the sediment does not raise concern and the project can proceed. However, there are also instances when there is greater concern over any sediment movement or erosion in the upstream reaches. For example, if the difference in elevation of the stream bottom upstream and downstream is great enough, concerns about erosion or head-cutting could grow. Allowing for erosion and sediment movement is not always appropriate. In particular, there may be upstream issues with infrastructure, like a bridge crossing that would warrant preventing or minimizing any upstream erosion if the designs predict the crossing would be impacted. In this example, full removal of the dam could occur, but there would need to be precautionary structures installed to prevent harming the bridge. Any type of grade control structure, or combination of structures, can be used to prevent the upstream erosion or head-cutting while still lowering the impounded water back to stream levels and restoring the channel function.

*In this situation, grade control structures were used to maintain water levels while allowing fish passage. Photo courtesy of USFWS.*

*This dam was partially removed, allowing for fish passage while protecting a historical structure. Photo courtesy of Jim Francis, MDNR.*

***The Franklin Dam Story - Part 4***

With the expectations of how Franklin Creek and the former impoundment should respond to the removal of the dam fairly well understood, the partners turned their attention to determining the proper driveway structure that needed to be installed. One of the goals of the project was to maintain access for the landowner over Franklin Creek, since the dam had functioned as a bridge. However, the new structure going in to Franklin Creek needs to be designed properly to avoid any future impacts that may hinder the benefits of the whole project.

The partners again turned to the original survey data collected in June of 2010. By analyzing this data, the USFWS, with assistance from the MDNR Habitat Management Unit, determined that the bankfull width of Franklin Creek, upstream of impoundment was just over 18 feet. Bankfull width is the width of the stream just prior to the moment a stream floods, or spills out of its banks. This width plays an important part in determining the size of a new structure, in that, any design should have a structure large enough to pass the amount of water flowing through the creek during a bankfull event. For Franklin Creek, the USFWS and MDNR calculated that the new structure would need to span at least 19 feet. Furthermore, to ensure that the stream bottom was properly reconnected to prevent the development of a new vertical barrier, the new structure would need to either have no bottom, or the bottom would have to be buried at least 2 feet.

Another detail that went into the design was the location of the new structure. Partners had determined

- **Full Removal – No Grade Control**
  When the limiting factors that would influence the design have all been incorporated, the full removal of the dam may still be a viable option for treating the site. If those constraints also allow for sediment movement and any possible upstream erosion would not threaten property or infrastructure and downstream sedimentation will not inundate important habitats or organisms, the project can proceed with full removal of the dam. In that case, there is no need for any structures to control the grade of the stream bottom and the natural sediment dynamics can begin to be restored as well.

*Here, the dam was completely removed and a grade control structure was installed. Photo courtesy of Ralph Reznick, MDEQ.*

Once the modification strategy that best achieves project goals has been selected, specifics of the project design can begin to be addressed. The details of the particular dam removal project can now be reviewed and planned for, prior to any implementation. When management practices have been laid out for each factor influencing the plan, the timing and chronology of specific tasks begin to emerge, resulting in a rough construction sequence.

## c. Timing of Dewatering

Before any earth-moving activities take place on the dam removal site, it is important that as much water be let out of the impoundment as possible, based on the limitations of the dam. Impounded water behind the dam should be released well before any earth-moving activities are implemented. This is not to say that standing water will not remain behind the structure. It means that the dam is not actively controlling water levels. What water remained behind the dam would be a result of how the dam was constructed and not due to gates being partially closed or stop logs being in place. Gates should be fully open and all boards removed as part of the preparation for the earth-moving activity.

based on the surveys, that the best location for the culvert was where the dam was originally. While discussing the location of the culvert with the landowner, he verified that the dam was built in the old streambed. This meant that the plan had to incorporate either a diversion channel or a system in which the stream was blocked and pumped around the project site in order for construction to be completed "in the dry." To aid in the water management and to allow for the most amount of time for the plants to establish and hold sediment back, project partners determined that autumn would be the best time for the removal of the old dam and installation of the driveway culvert.

Huron Pines took these design specifications and the construction plan and developed a permit application and submitted it to the State of Michigan Department of Environmental Quality in March 2011. Submitting in March ensured that ample time was available for any changes to be made or public hearings that may have been requested to be held well before the planned construction timeline. Huron Pines also submitted a Soil Erosion Sediment Control permit application to the appropriate county's Soil Erosion Officer. All permits were in-hand before any construction activities took place.

Dewatering the impoundment should begin, and be completed, long before the expected timeframe for the removal of the dam. By bringing water levels down, sediments will be exposed to sun and air and can begin to consolidate and vegetate. Until water levels are brought down, the sediment and organic matter can behave more like a slurry than as solids, contributing to their tendency to mobilize with increased water velocity. If the impoundment is dewatered very quickly, more sediment and organics are likely to suspend in the water and wash downstream. When water in the impoundment is let out very slowly, movement of sediments is minimized, as the sediments have a chance to continue to settle and consolidate as they dry out.

*At this site, the barrier was completely removed and no grade control was installed: the stream was allowed to cut through sediment to establish a new channel and floodplain.*

There is no agreed upon rate at which impoundments should be dewatered and therefore there is no definitive Best Management Practice. This is due to several factors, including the difficulty of predicting how sediments will move and if they will resettle in the water that remains impounded. Another point of contention is the disagreement between resource professionals about what rates of sediment movement are acceptable and which rates constitute harmful effects downstream. An approach to determining those threshold "levels" that constitute harmful effects is individually, specific to each project. There are numerous details about the downstream reach that will dictate what levels of sediment movement could be harmful, including:

- The particle size and composition of the sediments that will move.
- The quality of downstream habitats and biological resources such as spawning areas and mussel beds that could be impacted by incoming sediment.
- What the land use conditions are along and in the flood plain downstream of the project.
- The condition of the receiving waters.

Smaller particle sizes may just become entrained in the water column and be carried well beyond the downstream reaches, whereas larger particles may be causing concern because of their potential to cover habitats. Additionally, if the downstream waters are influenced by another impoundment further down the river, the substrate may already be sand, so moving more sand onto existing sand may not raise as much level of concern as it would if there were well-developed gravel beds. Similarly, if there are no private parcels adjacent to the banks downstream, sediment movement and deposition would not be perceived the same as if those sediments were filling in around people's docks or other structures.

Finally, if a hypothetical rate were to be agreed upon, such as lowering the impoundment by 6 inches per day (currently used as a common maximum release rate), it does not translate to the same volume of water for each increment of 6 inches. For example, the surface area of an impoundment for the first 6 inches of lowering is going to be a much higher volume of water than the last 6 inches, simply due to the geometry of the impoundment.

What is agreed upon as a Best Management Practice is that water needs to be released from the impoundment *slowly*. Though the term "slowly" does not define a rate of release, water levels should be lowered at rates that minimize the risk of negative impacts. As mentioned above, allowing water to leave the impoundment rapidly can directly cause unacceptable amounts of sediment to mobilize and wash downstream.

Suspended sediments such as the fine organic matter, if released in high quantities, can lead to stresses, even suffocation, of downstream organisms by causing a drop in dissolved oxygen levels. Meanwhile, causing the transport of too large a quantity of heavier particles, such as sand, can cause the downstream burial of benthic organisms and habitats. Releasing too much water can create artificial flooding downstream and lead to further instability of the streambanks and can also cause additional scouring of the stream bottom downstream of the dam.

The rate at which the impoundment is drawn down for each removal project will be determined by the partners guiding the work plan. The partnership will be led to the decision of how quickly to draw water down for each particular project by discussing and balancing the variables of sediment dynamics, impacts to downstream organisms from high water, and the need for the impoundment to be dewatered in a reasonable amount of time. While determining the rates for drawdown, the partnership should also decide upon ways to assess the success of their plan while water is being released. Things to investigate could include determining whether: water levels downstream are as predicted, too much organic matter is mobilizing; signs of excessive erosion are evident in the upstream sediments or on the stream bottom and banks downstream; and the planned timeline for completing the dewatering is still on schedule.

### d. Timing of Earth-Moving

For every example of a dam removal only taking a few days or weeks, there seems to be an example of a project lasting months, if not years. The project may go quickly because it is simple and straightforward or it may go much longer if complicating factors like contaminated sediments or upstream infrastructure is involved. Yet even on the longer duration projects there are considerations that need to be made in regard to when the bulk of earth-moving activities take place. As with any earth-moving practice, precautions must be taken to minimize the contribution of sediment pollution to the water body on which the work is occurring. Despite best efforts to prevent it, the reality is that some amount of sediment will inevitably be transported to the stream. The same can occur with unplanned flushes of water.

These unplanned impacts, though they may be minimal and brief in the broader context of the project, can still lead to harmful events if their occurrences coincide with greater biological events such as spawning and migration. During earth-moving activities at the dam removal site, there is likely to be more suspension of particles in the water column and higher chances for sand transport downstream. The impact from that sediment on the downstream ecosystem will be different depending on the time of year. If it occurs when fish or mussels are spawning, it could interrupt reproduction of that species for the full season vs. less impact if earth moving is taking place during a time of year which causes minimal concern. Increased sediment may also cause problems with the migration of anadromous fish. The DNR-Fisheries Division maintains a schedule to guide when it is acceptable for dredging and sediment disturbing activities to take place that minimizes effects on fish.

Addressing these bigger biological events and their timing is the responsibility of the partnership as they develop the project plan. Incorporating them into the schedule of earth-moving will help minimize the harm caused by any unplanned releases of sediment or flushes of water. If sand and suspended particles are sent downstream during the earth-moving, yet there is no spawning or rearing of juveniles downstream, the impact on reproduction will be less.

As an example, if the downstream waters are home to brook trout, it would be good to plan earth-moving activities for late summer. This would not risk covering the eggs with sediment during the winter or early spring. If sediment were to go downstream, the stream will still have time to sort out and distribute particles, minimizing the impact on spawning beds. That way when brook trout show up to spawn the following year, there isn't a fresh layer of sand over the formerly productive gravel beds. Similarly, if the project were to occur just after the trout hatch, or if there are juvenile mussels drifting in the water column, and there were a large release of water, it could physically wash all of the juveniles from their normal nursery areas.

### e. Sediment Management

The decisions of how sediment movement will be dealt with tend to be a focal point of the majority of dam removal project plans. Several issues associated with sediment movement must be considered when determining how much is acceptable, including:

- Is there upstream infrastructure that would be threatened by erosion?
- Are the sediments in the impoundment contaminated?
- Are there downstream habitats or organisms that warrant protection from possible burial by sediment?
- Will instability in the upstream sediments threaten property through bank erosion?
- Do upstream water elevations need to be maintained for existing water uses?

The partnership may determine that transport of upstream sediments and the risk of upstream erosion need to be minimized or even prevented. Another case may be that during the drawdown or removal, rates of erosion of the upstream sediment are greater than what were expected or what are acceptable.


*It is important to plan management of sediment movement, including accumulation of sediment downstream as shown above. Photo courtesy of the USFWS.*

A temporary, though effective, technique that could be used to manage sediment transport is that of a sediment basin. This is an intentional depression that allows sediment to settle out by slowing down velocities and limiting transport. Sediment basins, or traps, can be very effective at preventing downstream sedimentation, but they are not effective for smaller particle sizes such as clay and silt. Creation and maintenance of sediment traps also tends to be an expensive practice, therefore limiting their efficacy as a long-term solution.

If a sediment trap is chosen as a means to manage sediment transport, it is logical to locate the trap in areas already disturbed as part of the bigger project. If used in a dam removal, the technique of sediment traps should be used as a temporary means to trap sediment and not replace the need to analyze the overriding forces causing sediment transport. To deal with ongoing or planned sediment movement, there are well established Best Management Practices, applicable to several situations.

Best Management Practices for grade control, which would be used to treat many sediment movement scenarios, range from quite heavy-handed techniques to those that are much less intense. Examples of grade control activities in dam removals and stream restoration are abundant and each is tailored to the reasons why it was selected. Common structures include such things as cross vanes, W-weirs, J-hooks, root wads, etc., depicted below.

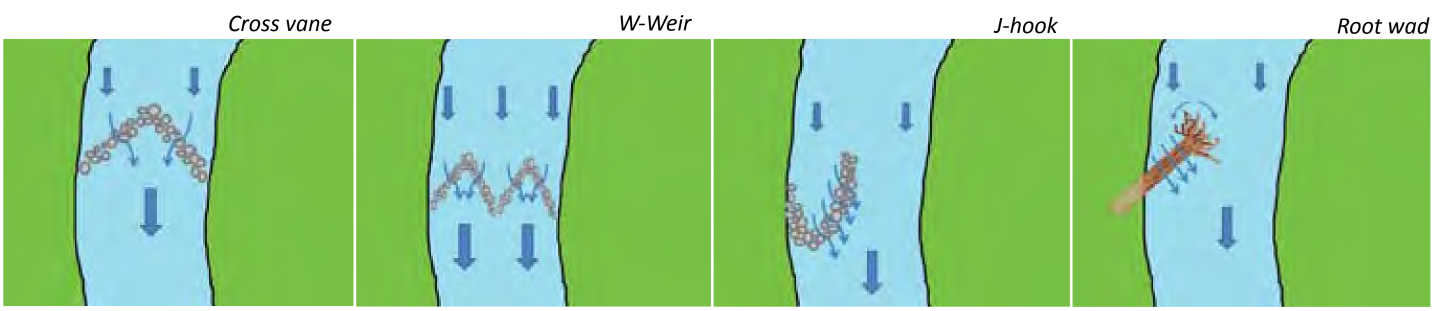



**Figure 6.**

For example, if water levels of the former impoundment need to be maintained for existing uses such as water intake to a hatchery or rearing facility, BMPs exist to help design the appropriate plan. In this case, hard materials such as natural stone, riprap, and/or regular intervals of sheet pile, could be used to create a step pool system. This may reduce the size of the impoundment and eliminate the water control structure, while still accomplishes a channel with continuous flow. That should allow passage of several aquatic organisms, yet also maintain upstream water elevations for the previous uses.

An example from the opposite end of the grade control spectrum would be used when sediment movement is allowable and no water elevations need to be maintained, but there is slight concern that uncontrolled upstream erosion would threaten infrastructure, such as a bridge crossing. A less intense grade control BMP would be used in this case. Something such as single cross vane made of appropriately sized riprap would help prevent head-cutting, while not creating a structure that would drastically limit passage of certain aquatic organisms or impound water.

Grade control structures are typically intended to be permanent installations that are intended to take flow from one elevation to a lower elevation. Their purpose is to slow water velocities, prevent streambanks from slumping and prevent the erosion of the streambed associated with excessive changes in slope. Many of the state-approved grade control structural BMP installations are created for dealing with overland flow, yet the theories can be easily adapted to instream conditions. It is important for grade control to be considered early in the project planning as an option and for structures to be designed appropriately based on specific conditions at each site.

### f. Natural Channel Design

A more complex technique of restoring the exposed lands in the impoundment involves *combining* many of the management practices already discussed based on their applicability to each situation present in the project. By creating this "prescription" of a series of treatments, the restoration of the former impoundment area back to a functioning stream system is sped up by several years. Used properly, the science of natural channel design can recreate a stable channel system and virtually skip the "adjustment" phase the stream would go through if it were allowed to reestablish its own channel.

*The small cross vane in the upper photo was removed, which allowed the second cross vane in the lower photo to control water elevation. Photo courtesy of USFWS.*

When the slope of the valley in the impounded area is known, the responses of the stream to a dam removal are more easily predicted. Coupling that information with comparisons to stream reaches, both up and downstream of the influence of the dam, enables partners to have a better understanding of typical stream characteristics that should reoccur. Those stream features include: meander frequencies, riffle/run/pool complex distances, sinuosity within the valley, radius of curvature of meanders, etc.

Natural channel design takes all of the data about these features and creates a plan that outlines how to go into the formerly impounded area and actively create the proper distribution and sizing of each characteristic. By designing and creating a stable channel as part of the project, the degree of instability is reduced, which decreases erosion and sediment transport and ultimately speeds up the restoration process. Also, when designed and installed correctly, the use of structures may be minimal and less heavy-handed than what project designs could have called for if each practice was planned independently of the others.

### g. Vegetation of Exposed Lands

When the water is drawn down and the sediment and organic matter are exposed, the resulting situation is one in which the risk of erosion and resultant sedimentation is very high. Vegetating the sediments needs to be treated with utmost importance. Best Management Practices for treating soils at risk of erosion are defined under Critical Area Planting. Within the BMP descriptions for critical area plantings, seed mixes, timing and potential soil amendments are all outlined to ensure the best selection for each situation. Though dam removals are not explicitly described in the critical area planting BMPs, soils that are “excessively wet” or “subject to concentrated flows” are cited for treatment. The given recommended treatments for wet soils could easily translate to the formerly impounded sediment.

Getting vegetation established as quickly as possible is an extremely important factor in helping control the erosion and movement of the exposed sediments. Though the Critical Area Planting BMPs do a good job of advising how to best facilitate the establishment of vegetation, there are other techniques that may better work in dam removals. As has been observed in many dam removal projects, vegetating the exposed sediments can be accomplished less intensively. This can be done by allowing natural conditions to favor growth of new plants from the existing seed source.

By timing the drawn down of impounded water to coincide with the onset of the growing season, the seed bank in the organic matter will be encouraged to sprout and grow. This takes advantage of the seeds that originated from vegetation along the stream, upstream of the impoundment. There is more variability in the density of growth of new vegetation than if the sediments were actively seeded using Critical Area Planting BMPs. However, relying on the existing seed bank for vegetation eliminates the cost of labor to place the seed and to figure out the logistics of how to navigate on or through the sediments. While the sediments are going through consolidation and drying after the water is drawn down they tend to be very soft and difficult to traverse.

Actively seeding the sediments could be a BMP used to ensure the stability of soil, which would be particularly important if the timing of the drawdown did not favor growth of the seeds already present. The need to establish vegetation on the exposed sediments cannot be stressed enough as it is one of the most naturally effective means to keeping soil on-site. Additionally, by actively seeding or installing live plantings, the project manager can drive what community of plants will reestablish. This could be of particular importance when attracting landowners to the project. Describing and controlling the plant life that will return may have an appealing quality to landowners worried about “weeds” and uncontrolled growth.

### h. Consideration of Invasive Species (Vegetative)

Whether the project plan calls for active seeding or allowing growth of the seed bank to provide the vegetation that will be used to stabilize the sediments, there needs to be close oversight on the composition of plants that do reestablish. The presence of seeds in the organic sediments provides a good representation of the plants already growing along the stream in the area of the dam, while planned seeding will incorporate native vegetation that has been proven to succeed in those conditions. However, with establishing vegetation on any newly exposed sediments, the risk of invasive species needs to be addressed.

*Purple loosestrife (Lythrum salicaria) is often found growing in wetlands along river banks and will quickly colonize bare sediment.*

If the seeds of invasive species exist in the sediments or if there are stands of invasive species in close proximity or upstream of the dam, the opportunity for their successful establishment in the project area increases. With newly exposed sediments and the nutrients present in the organic matter, there is great potential for growth of all plant species: native, non-native and invasive. Invasive species such as phragmites and purple loosestrife, if given the chance to become established on the exposed sediments, can dominate the plant community that results in the dam removal project.

Therefore, the partnership guiding the project should outline the frequency of monitoring events and the party responsible for determining if any invasive plant species are present in the returning plant community. There should also be an initial plan of treatment in the case that any invasive plant is discovered during these monitoring events or other investigations. Treatments of species such as phragmites and purple loosestrife include hand-pulling or digging plants up, hand-swiping plants with herbicide or a broadcast treatment with herbicides if the stand is big enough. Whichever treatment is warranted, the project plan needs to outline a preparedness for the possibly of these situations. Treating invasive plants rapidly after they are detected is integral to preventing their widespread establishment.

*Phragmites (Phragmites australis) is also quick to colonize open wetland soil.*

### i. Permitting

State and Federal clean water laws, such as the Clean Water Act, have been established to protect all of Michigan's waterways. The state of Michigan has established a permitting system for anyone planning to work in Michigan's lakes and streams. This permitting system ensures a thorough review of any proposed changes to the physical, chemical, and biological characteristics of the water body to ensure that any potential adverse impacts are minimized.

To learn the most current regulations and permitting requirements, search the Michigan.gov/deq website for "Joint Permit Application."

There are several sections within Michigan law that oversee and regulate activities surrounding dams and their management, including Water Resources Division, Inland Lakes and Streams, Dam Safety Program, Inland Lake Levels, and Wetlands Protection. Even within those sections, how each dam is treated is based on categories of size and use of the dam in question. This again reiterates the importance of involving individuals from the permitting agencies in the partnership and during the project development.

Permits, based on the projects they represent, can be classified as major (also called individual permits) or minor according to the size of the dam, the size of the impoundment, the amount of stream impacted by the project, change in use of the project area, etc. Each of these classifications is different for each section of Michigan law applicable to the project. For example, a project may be considered major by the Dam Safety Program, but minor by Inland Lakes and Streams, and vice versa. Additionally, some activities may require a permit from one state program, but not another. Draw down of an impoundment, for example, does not require a permit from Dam Safety Program but it does require an Inland Lakes and Streams permit. Activities surrounding dams that require permits include: construction of a new dam, reconstruction of a failed dam, enlargement, repair, alteration, abandonment, or removal. A good summary of these categories and classifications can be found as Appendix C to the Joint Permit Application to the State of Michigan.

If a dam is over 6 feet in height and impounds more than 5 acres of water, any projects happening to that dam would require a permit from the Dam Safety Program, part 315. Whether both of those categories are met or not, the dam is still regulated by the DEQ and activities will be reviewed by the Water Resources Division. There may also be other analysis of any project by other state programs including, but not limited to, Water Resources Protection, Inland Lake Levels, and Wetlands Protection. Oversight and permitting within the Inland Lakes and Streams program is also further refined, having 2 permit levels: minor or major (individual).

Projects taking place on dams that are less than 2 feet in height that have an impoundment smaller than 2 acres are likely able to be filed under an Inland Lakes and Streams minor permit. There are other regulations that limit this minor permit qualification and those will be found in Appendix C to the Joint Permit Application to the State of Michigan. The state has been working to streamline the permit process for these smaller dams to allow projects with less anticipated impacts to be more quickly permitted while allowing more time to review and scrutinize bigger projects with higher risk of possible impacts. Projects for dams higher than 2 feet in height are then still classified as needing a major (individual) permit.

When the project is ready to move forward with permitting, there are several details that need to be incorporated into the process. The partnership will have already determined the overriding factors that guide the design and project plan. Within the permit application, plans and designs must outline the intended activities, as well as summarize the current conditions. If the project is classified as major for the permitting, these designs and plans must be prepared by a licensed professional engineer. The design plans will detail how the project protects natural resources, public safety and the public best interest. The permitting process for major projects also includes a mandatory public notice period.

Though not required for minor projects, the involvement of licensed engineers or stream morphology experts in the design is typically recommended. Regardless of who prepares the designs, they must still highlight how natural resources will be protected and how risk of possible impacts will be minimized. These permit applications will lead to an on-site inspection by a department representative. A public notice period is not automatically required, though one may be held for specific projects based on the discretion of the permitting agent. Individuals or groups being impacted by the dam removal can also request a public hearing.

Once submitted, the permit application will either go to Lansing Permit Consolidation Unit (major projects) or directly to the permitting agent in charge of the county in which the project is occurring (minor permits). The review time for each statute varies, though it is safe to say that decisions on permit applications are typically rendered in less than 90 days for complete applications. Additional information may be required or adjustments to the project plan may be suggested. After those responsibilities are met, the permit application is considered complete and the state will move forward with processing. The typical review timeframe does not include interruptions caused by the need for public hearings which can be part of larger project permitting.

Involving the appropriate DEQ staff (which can be found in Appendix C and D) as part of the project partnership will help to guide the permitting process by ensuring that the designs and plans reflect the details and precautions required by the state. This also ensures that someone who should be involved in the project development will not be surprised by the project or that there will not be any unexpected inquiries into project plans.

## Case Study: Chesaning Dam Removal and Rock Ramp Construction Project

Andrea Ania, U.S. Fish & Wildlife Service

### History:

Originally built in 1863, the Chesaning dam was the first dam located on the Shiawassee River upstream from Lake Huron. The dam structure (old grist mill) degraded over time and partially collapsed during the spring 2005 due to excessive flow and ice damage. Emergency repairs were made to the dam and Michigan Department of Transportation (MDOT) installed a grade control structure upstream of the dam to protect the bridge and road in the event of dam failure. The dam owner (Village of Chesaning) reviewed its options to either repair or remove the dam. They found partial removal and rock ramp construction to be the most socially and financially viable alternative for the aging structure.

### Project Design:

The rock ramp structure measures 405' X 190' and consists of eight rock weirs/arches placed approximately every 30 feet beginning at the current MDOT control structure and continuing downstream with an approximate 3% grade. Four additional "J-hooks" or straight vanes were added for downstream erosion control. Construction occurred late summer 2009 and entailed the installation of the rock ramp and vanes and the complete removal of the old dam structure, totaling $1,410,400.

### Benefits/Pros of the Selected Design:

- Allows the Village of Chesaning to retain their annual Chesaning Showboat Festival.
- Provides fish passage – it was identified as a priority barrier for removal in two plans/reports: Saginaw Bay Walleye Recovery Plan (Michigan Department of Natural Resources, MDNR) and Enhancing Fish Passage over Low-head Dams in the Saginaw River Watershed (The Partnership for the Saginaw Bay Watershed and Public Sector Consultants).
- Provides kayaking opportunities.

### Limitations/Cons of the Selected Design:

- Does not restore stream function (e.g., sediment transport, flood behavior), which can result in the loss of in-stream fish spawning grounds both up and down stream of the dam.
- The impoundment will continue to fill with sediment over time because the upper rock weir slows water velocities, causing particles carried by the stream to fall out of suspension and settle out.
- Does not alleviate impacts to water quality such as water warming and reduced oxygen levels.

### Monitoring:

- To determine if target (walleye) or other species are passing over the rock structure.
- Single pass boat and backpack electro-shocking methods were used.
- Pre-construction monitoring by the USFWS occurred in August 2009, immediately before construction.
- Post-Construction monitoring in 2010 and 2011 by the Michigan DNR documented passage of four fish species in relatively low numbers.
- The results prompted dialogue with the consultant to re-evaluate the design and modify the structure (late summer 2011).

### Post construction modifications:

There were very clearly defined goals for the project that included maintaining water levels for the City of Chesaning, while developing a design that ultimately passed fish. The rock ramps in the design were planned to allow the target species, walleye, to migrate upstream during spawning events. Something to consider when implementing a plan such as this, is that the designs are based on the best available knowledge about fish behavior. That knowledge base continues to evolve. Furthermore, what is constructed on the ground does not always accurately reflect what was intended in the plan. That is where monitoring played a key role.

Fish passage was analyzed after the project and results were less than expected. It was discovered that some of the ramps were a slightly higher than planned and did not incorporate proper spacing between rocks, both of which altered the expected results. Therefore, the overarching goal, fish passage, was not being accomplished. The project partnership had a plan in place to adapt a new strategy after the planned construction was completed.

In August, 2011, post construction modifications were made to the rock ramp to improve fish passage, particularly for walleye. Modifications included:

- Open up 1-foot wide gaps between the existing weir stone to enhance fish passage.
- Reset some of the larger ramp stone as partial weirs in between the existing weirs. The partial weirs about 40-ft. long extending from the river's edge in the upper four pools (between existing weirs). Their purpose is to reduce the water level difference between weirs along the edge of the river to also enhance fish passage upstream.

*Before*

*After*

## 1. Michigan Dam Removal Projects

Every dam removal will be different, providing a different set of circumstances and goals that will have unique solutions. However, this should not be seen as daunting. Rather it provides endless opportunities for the field of dam removal to continue to evolve into one of the most prominent techniques available or restoring the streams of Michigan and throughout the country. That fact that each project will be different enables partners to approach each dam with a new sense of creativity and willingness to take on the unknown details.

This document was not written to provide the exact solution to every dam removal or modification that will be encountered in Michigan. Instead, the goal is to provide partners with a thorough discussion of how to approach and think about each project. For those that have similar characteristics, there are well-established ways for dealing with each condition across many projects. However, the common thread that needs to be a component of every dam removal or modification project is the creative thought process and flexibility that all project managers and partners should exhibit as they work through planning, design and permitting, and implementation.

### a. Monitoring and Adjusting Plans

As the project proceeds with dewatering and earth-moving, the plan and design guiding those actions reflect what is expected and intended with the project. That does not always accurately predict how the changes in the stream will occur as the site adjusts or unanticipated situations arise. Therefore, the partnership developing the project plan needs to include not just an explanation of expected changes, but acceptable degrees of those changes. If conditions change differently than what was expected in the plan, the boundaries can be used as thresholds to gauge whether or not the unexpected conditions need to be addressed with alternate management practices.

The concept of sediment movement provides a great example of how this supervision and monitoring can lead to management changes to the project plan. If sediment movement has been addressed by the partnership and the decision was to allow for movement, there should also be a description of what would constitute too much sediment transport. Again, referring to the example of a bridge crossing upstream of the dam provides a good hypothetical situation where some sediment movement would be acceptable, but too much could undermine the footings of the bridge. In the project plan for this situation, it should be outlined how to determine if the amount of sediment movement, while it is ongoing, is enough to raise concern about the bridge. When it is discovered that sediment movement is approaching the threshold, a grade control BMP could be used just downstream of the bridge to provide protection from erosion. If sediment movement never becomes a concern, funding and effort will have been saved by not immediately including a need for a grade control BMP.

### b. Knowledge Sharing and Communication

Knowledge of dam removals and expertise in the field continue to grow in Michigan as more and more dams are being renovated, repaired or removed. With each project completed, the breadth of collective experience across the natural resource community expands. Lessons learned, innovative approaches to problem solving, and successes of adaptively managing the project in changing conditions all contribute to furthering the knowledge base into which resource professionals can tap during future projects, (like those provided in Appendix E). However, it cannot be stressed enough that practitioners of dam removal projects communicate with each other, permitting agencies and funding sources to disseminate this expansion of experience. With the increased communication, a collective paradigm of dam removal can be shared and evolved. That ensures that projects being implemented throughout the region represent the general attitudes and beliefs of the majority of natural resource professionals practicing comparable dam removals in similar regions.

Throughout meetings to organize and implement the small dams workshop and to develop this guidebook, it was repeatedly discussed that creating an effective means for sharing knowledge and information of dam removals in the Great Lakes region needs to also be of high priority. In fact, this was agreed upon by resource professionals as one of the most challenging situations to furthering the field of dam removal in Michigan. The need for a manner by which information and experience gained from each project can be shared, is well understood. Without the avenue to share data and information, each individual project partnership will depend on developing their own techniques to deal with situations that may have well-established solutions in other regions. This becomes particularly important as Best Management Practices for dam removal strategies are developed. In order for BMPs to become widely accepted, a network for sharing, teaching and learning must be created.

The field of dam removal is going to expand and demand more attention of the natural resource community as dams continue to age and deteriorate. Whether time and funding is spent cleaning up the aftermath of dam failures or it is allocated to proactively treating and removing dams, increasing resources will be going into dam management. By actively finding and treating the dams that pose the greatest risk to natural resources, the treatment of dams and the allocation of resources will become more efficient and practical. Without also improving the efficiency with which natural resource professionals communicate the techniques and results of these projects, the discipline of dam removal will not achieve its full potential as a progressive technique used to restore aquatic habitats.

This guidebook is meant to be a living document that can serve as the groundwork for fostering that collaboration. As new techniques are developed and tested their use and success can be incorporated into future editions and help continue to guide projects on the forefront of dam removal and stream restoration. With this step in place, there is a foundation for the next step of creating a local or regional clearinghouse and network for information sharing. Ultimately, we all want the best projects to be done, efficiently and effectively, and to the greatest benefit to our natural resources.

***The Franklin Dam Story - Part 5***

On November 9th, 2011, Franklin Creek was reconnected to the Liberty River for the first time in nearly 70 years. Though that is the date that the sheet pile was finally removed to allow water to flow freely, the process of removing the dam began two years prior, when water was slowly released from the impoundment. During the growing season of 2010, water was drained to the lowest extent possible while the dam was still in place. This allowed the upper half of the impoundment to become well vegetated, leading to more and more stability of the sediments.

Dewatering continued with the onset of the growing season in 2011, so as soon as plants began to grow in 2011, partners were ready to continue lowering water below the initial limits of the dam. This was accomplished by moving rock rip rap and broken concrete by hand. Partners would move enough stones until signs of sediment movement began to show. When those signs were witnessed, such as the onset of more turbid water, moving stones would cease. The pond would be left at that elevation for a week or so to provide ample time for the system to stabilize and revegetation to continue before more lowering occurred. In July 2011, the concrete slab of the dam, over which Franklin Creek had flowed, was lifted with the help of the Mr. Snoop and his family, who also provided the heavy equipment. Throughout the following two months, more rocks and concrete were removed until the water level in the impoundment was within six inches of the water level downstream in the Liberty River. Once the water elevations were that close to each other, partners let the vegetation get a strong foothold before final earth-moving. During that time, Huron Pines created and distributed a bid package to several local contractors and a mandatory site visit for potential contractors was held.

The most capable bidder was awarded the contract to complete the Franklin Creek Dam removal and culvert installation. In November of 2011, they began work on the project by creating a temporary crossing over the dam. Once over the dam, they created a diversion channel by installing two culverts in the driveway berm. With the diversion completed, they could place sheet pile and block flow from where excavation was planned. The destruction and removal of Franklin Creek Dam was underway. In just three days, the contractor removed the old structure, excavated a pad for the new culvert 2 feet below the planned new streambed, placed the new culvert and rebuilt the driveway. When the final piece of sheet pile was removed, all of the original goals outlined in the partnership agreement were all met and Franklin Creek was once again able to return to the a functional stream and the healing process was in headed in the right direction.

It has taken years to get to the goal of once again passing fish from the Liberty River into Franklin Creek. However, the work does not stop there. The Franklin Creek Dam Removal project is yet another example of a successful, voluntary dam removal and the lessons learned and techniques used need to be disseminated to contribute to better future projects. For example, the manner in which effected landowners were involved through communication is an important aspect to include in every dam removal. The revegetation of the impoundment was captured on a remote camera and has been turned into a time lapse video that can be viewed here. This provides an excellent tool to educate landowners on what they can expect as water is lowered, as many landowners fear that it will look like a wasteland.

Finally, there will be many more visits to the project so that partners can monitor for high rates of erosion, invasive species, and to make sure the project is progressing as expected. Temperature monitoring of the water will also continue. All of these post construction tasks play an equally important role in determining the success of the project as the years of planning leading up to the dam removal. By providing oversight and management strategies throughout the whole process, partners will be that much better poised to successfully complete their next dam removal project.

**Summary of Timeline and Milestones**

- Project Begins – November 2009
- Impacted landowners researched and contacted – March 2010
- Dewatering began – May 2010
- On-site meeting held for impacted landowners – June 2010
- Stream and dam surveys completed to guide design – June/July 2010
- Initial draft of designs completed and presented to landowner – December 2010
- Permit applications submitted – March 2011
- Dewatering continues, ensuring no boards are replaced in dam – April 2011
- Permits to remove entire dam structure and install adequate crossing received – June 2011
- Removal of concrete slab at base of dam to lower water and continue dewatering – July 2011
- Culvert bid and purchased – September 2011
- Bid package (for contractor to remove dam and install new culvert) released – September 2011
- Contractor selected and culvert delivered – October 2011
- Final dam removal and culvert installation – November 2011
- Return monitoring visits – March 2012

## Modifying Dam Removal Plans based on Project Limitations: Tributary to Myers Creek

Patrick Ertel, Huron Pines

### Background and Setting

Myers Creek is a coldwater stream which flows into the Black River in Cheboygan County, MI. At the confluence of the two, water temperatures in the Black River no longer support a coldwater ecosystem. Therefore the coldwater ecosystem supported by Myers Creek is geographically isolated. Of the tributaries that feed Myers Creek, many are coldwater ecosystems driven by inputs of groundwater from seeps that develop in the sand over clay nature of the soils in Cheboygan County, making favorable habitat for native eastern brook trout. The tributary on which this dam was created, originates approximately ½ mile upstream of the former dam site where four major seeps in the valley hillsides come together. By the time the stream reached the dam, it was nearly 4ft wide with depths up to 1 ft. The riparian zone, outside of the area influenced by the earth-moving activities, is dominated by heavily forested cedar swamps.

### Building of the dam and ecological impacts

In 2002, the landowner installed approximately 225 ft of 15 inch diameter flexible plastic culvert, through which he would ultimately force the stream to flow. At the upstream end of the culvert a riser box was installed that functioned to control water levels in the newly formed impoundment. In the impoundment, the landowner stocked around a dozen rainbow trout. The valley through which the plastic culvert ran was then filled with over 7000 cubic yards of soil. At the downstream end of the earthen dam, the fill was nearly 25 ft deep. All of the fill material was harvested from surrounding lands within the landowner's property. The resulting situation of high water velocities and the extremely long culvert prevented many species, if not all species, of fish from passing.

### Dam removal designs and plans

After the legal battle over the site remediation had come to a conclusion, Huron Pines was invited to be the lead organization to manage the stream restoration project. Through collaboration with several partners, a full design of what would need to be implemented was completed. During the autumn of 2008, the plastic culvert ultimately failed because of the weight of the fill and the culvert collapsed, creating a large hole in the fill and causing the water in the impoundment to rise rapidly. An emergency excavation of the culvert revealed the failure. From the failure location, the fill and culvert were removed for 65 ft downstream to free the lower portion the stream in the project area. Field stone riprap, geotextile and cedar terraces were used to stabilize the stream bottom and the seeping banks.

The original design included using both upstream and downstream reference reaches to determine what slope and meander frequency the stream should be returned to when it is uncovered. Techniques for instream habitat provision, grade control, and streambank stabilization were balanced with designed freedom for the stream to reestablish several functional features including riffle/run/pool sequences, a small flood plain and localized meander patterns. When this design went through the bid process, the cost of the project totaled just over $99,000.

### Actual Dam Removal Project

When the project costs were discussed with all of the partners, the landowner and the state ended up going back into the legal process. In 2010, the state and the landowner reached a settlement for $50,000. Being significantly less funding than the original estimate, and more than 2 years later, the plan for how to treat the dam removal and stream restoration needed to change drastically. Nearly all of the funding was set to be used simply for the excavation costs, estimated in the original plan. To cut costs, the partners reduced the excavation amounts by planning for steeper valley slopes and no longer building the planned flood plain. No structures such as coir logs or woody debris would be installed to help stabilize the toe of any streambanks. Finally, no funding would remain as contingency dollars in the case that more seeps, like those uncovered in 2008, were encountered as the streambanks were exposed.

## Results

Over the course of a week in September 2010, nearly 7000 cubic yards of fill was removed and spread on site. The 225 ft of stream that was formerly in the 15 inch plastic culvert was once again flowing unimpeded. The impoundment, which had previously been drawn down to the best the site would enable was eliminated. Just as had been believed, the landowner placed the culvert in the old stream channel. So, during excavation the old channel was unearthed, as were many of the old stumps on the streambank, which provided a frame of reference and guidance to where to establish the new channel. Several other groundwater seeps were unearthed and continued to seep and carry fine-grained sand towards the stream. However, there was not enough funding for the project to enable the stabilization of the seeps with drains or more aggressive BMPs.

All told, this unnamed tributary to Myers Creek again flows freely and vegetation is growing on the exposed banks. The treatments that were implemented at this site did not represent the full suite of stream restoration techniques. Rather, because of funding limitations, this project was a "bare bones" version of minimal treatments needed to complete a dam removal. However, what is there now is much better for the stream and the high quality ecosystems living therein, as compared to what was impairing the tributary for nearly 8 years. Additionally, like many ecosystem types, streams have an inherent resiliency and when overriding conditions revert back to the way they should be, streams will continue to get heal themselves.

*Above, Myers Creek impoundment before dam removal. Below, the establishment of the new channel through the former impoundment after the removal.*

*Above, Myers Creek impoundment looking downstream at the former dam site. Below, restoration of the banks and channel after removal.*

**Step 1: Determining the Impacts of the Target Dam**

1) Why was this dam selected for treatment?
2) What is/are the major impacts on the stream caused by the presence of the dam?
3) Which agency would be in charge of oversight of this dam (Dam Safety/Water Bureau)?
4) Is this dam part of the existing databases for known dams in Michigan?

**Step 2: Developing the Project Partnership**

5) Who are the key partners for this project?
6) What are the goals for the project, as identified by the key partners?
7) What are the strategies planned for communicating project plans and timelines to the potentially impacted neighbors, community members, and general public?
8) What are the unique roles for each of the identified key partner?
9) What is the timeline for every partner to accomplish each of their tasks?
10) What partner tasks are there that would depend on results of other partner tasks?

**Step 3: Understanding the Expected Changes Resulting from the Project**

11) Based on the goals of the project, which conditions identified in Question 2 will change, and to what degree, as part of the project?
12) How will the slope of the stream change with the project?
13) What are the plans to manage sediment movement, based on quantity, contamination, etc?
14) What concerns exist about stability of the new channel as it establishes post-dam removal?
15) How will targeted aquatic organisms respond to the project?
16) What are the possible benefits or impacts to non-target species?

**Step 4: Designing and Implementing the Project Plan**

17) Will the entire dam be removed or are there portions that will remain?
18) What is the plan for dewatering the impoundment?
19) How will incoming water from the stream be dealt with before or during removal?
20) How will the stability of the new channel be monitored and/or will active management strategies be employed?
21) What are the stages for earth-moving activities and when will those activities occur?
22) What are the implications of the project on the prevalence or spread of invasive species?
23) Are all of the components of a complete permit application assembled and when will the permit be submitted to allow for ample time for the review and approval process?

**Step 5: Finishing the Project**

24) If unexpected situations arise, what is the plan for making decisions quickly in the field?
25) What is the overriding feature or goal that must be preserved when you are forced to alter project plans because of unexpected conditions?
26) Which partner is in charge of monitoring and what details will they monitor?
27) What is the process by which the partnership will make decisions when monitoring reveals an adaptation in the plan is needed?
28) How will the partnership determine the project is finished?
29) What is the plan for disseminating the results of the project?
30) How will lessons learned in this project be incorporated into future project plans?

Franklin Creek Dam Removal on
Snoop Property
Oscar County, MI 55555

**A Partnership Between**

The Snoop Family (Landowner)
And
US Fish & Wildlife Service – Fish Passage Program
And
Michigan Department of Natural Resources and Environment
And
Huron Pines

**Project Background:**
During the spring of 2009, the dam on Franklin Creek, a coldwater tributary to the Liberty River, experienced a failure. Water levels were high and the condition of the structure was failing, which created a situation in which the water from Franklin Creek could not all pass through the spillway and it began to flow around the structure. As these uncontrolled paths for the water continued to flow, they increased the erosion of earthen material from the berm. The end result was a dam with large eroded gullies on both sides of the structure. Water levels behind the dam could no longer be contained and the dam was failing. The water had to be maintained at lower levels in order to reduce further risk to the structure. With the earthen berm eroded away from the sides of the dam, the structure is now in poor condition and cannot withstand significant pressure from impounded water or begin driven on. In addition to functioning as a dam, this earthen embankment was used by the landowners as the only driveway access to their house. Since the event that caused the gully, the landowners have not been able to fully access their home and have been forced to live elsewhere.

The failure of the structure and the release of the water have been documented by the Michigan Departments of Natural Resources and Environment Quality, and a project file was created so the actions at the dam could be overseen. In June of 2009, the US Fish and Wildlife Service – Fish Passage Program was brought in as a party interested in seeing the dam on Franklin Creek be better suited to fish and other aquatic organism passage. In November of 2009, Huron Pines was invited to participate in the project management role. Funding from US Fish and Wildlife Service has been secured by Huron Pines to fund a major portion of the project. The intent of the project is to replace the failing dam structure with a structure that allows free flowing water and will still function as a driveway crossing. This will likely be a bottomless structure or an embedded culvert similar to structures used in typical road/stream crossing replacements.

**Project Goal:**
The purpose of the project is to restore connectivity of 13 miles of Franklin Creek upstream of the dam, directly to the mainstream of the Liberty River. By using a bottomless or buried structure for the new driveway, passage of organisms native to streams of northern Michigan will be reestablished. Also restored, will be the function of the stream, including, but not limited to: downstream movement of sediment, transport of nutrients such as woody material downstream, redefining of upstream banks and floodplains, and a reduction in thermal impacts originating in the impounded water.

The participation of the landowner is a good-faith measure and is contingent upon the replacement of the dam structure with a new crossing that will enable him to once again access his house by using the reconstructed driveway. The selection of the new “culvert” structure will be determined by what will be the healthiest size and shape for the ecology of Franklin Creek.

The project will be deemed successful when Franklin Creek can flow unimpeded through the new driveway culvert and the driveway is again open to vehicular traffic.

Partner Roles:
In order for the project to be implemented successfully and in a timely manner, it is important for each partner to understand exactly which portions of the project are their responsibility. Additionally, partner responsibilities are closely coordinated with other project tasks and can influence the overall progress of the project. What is expected of each partner is outlined below:

The **US Fish & Wildlife Service – Fish Passage Program** is the major funding source for this project. In addition to being the lead funding agency, there are other responsibilities Service staff has agreed to participate in or to lead. Service staff agrees to lead the project design that will be used a key component of the permit application and will guide the selection of the appropriate structure. Designs will be completed by Monday, January 31, 2011.

Service staff also agrees to provide support during pre-construction bidding and planning, construction oversight, and post-project monitoring, as well as maintaining monitoring equipment that will be onsite during entire process (remote camera system).

The **Michigan Department of Natural Resources** agrees to participate in the project in an advisory and oversight role. In particular MDNR-Habitat Management Unit staff will aid in project design and planning by reviewing and guiding designs being created by USFWS staff. Reviews and recommendations regarding the project design will be made in a timely fashion, so as to enable the final designs to be completed by Monday, January 31, 2011.

MDNR staff also agrees to participate in post-project review. This activity is integral to the success of the project and will ensure that results are within the acceptable limits of what is expected from removing the dam and restoring natural stream grade.

The MDNR Fisheries Biologist assigned to management of the Liberty River agrees to lead certain aspects of pre- and post-dam removal monitoring. Specifically, they will be in charge of placement and recovery of temperature loggers upstream and downstream of the dam. Additionally, any monitoring of fish populations, such as shocking activities, will be led in part by the MDNR Fisheries Biologist.

The **Michigan Department of Environmental Quality** agrees to facilitate the proper design and permit development. By participating in the project before any permits are submitted, the MDEQ can steer the project in a manner that will lead to designs and construction phasing that will correlate to existing state regulations. This will also help speed permitting along as no unexpected project details will need to be reworked to be permissible by the state.

The **landowner, Mr Snoop,** agrees to allow the project to occur on the Franklin Creek parcel in his ownership that encompasses both side of the Franklin Creek Dam. The landowner agrees to allow access to his property for activities related only to the removal of the dam, installation of the new structure and for evaluation of the stream condition before, during, and after the project. Follow up visits after 2011 by project partners will be organized with the landowner on an individual basis.

In the majority of projects Huron Pines implements on private property, the landowner is required to provide 50% of the project costs. In the case of Franklin Creek, the landowner also agrees to provide, both cash and in-kind contributions towards the project, combining to an amount near 50% of the total. In-kind services include tasks such as destruction and removal of the old structure, freeing the new channel of debris from construction, and finishing landscaping of the site, once the new structure is placed. The landowner will also be providing heavy equipment to accomplish several earth-moving tasks. A list of individual tasks will to be provided by the landowner and agreed upon by project partners.

**Huron Pines** agrees to fill the project management role. What that entails is overseeing the entire project and representing each partner group as a single point of contact. More specifically, roles involved in managing the overall project include:

- *Financial Management* – Huron Pines will be in charge of securing additional funds for the project, managing the grants and contracts associated with those funds, and maintaining proper reports and audits.
- *Design Selection* – The final decision of the project design will be made by Huron Pines, taking into account all of the partner input and expertise.
- *Development and Submission of Permits* – In order to implement a successful project, all permits need to be secured well in advance of planned construction. Huron Pines will take the lead in compiling permit applications and necessary documents and will submit all state and local permit applications.
- *Contractor Bidding* – Advertising the project to invited contractors and representing the specific plan of work during construction meetings is also a responsibility of the project manager. This includes distributing results from bid invites to partners for evaluation.
- *Construction Oversight* – Huron Pines will be on-site during all construction activities or will designate a temporary replacement if they cannot attend, such as USFWS or MDNR, but always a project partner. Oversight includes ensuring a safe work environment, conditions of permits are met, and designs are built to specification.
- *Project Monitoring* – Visits to the project site before, during and after construction will be focused on monitoring project progress and assessing whether the project goals are being accomplished.
- *Outreach and Public Relations* – All communication about the project to the public or agencies not partnering on the project should be handled by Huron Pines, the project manager. This includes proactive outreach to residents in proximity to the project and broader outreach efforts like newspaper/newsletter articles, as well as responsive communication to concerns raised throughout the project. This ensures consistent messaging and an objective delivery of project facts. Any questions about the project from outside of the partnership should be directed to and answered by Huron Pines.
- *Timing of Project Tasks* – Huron Pines will be in charge of scheduling project tasks and ensuring that each step is in motion at the appropriate time with the ultimate goal of completing the project early in the autumn of 2011.

**Expected Project Timeline:**

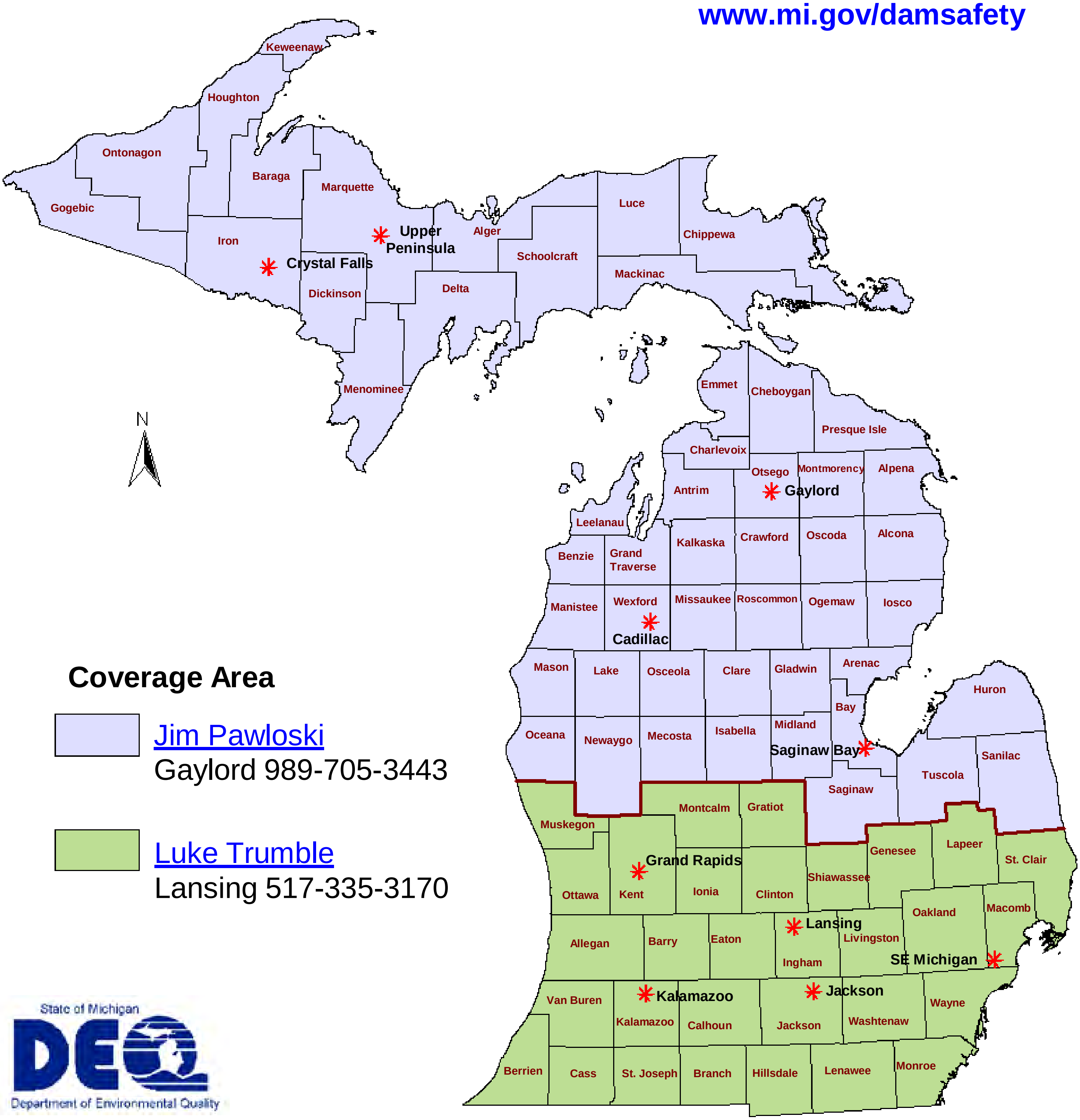
First Communication to Surrounding Landowners – Spring 2010
Surveys Completed for Designs – Summer 2010
Total Funding for Project Secured – Fall 2010
Second Communication to Surrounding Landowners – Fall 2010
Designs Completed – Winter 2010
Permits Submitted – Spring 2011
Initial Destruction of Dam – Summer 2011
Complete Dam Removal – Fall 2011
Install New Crossing – Fall 2011
Monitoring of Site Conditions – Spring 2012
Assessment of Project Success – Summer 2012

**Partner Signatures**

| | |
|---|---|
| US Fish and Wildlife Service – Fish Passage Program | Date |
| Michigan Department of Natural Resources | Date |
| Michigan Department of Environmental Quality | Date |
| Mr. Snoop, Landowner | Date |
| Huron Pines | Date |

# *Dam Safety Staff Map*

**www.mi.gov/damsafety**




**Water Resources Division** **517-373-1170**

www.michigan.gov/wrd

2/24/2011

# Land/Water Interface Permitting Staff Map

www.mi.gov/jointpermit


**Contact Information**

Office Location

District Boundary

Field/District Office Counties

- Upper Peninsula: John Gustafson 906-346-8561, Sheila Meier 906-346-8558, Jay Parent 906-346-8557, Mike Smolinski 906-346-8562
- Crystal Falls: James Caron 906-875-2071
- Cadillac: Susan Conradson 231-876-4443, Barry Peterman 231-876-4442, Robyn Schmidt 231-876-4444
- Gaylord: Roxanne Merrick 989-705-3442, Scott Rasmusson 989-705-3437 Saginaw Bay Office: 989-891-9237 (interim staff assignments)
- Saginaw Bay: Theresa Custodio, 989-894-6223, Cathy Sleight 989-894-6222, Doug Morse 989-894-6224, Brian Rudolph, 989-894-6225, Kip Cronk 989-894-6228
- Grand Rapids: Nancy Cuncannan 616-356-0209, Bob Day 616-356-0030, Michelle Hohn 616-356-0204, Minors: Terry Longanbach 616-356-0206
- Lansing: Chris Clampitt 517-335-6273, Tom Kolhoff 517-335-6270
- SE Michigan: Katie Fairchild 586-753-3864, Melanie Foose 586-753-3866, Andrew Hartz 586-753-3867, Jeremy Richardson 586-753-3860, Minors: Beth Perris 586-753-3889
- Kalamazoo: Derek Haroldson 269-567-3567, Larry Poynter 269-567-3566, *Minors/General: Nancy Deskins 269-567-3563
- Jackson: Katherine David 517-780-7021, Justin Pung 517-780-7916, James Sallee 517-780-7910

State of Michigan

DEQ

Department of Environmental Quality

**Water Resources Division 517-373-1170**

www.michigan.gov/wrd

1/9/2012

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