Ecological Impacts of Removal of the Historical Advocate Dam in Hatfield, Massachusetts

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Abstract

Dam removal affects to impoundment wetlands were studied using the historical Advocate Dam on the Mill River in Hatfield, Massachusetts. Dam removal has been considered for the purpose of increasing fish passage, increasing potential federally endangered dwarf wedgemussel habitat, and for returning the river to its natural flow regime. The first objective of this assessment was to analyze the relationship between wetland type and water level inundation. The second objective was to look at the relationship between vegetation, elevation, and water level fluctuations based on land surface cross sections and dam removal water levels. The third objective was to study how the extent and distribution of wetlands would shift if the water level dropped due to dam removal. Wetland inundation times suggested that certain wetland types were more tolerant of a range of moisture levels, while others required more consistent conditions. A drop in water level after dam removal would limit water to smaller river channels and dry out the wetlands, with a decrease in total wetland area of approximately 73%. This analysis represents the extreme case scenario. Because of significant beaver activity within the wetlands, the potential for a beaver maintained dynamic wetland system after dam removal is high. Future research should focus on modeling the extent of beaver activity in the area upstream of the dam, and the beaver induced transition from a semi-static impoundment wetland to a more dynamic mosaic of wetlands after dam removal.
Within the United States, there has been little comprehensive scientific documentation of dam removal affects to the riparian ecosystem, none that address the full range of ecological responses. In particular, there are very few works that address dam removal affects to upstream wetlands. Dam removal affects on impoundment wetlands were studied using the historical Advocate Dam on the Mill River in Hatfield, Massachusetts, USA. Dam removal has been considered for the purpose of increasing fish passage, increasing potential federally endangered dwarf wedgemussel habitat, and for the return of the river to its natural flow regime. The first objective of this assessment was to analyze the relationship between wetland type and inundation time. The second objective was to look at the relationship between vegetation and pre and post dam removal water level fluctuations. The third objective was to study how the extent and distribution of wetlands would shift if the water level dropped due to dam removal, simulated using a digital elevation model. Wetland inundation times suggested that certain wetland types were more tolerant of a range of moisture levels, while others required more consistent conditions. A drop in water level after dam removal would limit water to smaller river channels and dry out the wetlands, with a potential loss of the majority of the wetlands. This analysis represents the extreme case scenario. Because of significant beaver activity within the wetlands, the potential for a beaver maintained dynamic wetland system after dam removal is high, and should be researched in the future. This study highlights the importance of including relevant ecological components of individual river systems in assessing the feasibility of dam removal. The impact to upstream wetlands should be considered in dam removal studies when applicable.
Acknowledgements

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Introduction

Approximately 76,000 dams have been constructed within the United States since the early 1900s, according to the US Army Corps of Engineer’s National Inventory of Dams (Postel 2003). Beginning in the 1990s dams began to be removed over concerns of safety, disrepair, and in some cases for the purpose of river restoration. To date, approximately five hundred low head dams have been removed. However, very few have been documented in scientific studies. According to Hart et al. in the article Dam Removal: Challenges and Opportunities for Ecological Research and River Restoration, there is a need for more in depth research into the ecological consequences of dam removal. The majority of the studies completed so far have focused on the response of individual components of riparian systems to dam removal. None have documented all potential ecosystem responses for a complete ecological assessment of dam removal (Hart et al 2002).

Using the historical Advocate Dam on the Mill River in Hatfield, Massachusetts as a case study, I researched dam removal effects on impoundment wetlands, a topic that has not yet been addressed in any dam removal studies that I have found. I focused on the relationship between water levels and impoundment wetlands, to determine how a drop in water level due to dam removal would affect wetland communities. This study represents a small portion of a project of much larger scope undertaken by the Northeast Instream Habitat Program (NEIHP) of the University of Massachusetts. The NEIHP project seeks to investigate dam removal for the purposes of improved fish passage and river connectivity. As a research intern involved in this project I have had the privilege of using previously collected field data, as well as collaborated works, for my own use and analysis.
The first part of this study describes how dams and dam removal alter riparian systems and reviews existing scientific literature in dam removal. The second part focuses on my own research of dam removal effects to impoundment wetlands.

The main objectives of my work are:

- To relate the wetland types upstream of the dam to hydrologic conditions based on percent inundation.
- To predict how a drop in water level would affect wetlands based on land topography using cross section profiles.
- To determine how dam removal would affect the extent and distribution of wetland types.

Figure 1: The old mill across the river will become a bed and breakfast.
To Remove or Not Remove?

The feasibility of removing the Advocate Dam requires a careful analysis of possible ecological consequences and benefits. The establishment of unimpeded flows and habitat connectivity between the Mill River and Connecticut River may benefit native flow-dependent fish and mussels. The ideal fish-spawning habitats along the Mill River and its tributaries could serve as a source for repopulating rare species to the Connecticut River. In a recent study completed by NEIHP called Instream Flow Requirements of Mill River, stream reaches above and below the dam were identified as suitable habitat for the federally endangered dwarf wedgemussel. Dam removal would allow for the connection of those reaches, and a potential increase in dwarf wedgemussel habitat. There are however, some environmental risks. Extensive wetlands above the dam could be significantly affected by the dam’s removal. Removing the dam might allow predatory and exotic fish species access to the upper Mill River, which could threaten rare mussels, including the dwarf wedgemussel. The dam also has historic and scenic values, and the impounded pool above the dam is a valued recreational area on the Mill River.

In order to open a dialogue with community leaders and residents about the potential removal of the Hatfield dam, information is needed about the costs and environmental risks and benefits of dam removal. This study focuses on the effects of dam removal to the wetland area in the dam impoundment, looking specifically at how changes in hydrology would affect wetland communities.
Background

Dam Effects

Dams change the fundamental nature of river systems, affecting not only the passage of water itself, but all of the aquatic and terrestrial life that rely on long and short-term patterns of water flow. More than 76,000 dams of have been constructed within the United States, providing a variety of services such as hydroelectric power, flood control, water supply, navigation and recreation (Pohl 2002). Only one river of greater than 1000 km in length, the Yellowstone River in Montana, flows freely without obstruction (Postel 2003). The majority of riparian systems therefore experience various degrees of disruption and impact. Dam removal also destroys the equilibrium that develops in a dammed river. Though approximately 500 dams have been removed during the past decade, there has been little scientific research in this area. The first step in this process is to identify how dam construction alters natural systems.

The immediate effect of dam construction is the inundation of upstream reaches, and the destruction of riparian structure and function. The riverbank, and all the vegetation that grows upon it, disappears under water to be replaced by a shoreline that is initially unstable. There is a natural shift away from aquatic species native to streams, to species that live in and near lakes. Downstream from the impoundment, changes are felt equally as strong. Dams hinder flows and reduce the daily, seasonal, and yearly variations in flow, water temperature, and sediment loads. This loss in variation means a loss of habitat diversity, and in turn species richness (National Research Council 2002).

Dams used for hydropower affect a river system differently than a dam that diverts water for irrigation. Flood control dams and hydroelectric dams do not necessarily change the amount of water that flows downstream, but they may alter the
magnitude and timing of flow. Flood control dams restrain and store water during peak runoff times for release at a later time. This lessens peak river flows and lengthens moderate flows. If flow variation is compensated for with specific water releases downstream damage will be less extreme. Diversion dams, that supply water for irrigation, or drinking water, are much more detrimental to riparian communities. In some cases downstream flows are nearly nonexistent during dry seasons when human water demands are highest (National Research Council 2002). Dams with large reservoirs and high withdrawal levels cause the most upstream and downstream impact.

Dams change high-velocity rivers into slow-moving rivers, with artificial lake habitats. River water impoundments with large reservoirs often have warmer layers of water near the surface, while colder waters sink to the bottom. Water does not mix well in deeper reservoirs, which can lead to eutrophication in the more extreme scenarios, but also low-oxygen water near the bottom. Water may be released downstream from these cooler, poorly oxygenated bottom layers, and though some fish prefer cold waters, many cannot tolerate cold, low oxygen water. Warmer waters released from the top of the reservoir can also negatively affect fish that prefer colder waters, by discouraging them from moving upstream where the water may be intolerably warm (Bednarek 2001).

Sediments accumulate behind dams altering upstream and downstream habitats and water quality. Dams restrict the quantity and size of sediment that reach downstream reaches. Large bed materials, such as boulders and cobble, are not readily transported in dammed rivers, which can cause the streambed to rise upstream of the dam. Small grain sediment, such as sand and silt accumulate behind dams, which can decrease reservoir depth and increase
surface area. Over time, sediment accumulation may cause even more habitat loss behind the dam as the reservoir depth decreases and waters expand outward. Habitats that depend on continuous sediment transport and deposit disappear during this process. Upstream, sediment starved waters can down cut the channel and erode riverbed materials (Bednarek 2001).

Dams disrupt the connectivity of river systems, causing distinct upstream and downstream habitats, flow, and water conditions. Migratory fish, both those that depend upon seasonal freshwater and seawater habitats, and more native fish that travel up and down the river to find suitable spawning sites, need undisrupted river passage as a part of reproductive processes. Though fish are the most impacted migratory species, other populations that depend upon the riparian corridor for passage, may experience isolation in some of the distinct habitat regions that form around dams (Bednarek 2001).

A recent study of the Fox River in northern Illinois examined the effects of fifteen low-head dams (<15 m) on biotic and abiotic riparian communities (Santucci et al. 2005). Fish, macroinvertebrates, habitat, and water quality were tested at sites above and below the dam. Fish communities in free-flowing river reaches were healthier on average than in impounded reaches, with a greater species richness, abundance, and size. Impounded areas supported few macroinvertebrates, and those that were found were of lower quality. In all test sites dissolved oxygen and pH
were highly variable, but the most extreme maximum and minimum dissolved oxygen levels were experienced in impounded areas, as well as the highest average pH level (Santucci et al. 2005). One of the most important variables contributing to differences in aquatic community richness in free-flowing river reaches was habitat diversity. River reaches that were not impeded by dams were more diverse, with areas of distinct water depth, water velocity, bed material, and vegetative cover. Impounded areas were more homogeneous, with habitats that were generally characterized by deep open-water, slower more constant velocities, and a silt/sand dominated substrate (Santucci et al. 2005).

**Dam Removal**

Throughout the past century over five hundred dams have been removed within the United States for various reasons, including concerns about safety, disrepair, functionality, and in some cases as a part of river restoration (Hart et al. 2002). During the initial drive to control and manipulate water, dams were constructed without knowledge of their environmental impacts. Today, dam removal has become an important tool in river restoration, though little scientific research exists to suggest how dammed rivers will transition into free-flowing rivers. The majority of the scientific work that addresses dam removal focuses on smaller dams and rivers. In many cases there are insufficient records of pre-dam conditions,
or dam impacts, which makes a proper analysis of dam removal difficult.

The changes that develop after dam construction are only reversed with equally as severe results during dam removal. Dam removal alters the equilibrium of a river by changing flow and water quality, releasing impounded sediments, reconnecting riparian habitats, and by the shift from reservoir to free-flowing river. The river segments immediately downstream of a dam experience the most dramatic changes in flow, and in sediment deposit. Channel incision is one of the most immediate responses to lowered water levels. The rate and magnitude of incision depends on river conditions such as bed material, bank stability, and vegetation type.

After the immediate drop in the water level and the possibility of channel incision, sediment build-up behind the dam begins to be released downstream. When the IVEX dam on the Chagrin River in Ohio collapsed, the channel bed incised to within one meter of the base bedrock layer (Doyle et al. 2002). The channel then began to widen and large quantities of sediment were released for deposit downstream (Doyle et al. 2002). In some cases, waves of sediment move downstream, as a unit, causing changes on a watershed scale. Depending on river conditions, sediment waves can widen the channel and initiate meander migrations, or channel narrowing and incision can occur. There are numerous documentations of sediment waves, including the flood dam breaks on the Fall River in Colorado in 1993, and the Kowai River in New Zealand in 1983 (Doyle et al. 2002). In the short term, river water with high sediment loads can damage habitat, nutrient availability, and spawning grounds. The effects can be particularly
severe if the sediment is contaminated with toxins. In the case of the Fort Edwards Dam on the Hudson River, New York, which was removed in 1973, PCB laden sediments were washed downstream (Bednarek 2001).

The transition from reservoir to free-flowing river initiates instantaneous habitat successions that affect biotic communities. When the Manatawny Creek dam was removed, shifts in benthic, macroinvertebrate, and fish communities, were observed within the first year (Bushaw-Newton et al. 2002). Before the dam was removed, the benthic fauna was composed of chironomid midges, oligocheate worms, and caenid mayflies, which are common to lake environments. Nine months after the dam was removed, mayflies, caddisflies, and stoneflies were observed, which most commonly inhabit river riffle and run habitats. Within one year the abundance of riffle fish species significantly increased, particularly the rock bass and green sunfish. Although ten percent of the fish exhibited signs of stress, such as lesions and parasites, within one year after dam removal these symptoms decreased (Bushaw-Newton et al. 2002).

While there have been few dam removal studies in general, none have focused on dam removal impacts to impoundment wetland ecology. In January of 2005 a dam removal study of the historical Advocate Dam, on the Mill River in Hatfield, Massachusetts was initiated. Rather than focusing on sediment release, flow changes, or fish habitat, this study focuses on the ecological impacts of dam removal to impoundment wetlands.

Advocate Dam Removal and Impoundment Wetlands

It is with this context in mind that we can begin to look at dam removal impacts to upstream wetland communities. There are two components to this analysis, hydrology
and ecology. Some form of mill or dam has modified river flow at the Advocate Dam site for nearly three hundred years. All flora and fauna in the Mill River ecosystem have adapted to the current conditions, but it is particularly within the dam impoundment that the most significant ecological changes took place after dam construction. Though there are no records indicating that the impoundment wetlands did not exist before the dam was in place, it is possible that riparian conditions pre-dam were different. The question then becomes, how will dam removal affect the wetlands above the Advocate Dam? To answer this question, this study will look at the relationship between water level and wetlands. Extensive surveys were completed to identify wetland communities within the impoundment, to create a detailed record of changes in water level, and to study potential changes to wetland communities.

Study Area

The Mill River is a tributary of the Connecticut River and drains approximately 121 km² in the towns of Conway, Deerfield, Hatfield, Northampton, Whatley, and Williamsburg of Massachusetts (Figure 2). In spite of its small size, the Mill River watershed is widely recognized as one of the state’s most significant because of its exceptional wildlife habitat. At present the river and its tributaries are known to support the greatest diversity of freshwater mussels in Massachusetts, including the state’s only viable population of federally endangered dwarf wedgemussels (*Alasmidonta heterodon*). It also contains one of the Commonwealth’s largest tracts of unfragmented forest which
provides habitat for over 20 state-listed endangered or special concern plants and animals.

The approximately 46 m wide, 4.5 m high, 125 year old Advocate Dam is located in Hatfield, Massachusetts near the mouth of the Mill River. The 3 m tall constructed dam was built in 1881, on top of a 1.5 m tall rock outcrop.
Figure 2: The dam impoundment is located in Hatfield, MA, on the western side of the Connecticut River. The Mill River watershed is outlined in black, with town names in bold, and stream names in italics (Mass GIS).

As the last standing dam on the main stem of the river, it blocks the movement of fish including Atlantic salmon (*Salmo salar*), American shad (*Alosa sapidissim*),
Blueback herring (*Alosa aestivalis*) and Sea lamprey (*Petromyzon marinus*), and other aquatic organisms between the Connecticut River and the Mill River watershed (NREC 2004). The tributaries to the Mill River, however, appear to contain ideal spawning and nursery habitat for Atlantic salmon (NREC 2004). A recent inspection of the dam by the Massachusetts Office of Dam Safety has rated this dam as ‘at risk of failure,’ which raises the possibility of dam removal for the sake of public safety, as well as river restoration.

**Physical Parameters of the Mill River and Dam Impoundment**

The headwaters of the Mill River are located in Conway, MA, where the Mill River is a cold, fast-moving rocky stream (Figure 2). It flows southward to flatter terrain, where it changes from a steep mountain stream into a quieter stream with shallow meanders with a sand/silt substrate. The section of the stream that flows through Whatley, MA is shallow with small meanders. It winds eastward towards South Deerfield, MA where it enters the Great Swamp. Its meanders continue south along the borders of residential and agricultural plots, until it reaches a series of water supply wells in Whatley, where extensive erosion warranted the installation of simple stabilizing structures along a small stretch of the stream. Two tributaries, the West Brook and Running Gutter Brook, enter the Mill River below Whatley. From here, the somewhat colder, wider stream is impounded behind the historical dam in Hatfield forming an extensive wetland system (Newton et al. undated).

The Mill River has a mild average gradient of approximately 0.0006 m per m, which is similar to the valley slope of the Connecticut River Valley. The river channel has numerous meanders with a channel sinuosity ratio of 1.9. The dam impoundment is flatter with a slope of 0.0003 m per m, and is also highly sinuous with evidence of many
former channels and oxbows. The average annual discharge within the impoundment is 454 cfs. Water flows through the impoundment at a very slow rate; the average velocity is 0.15 m/sec (MacBroom 2004). Water behind the dam does not form a traditional backwater pool or reservoir, rather it fills in a deeply incised meandering river channel. The channel directly above the dam is incised to 3 to 3.5 m below the top of the bank of what was the former river channel. However, continued incision is controlled by a bedrock layer that extends upstream from the dam (MacBroom 2004).

**Geologic Setting**

The Connecticut River formed in the wake of retreating ice sheets during the last ice-age, which occurred approximately 18,000 years ago. The river valley flows through what was once Lake Hitchcock, a large proglacial lake that extended from southern Connecticut, through Massachusetts, and into southern New Hampshire. The lake drained 12,000 years ago when the natural rock dam in southern Connecticut weakened and broke. Lakebed sediments and glacial till are a main component of surficial geology in these regions today (NREC 2004).

The Mill River watershed can be divided into two regions, the western highlands, with a maximum elevation of 450 m, and the eastern lowlands that extend down to the Connecticut River floodplain (Figure 2). The lowland region is primarily composed of a layer of Mesozoic sedimentary rock beneath a 30 m thick clay layer. Pockets of glaciolacustrine and Aeolian sand, with an average depth of 8 m, form the aquifers that supply domestic wells. The western highland has a Paleozoic igneous and metamorphic rock layer, overlain in some areas with a thin deposit of glacial till (Newton et al. undated).
A Mill River, river bottom sediment deposit survey, completed in April of 2006 identified the dominant bed materials for a portion of the impoundment stretching 1.5 km upstream from the dam. The majority of the surveyed river channel was composed of a fine grained sandy-silt material, with some pockets of clay, and organic matter in shallower waters. Approximately 60 m above the dam a bedrock layer begins that extends to the natural rock ledge below the dam wall, and for several meters past the dam. There is little to no deposited material on top of the bedrock layer.

**History of Development**

The first humans to settle in the Mill River watershed were the Pocumtuck Indians. They lived in the region for thousands of years before the first European contact in the 1600s, using the land for fishing, hunting, gathering, and small scale farming. The highly fertile eastern lowland was a particularly important site for agricultural development for both Native Americans and European settlers, and even today it is considered to be among the best farm land in New England. Native American environmental impacts were minimal in comparison to European development several centuries later. Within two centuries of European migration to the Connecticut River Valley, 75 to 90% of the forest had been cleared, the beaver population had been decimated, and 34 dams had been constructed on rivers and streams in the Mill River watershed (NREC 2004).

The Pocumtuck economy was largely based in hunting, trading, bartering, and farming. As European settlers began to develop permanent communities within the region, Pocumtuck trappers learned the trade of fur was a highly lucrative business. Beaver pelts, in particular, were a highly desired commodity, and for as long as beaver
populations were maintained, the Pocumtuck prospered. The decline of the Pocumtuck can be linked to the virtual extinction of beaver populations throughout the Mill River watershed, as well as throughout the United States (Memorial Hall Museum 2001).

The earliest known mill in the watershed was built on the mainstem in the late 1600s, not far from the Conway/Deerfield border (Sharon 1989). As the number of settlers increased, so did the number of mills. The demise of the West Brook and Roaring Brook mills came in the early 1900's when the towns of Deerfield and Northampton received permission to construct larger dams for public drinking water supplies. South Deerfield's public drinking water supply reservoirs are located on the Roaring Brook tributary in Whately, and Northampton's on the West Brook tributary to the Mill River. When Northampton constructed a 25-million gallon reservoir on West Brook in 1901, the flow of water in the brook decreased so significantly that the remaining water-operated mills were forced out of business. In 1969, Northampton built a 750-million gallon reservoir above the old reservoir. Today, during dry conditions, all the water in West Brook below the reservoirs comes from ground water and other smaller tributaries (Sharon 1989).

**History of the Advocate Dam**

The historical Advocate Dam is one of the last standing remnants of early industrial development in the Connecticut River Valley. The first gristmill/saw mill was built on the Advocate Dam site in 1661, on top of a natural rock ledge, which was used by Native American as a crossing site for many years (Sharon 1989). After manufacturing various products, including shotguns, the mill was rebuilt in 1881, when the existing dam and buildings were constructed. Water turbines were installed on both sides of the dam in 1917. The dam was called the D.F. Riley Grist Mill Dam, named
after the grist mill owner of 1935 to 1965, Daniel Riley. It was later renamed the Advocate Dam, after the local newspaper printed there during the late 1900s (Department of Environmental Management 1998). On June 2, 1982 the dam and former mill building were added to the National Register of Historic Places (MacBroom 2004). Today the mill site adjacent to the dam has been bought for restoration as a restaurant and bed and breakfast.

**Plant and Animal Species**

For the past five years NEIHP has completed numerous studies throughout the watershed, including the compilation of a list of rare animal and plant species found within the Mill River watershed. The impoundment wetlands form a particularly rich habitat of complex wetland environments. Tables 1 and 2 list important species that can be found throughout the watershed.
Table 1: Rare animal species found in Mill River watershed (NREC 2004).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Turtle</td>
<td><em>Clemmys insculpta</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Spring Salamander</td>
<td><em>Gyrinophilus porphyriticus</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Jefferson Salamander</td>
<td><em>Ambystoma jeffersonianum</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Marbled Salamander</td>
<td><em>A. opacum</em></td>
<td>MA Threatened</td>
</tr>
<tr>
<td>Dwarf wedgemussel</td>
<td><em>Alasmidonta heterodon</em></td>
<td>MA &amp; Fed Endngrd</td>
</tr>
<tr>
<td>Eastern pond mussel</td>
<td><em>Ligumia nasuta</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Squawfoot</td>
<td><em>Strophitus undulates</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Triangle floater</td>
<td><em>Alasmidonta undulata</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Zebra Clubtail Dragonfly</td>
<td><em>Stylurus scudderi</em></td>
<td>MA Endangered</td>
</tr>
<tr>
<td>Spine-Crowned Clubtail</td>
<td><em>Gomphus abbreviatus</em></td>
<td>MA Endangered</td>
</tr>
<tr>
<td>Skillet Clubtail</td>
<td><em>Gomphus ventricosus</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Stream Snaketail</td>
<td><em>Ophiogomphus asperses</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Umber Shadowdragon</td>
<td><em>Neurocordulia obsolete</em></td>
<td>MA Special Concern</td>
</tr>
</tbody>
</table>

Table 2: These seven state-listed plant species are presently known to grow in the watershed (NREC 2004).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winged Monkey Flower</td>
<td><em>Mimulus alatus</em></td>
<td>MA Endangered</td>
</tr>
<tr>
<td>Deergrass</td>
<td><em>Deschampsia cespitosa</em></td>
<td>MA Endangered</td>
</tr>
<tr>
<td>Bush's Sedge</td>
<td><em>Carex bushii</em></td>
<td>MA Endangered</td>
</tr>
<tr>
<td>Green Dragon</td>
<td><em>Arisaema dracontium</em></td>
<td>MA Threatened</td>
</tr>
<tr>
<td>Variegated Horsetail</td>
<td><em>Equisetum variegatum</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>Fringed Gentian</td>
<td><em>Gentiana crinita</em></td>
<td>MA Special Concern</td>
</tr>
<tr>
<td>American Ginseng</td>
<td><em>Panax quinquefolia</em></td>
<td>MA Special Concern</td>
</tr>
</tbody>
</table>

While not endangered, beavers are active within the dam impoundment causing high levels of disturbance to both hydrologic and aquatic regimes. Three beaver homes were observed along main channels throughout the impoundment (Figure 3). A beaver
Dam extends across the river channel mid-way through the Advocate Dam impoundment, with a height of approximately 0.75 m. Trees have been felled both upstream and downstream of the dam, with the highest degree of disturbance upstream of the dam. I observed one beaver during October of 2005, with a length of more than 1 m from head to tail, and a width of approximately 0.5 m.

Figure 3: The wetlands are full of life. Turtles can be found lying in the sun on every log, birds constantly chatter, and beavers are always busy.

Due to the great variety of species that reside in the highly diverse wetland habitats within the impoundment, it is important to carefully consider the potential ecological impacts of dam removal. This is particularly true for the many special concern, and endangered species, that have been found within the Mill River watershed, and who may rely upon this natural system. Changes to the wetland hydrology due to dam removal
will affect not only the flora, but also the fauna that rely upon wetland habitats for survival.

Methods

Stage-Wetland Inundation Analysis

The purpose of this analysis is to understand the relationship between wetland type and percent inundation for the May to October growing season. Beginning in March of 2005 stage measurements were taken at three locations throughout the impoundment, at the Iron Bridge, Bridge Street, and Chestnut Street, using established USGS stage markers as a reference datum. In May of 2005, stage recorders were installed at these locations to collect stage data at fifteen-minute intervals. All data were downloaded and processed through the end of October 2005. Piezometers were reinstalled in the field in November 2005, and continue to collect water level stage measurements. I assisted in final logger collections and processing in October 2005.

Stage duration curves are an adaptation of flow duration curves, and display the percentage of time that specific stages are exceeded (Gordon 2005). I constructed a stage duration curve using daily average stage data collected from May through October of 2005. Because this record is limited to less then one year, changes in stage due to infrequent storm events (such as a hundred year storm) would not be accurately reflected in the stage duration curve. To create a more realistic curve based on a longer period of record, stage values were extrapolated from a correlation of discharge at the Mill River, Northampton, MA, and stage at the Mill River, Hatfield, MA. Mill River, Northampton daily average discharge was downloaded from the USGS Real-Time Hydrologic database for 1939 to 2005. We assumed that the hydraulic conditions at each river are similar.
The two rivers are within close proximity of each other, which means geologic, ecologic, and environmental conditions are comparable. Most importantly, the flow gage at the Mill River, Northampton is above a dam impoundment, as are the stage loggers at the Mill River, Hatfield (Appendix A).

Discharge data were filtered to select only those values within the May to October growing season, as this represents the most important time of year for plant growth. Generated stage values were therefore limited to this season as well. Using the generated stage record for the Mill River, Hatfield, stage duration curves were constructed for a dry year and a wet year to show extremes, and for a twenty-year period, which was representative of both normal and extreme conditions. Twenty exceedence levels were defined for each period of record, based on the maximum and minimum stage for the given dataset. Each period of record of stage was categorized as within an exceedence level, to calculate the percent exceedence, and to form each stage duration curve.

Average wetland vegetation elevations were used along with stage duration curve analysis to find the inundation time of each wetland type. Average wetland elevations were calculated from data collected in the transect survey, and were categorized within exceedence levels in the same manner as records of stage. Percent exceedence values were considered to be equivalent to inundation time, as it represented the percent of the May to October growing season that the average elevation of a given wetland type was submerged under water.

**Transect-Water Level Survey**

Wetland impacts, due to a drop in water level after dam removal, are related to the topography of the impoundment. Cross section profiles of several transects located
within the impoundment were linked to water levels pre and post dam to learn more about this relationship. Ten planned transect lines were identified within the impoundment, running perpendicular to flow, stretching across the river valley and impoundment wetland (Figure 4). We surveyed seven transects of approximately 200 m in length in November of 2005. Elevation measurements were taken using a total station. At each survey point, elevation, wetland vegetation type, and plant species were recorded. Vegetation type classifications were based on the plant association at the root level. When points were surveyed at the edge of more than one wetland type, the more northern type was recorded for that point. A total of 260 points were surveyed. Based on survey data, average elevations were assigned to each of the seven wetland vegetation types which were identified as dominant groups within the impoundment, and are listed as follows: aquatic bed (ab), emergent (em), emergent scrub-shrub (emss), scrub-shrub emergent (ssem), scrub-shrub (ss), scrub-shrub forest (ssfo), and forest (fo).

Wetland vegetation types were defined based on United States Geological Survey (USGS) definitions (Cowardin et al. 2004). Aquatic bed wetlands support plants that grow at or above the water surface for the majority of the growing season. This plant type grows best in conditions of constant inundation or regular flooding. Aquatic bed plants grow either on the water surface, like water lilies, or with roots down to the substrate (Figure 5). Emergent wetland plants are adapted to living in waterlogged conditions, with erect, non-woody, rooted growth. This vegetation type is present for the majority of the growing season, and is dominated by perennial plants. They can grow at, above, or below the water surface, usually within transition zones between land and water.
Figure 4: Transect cross sections were formed based on transect survey elevation data, which was also an important data source for the DEM.

Scrub-shrub wetlands are dominated by woody vegetation usually less than six meters tall. Small trees, young trees, and shrubs grow in this wetland type, with a wide range of water regimes. Water can be found immediately beneath the land surface, with soil conditions ranging from moist to very wet. Forest wetlands are most common in the Northeastern United States. They are usually composed of a taller overstory, and an understory with young trees and shrubs. Flooding occurs most often during the spring, and though soils are considered better drained than other wetland soils, they are generally poorly drained (Cowardin et al. 2004). Emergent-scrub-shrub, scrub-shrub emergent, and
scrub-shrub forest wetland types were used as additional classification groups for this study.

Figure 5: The river channel near Transect 2 showing the range of wetland types.

Transect land surface cross sections were plotted with average, maximum, and minimum water levels to model hydrologic conditions with and without the dam (Appendix C). The current average, maximum, and minimum water levels were calculated from the extrapolated record of stage. Post dam removal water levels were defined as 1.5 m and 2 m less than current water levels.

The projected drops in water level were calculated based on the height of the dam wall and the channel geomorphology upstream of the dam. The 500 m stretch of river upstream of the dam is deeper than the majority of the channels throughout the
impoundment, with a maximum depth of 5 m. The bedrock layer which begins 60 m upstream of the dam would act as a hydrologic control. In this region the water is shallower, reaching a depth of 1.5 m, 35 m above the dam. Immediately before the dam wall the water depth increases to 2.5 m or more (accumulated sediments may have affected depth measurements). The river bottom elevation therefore begins to rise 60 m before the dam, reaches a peak at 35 m, and declines sharply immediately before the dam. Due to these conditions, it is expected that after dam removal the water level would drop by 1.5 m throughout the impoundment even though the dam wall has a height of 3 m, and that a 2 m drop in water level represents the extreme case scenario.

**Digital Elevation Model Wetland Analysis**

I created a digital elevation model of a portion of the impoundment to predict how dam removal would change the extent and distribution of wetlands. In order to quantify wetland changes after dam removal, current wetland zones and dam removal wetland zones were plotted in a digital elevation model of a portion of the impoundment. This portion extends upstream from the dam approximately 200 m, with almost 1500 m of river channel, covering areas where the river channel is clearly defined, as well as areas where there are extensive wetlands. Three sources of data were used to generate the DEM: 1) transect surveys; 2) river bottom elevation surveys; 3) water level traces digitized from aerial photos.

A team of University of Massachusetts Graduate Research Technicians collected river bottom elevations using a Sontek Riversurveyor, or Acoustic Doppler Profiler device (San Diego, CA), on February 17, 2005. The river bottom elevation survey was limited to the wetland region extending upstream from the dam, halfway to Bridge Street,
as well as to main river/wetland channels. At each data point three river bottom depths were recorded, as well as GPS coordinates. River bottom depths were averaged, and subtracted from the stage level on the day of the survey, to create a precise river bottom elevation database. All data points were plotted in ArcMap, and data point coordinates processed for the correct projection for use in generating the digital elevation model (Appendix E).

Water levels from 3 different days were digitized from aerial photos and linked to elevation. Aerial photos were taken in April of 2005 with three flight runs on the 6th, 9th, 15th. Each run followed specific flight lines across the impoundment to produce a series of photos on each day. I stitched together individual photos using Erdas Imagine software to produce a single image for each day in April, which was then georeferenced in ArcMap. In ArcMap shorelines were delineated manually for each of the days in April using the aerial photos as a base. Water level delineations were linked to the stage data for the specific day in April, to assign an elevation to each water level trace, and the points along that trace line (Appendix D).

All elevation data including transect survey elevations, river bottom elevations, and water level traces were used to create a digital elevation model. Several initial attempts at making a bathymetric model using the data in ArcMap produced unsatisfactory results, because point triangulations formed a highly inaccurate surface due to the lack of a regular point grid. With the help of a modeling program called River 2D Bed (Edmonton, Albreta), elevation data were processed to form a regular grid of points for analysis in ArcMap.

All River 2D input data were first processed in ArcMap so that all points were projected in the North American Datum 1983 Massachusetts State Plain coordinate
system. XYZ coordinates were extracted from ArcMap for the text based River 2D code, with each point defined as either an individual node, or as a part of a boundary line or breakline. Breaklines, boundaries, and nodes were imported into River 2D Bed, and all points were triangulated. All XYZ data were then exported as a regular 1 m grid of points into ArcMap for further analysis. In ArcMap the point grid was again triangulated to form a TIN layer. The TIN layer was converted to a raster layer for analysis (Appendix D).

To calculate the change in wetland area after dam removal, the raster layer was reclassified by assigning four wetland vegetation elevation zones: aquatic bed, emergent, scrub-shrub, and forest. Each zone was defined by the maximum and minimum wetland vegetation elevations of each wetland type, which were collected in the transect survey (Figure 6). The emergent scrub-shrub, scrub-shrub emergent, and scrub-shrub forest wetland zones were eliminated as separate classes, because they were subgroups of the four main wetland types, and fell within the maximum and minimum range of elevation for each of the four main zones. Wetland zones were defined based on the minimum and maximum elevations for each wetland type, which were derived from the transect survey in November 2005. The aquatic bed elevation zone is between 38.19 m and 38.6 m, the emergent zone 38.61 m and 38.8 m, the scrub-shrub zone 38.81 m and 39.2 m, and the forest zone 39.21 m to 40.0 m. The dam removal wetland zones were defined as 1.5 m and 2 m less than the current wetland zone, and were used in the second and third reclassification of the raster layer. The reclassified rasters highlighted elevation zones of each wetland type. For each raster reclassification the area of each wetland vegetation type was calculated, to find the wetland area pre and post dam removal.
An extensive wetland survey, completed by a University of Massachusetts biologist in the summer of 2003, was used as a comparative reference for the results of DEM analysis. Bradley Compton classified and identified regions of varying wetland vegetation type throughout the impoundment based on the National Wetland Inventory wetland classifications. Wetland delineations within the impoundment were completed using a GPS unit in the field and detailed aerial photo vegetation analysis in ArcMap. The survey information was processed in ArcMap to produce a detailed map of wetland communities throughout the impoundment. Wetland areas defined in DEM analysis were compared with field survey delineations for a sample area of approximately 62,720 m².

Results

Stage-Wetland Inundation Analysis

According to stage wetland analysis the percent inundation of each wetland type depends on yearly hydrologic conditions. For example, during dry years submerged wetland types (aquatic bed) are inundated for 92% of the May-October growing season, in wet years inundation occurs 97% of the time, and based on a longer, 20 year period of record, inundation occurs 100% of the time (Table 3).

Table 3: Percent inundations for each wetland type.

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Field Data 2005</th>
<th>1985-2005</th>
<th>Dry Year</th>
<th>Wet Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic Bed</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Emergent</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Emergent scrub-shrub</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Scrub-shrub emergent</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Scrub-shrub</td>
<td>75</td>
<td>92</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>Scrub-shrub forest</td>
<td>42</td>
<td>89</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>Forest</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>
Percent inundations based on 2005 field data are similar to dry year values. According to the University of Massachusetts Cranberry Station weather report, 2005 summer (June-August) temperatures were average, but it was also very dry and sunny. Were it not for the extreme weather conditions due to Hurricane Katrina, rainfall would be 19.6 cm below average, and sunshine was 5 degrees above average (UMass Cranberry Station 2005).

The tolerated range of inundation varies according to wetland type. Aquatic bed and emergent wetlands need constant saturation, with 100% inundation. Scrub-shrub wetlands can tolerate a larger range of conditions, where in dry years percent inundation is as low as 42%, and in wet years as high as 100%, which is a 58% difference in inundation. Forest wetlands need even drier conditions with less than 7% inundation (Table 3).

**Transect-Water Level Survey**

Transect survey water level analysis show that a drop in water level due to dam removal would have detrimental consequences for wetland communities. According to the 260 surveyed transect points the wetland communities of interest grow within a 0.85 m elevation zone (Figure 6). Within this zone water level fluctuations allow for a range of wet to moist conditions. The high levels of saturation many of these wetland communities require, as evident in inundation times derived from stage duration curves, as well as the small zone of elevation in which they can be found, show that these wetland types grow in a relatively flat, wet terrain. As might be expected, drier wetland types, such as scrub-shrub and forest, grow at higher elevations, where water levels
infrequently rise high enough to saturate the soil. Wetland types that require constant saturation, such as aquatic bed and emergent vegetation, grow at and around the average water level (39.1 m) (Figure 6), and as is suggested by stage duration curve analysis they are inundated almost 100% of the growing season.

Figure 6: Shows average, max, and min wetland vegetation elevations in meters, for each wetland vegetation type.

According to transect cross section analysis a 1.5 to 2 m drop in water level would limit water to the former river channel. The former river channel is assumed to be the river channel through which all water flowed pre-dam. It can be seen clearly in transect cross sections as drops in the land surface, and in aerial photos as wider, deeper channels. Current water levels (average, maximum, and minimum) fluctuate around the land surface, around what is probably the former river’s floodplain. If the water level dropped by 1.5 m, the maximum water level would not exceed the top of the former river channel bank (Figure 6a and 6b).
**Figure 7a:** The transect 4 cross-sectional profile shows the former river channel, and average, maximum, and minimum water levels.

**Figure 7b:** In dam removal conditions, the highest possible water level does not exceed the top of the banks of the former river channel.

In all transect graphs water fluctuations occur on or around the floodplain surface, which means that most wetland plants in that region experience varying degrees of saturation.
throughout the year, without the risk of drying out. If the water level were to drop by 1.5 m, the water would be limited to the former river channel with little chance of overbanking, and this is true even more so for a 2 m drop in water level. This would mean a loss of the majority of the current wetland habitat, and an isolation of water flow to the former river channel.

**Digital Elevation Model**

As was concluded in transect survey analysis, a 1.5 to 2 m drop in water level would result in a decrease in wetland area. According to ArcMap raster analysis approximately 73% to 78% of the current wetlands could be lost if the dam were removed (Table 4)(Figure 8b).

**Table 4:** Dam removal would result in large scale wetland losses.

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Current wetland area (m²)</th>
<th>1.5 m drop water level (m²)</th>
<th>% loss in area</th>
<th>2 m drop in water level (m²)</th>
<th>% loss in area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic bed</td>
<td>11,711</td>
<td>5,389</td>
<td>54%</td>
<td>5,612</td>
<td>52%</td>
</tr>
<tr>
<td>Emergent</td>
<td>9,107</td>
<td>3,271</td>
<td>64%</td>
<td>2,454</td>
<td>73%</td>
</tr>
<tr>
<td>Scrub-shrub</td>
<td>55,796</td>
<td>5,547</td>
<td>90%</td>
<td>4,759</td>
<td>91%</td>
</tr>
<tr>
<td>Forest</td>
<td>23,599</td>
<td>12,457</td>
<td>47%</td>
<td>9,574</td>
<td>59%</td>
</tr>
<tr>
<td>Total</td>
<td>100,212</td>
<td>26,664</td>
<td>73%</td>
<td>22,399</td>
<td>78%</td>
</tr>
</tbody>
</table>

Models of dam removal impacts to wetlands with a 1.5 m and 2 m drop in water level are a similar. The wetland type with the greatest loss in area is scrub-shrub, followed by emergent, aquatic bed, and forest wetland vegetation types. According to DEM analysis upland communities would move in where wetlands were lost. This would mean a shift from impoundment wetlands to a riparian system similar to upstream Mill River reaches. The system becomes much drier. The average floodplain valley width
would decrease from approximately 145 m to 32 m for the modeled wetlands, showing an isolation of water to the main river channel after dam removal.

**Figure 8a:** Shows current extent of wetland impoundment highlighting aquatic bed, emergent, scrub-shrub, and forest wetland types.
**Figure 8b:** Models the wetlands without the dam in place, with a potential water level drop of 1.5 m.

DEM modeled wetlands show an 11% difference in total area in comparison with wetlands surveyed in 2003. The aquatic bed and forest wetlands were similar in extent for the modeled and surveyed wetlands. The greatest variance is between emergent and scrub-shrub wetland types. Within the designated region of comparison the DEM modeled wetlands showed some upland dominated areas, while the 2003 survey

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>DEM Area (m²)</th>
<th>2003 Survey Area (m²)</th>
<th>% difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic bed</td>
<td>7,278</td>
<td>6,367</td>
<td>13% less</td>
</tr>
<tr>
<td>Emergent</td>
<td>5,729</td>
<td>18,190</td>
<td>218% greater</td>
</tr>
<tr>
<td>Scrub-shrub</td>
<td>29,617</td>
<td>14,890</td>
<td>50% less</td>
</tr>
<tr>
<td>Forest</td>
<td>1,470</td>
<td>1,087</td>
<td>26% less</td>
</tr>
<tr>
<td>Upland</td>
<td>1,316</td>
<td>0</td>
<td>100% less</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>45,410</strong></td>
<td><strong>40,535</strong></td>
<td><strong>11% less</strong></td>
</tr>
</tbody>
</table>

Table 5: Comparison between surveyed and modeled wetlands.
did not. These discrepancies could stem from initial differences in survey method in the field. The DEM modeled wetlands are based on wetland zones that were defined from transect surveys and the identification of wetland type by graduate research technicians at NEIHP. The surveyed wetlands were classified two years earlier by a biology professor Bradley Compton, who had more experience in identifying wetland communities. Variance could also stem from the different hydrologic conditions in 2003 and 2005, and the natural environmental shifts that would inevitably occur over two years time. According to the UMass weather station 2003 was a cold year with above average rainfall, and below average sunshine. 2005 was drier and sunnier than average (UMass Cranberry Station 2005). The wet and dry extremes that highlighted 2003 and 2005 could account for the distribution of emergent and scurb-shrub wetlands for each year, where in 2003 there was more emergent and in 2005 there was more scrub-shrub wetland. The accuracy of the DEM could also be limited by a small elevation database, and this could be another source of error in predicted wetland areas, particularly because wetland vegetation elevation zones were within a small range of elevation.

Despite these discrepancies, this comparison validates the wetlands modeled using the DEM.

Discussion

In order to assess the feasibility of removing the Advocate Dam it was important to determine how a drop in water level would affect wetlands within the impoundment. As a part of this assessment my objectives were to 1) analyze the relationship between wetland type and water level inundation for the May to October growing season, 2) to look at the relationship between vegetation, elevation, and water level fluctuations based
on land surface cross sections and dam removal water levels 3) to study how wetlands would shift if the water level dropped due to dam removal.

Stage duration curve analysis allowed for the calculation of the inundation time of several wetland types. This analysis gave insight into the hydrologic conditions necessary for the development of each wetland type. This analysis links the distribution of wetlands to their elevation above water level. For the purposes of this study this is an important distinction, and is the basis of further analysis in cross section profiles, and in calculating the shift in wetland zones using the digital elevation model.

Water level analyses based on land profile cross sections yielded important conclusion about dam removal affects to wetlands. The current wetland formed in the floodplain of the Mill River before the dam was in place. A 1.5 m drop in water level would limit water to that former river channel, so that even the highest flows would not top the banks of the river channel. This would significantly limit areas of inundation to a much smaller corridor along the channel. However, if the dam were removed, water velocities could increase and water level fluctuations could become more extreme. It is beyond the scope of this study to quantify these changes, but it is necessary to acknowledge that these changes could occur, and that they would play an important part in maintaining wetlands. Some degree of wetlands would be preserved in the river floodplain by slightly more dynamic, fluctuating, water level. On the other hand, because of the combination of a mild gradient within the impoundment, low water velocities, and a bedrock layer near the end of the impoundment, even if the dam were removed water velocities may not significantly increase.
According to DEM analysis if the dam were removed there would be a 73% loss in wetland area, and a shift towards a drier, forest dominated wetland. The wetlands modeled in low water conditions after dam removal may not reflect the reality of how wetland zones would shift in this scenario. The relocation of aquatic bed and emergent wetlands to the region immediately adjacent to the river channel is based on a shift in wetlands due to their elevation above water level. These areas were then selected based on a single criterion, and represent regions in which the level of saturation is suitable for the identified wetland communities. Other factors such as land slope, water velocity, and light availability were not taken into account, and could be highly significant in determining how wetlands would shift if the dam were removed.

Because DEM data was limited to only a small part of the impoundment, where the river channel is more defined, and wetland areas less extensive, this analysis may not accurately reflect changes throughout the impoundment as a whole. The impoundment is more complex topologically upstream, where there are many small channels, islands, and pools, and changes to wetlands could be different.

One variable that has not been factored into analysis of dam removal impacts to impoundment wetlands is the potential for increased beaver activity if the dam is removed. Beaver induced flooding and natural dams might mitigate wetland changes due to dam removal. Lower water levels might create better beaver habitats, allowing them to move downstream towards the dam, where waters may once have been too deep for a beaver dam, because of the Advocate Dam wall. A dynamic wetland would take the place of the impoundment wetland. Though the beaver maintained wetlands might not be quite as stable as impoundment wetlands, they would allow for fish passage upstream. Beaver dams themselves are highly permeable, and usually of low height, which would
be of no obstacle to fish migration. The beaver community that now populates the wetland area is healthy and likely looking for new dam sites. A beaver dam is already in place halfway through the impoundment, and there are several beaver homes as well. Unfortunately, it would be difficult to predict how the wetland would change if the dam were removed and beavers moved in. Changes to the wetland overtime would be highly dependent on beaver activity, which may not be enough to ensure stable habitats for many of the important species that could live within the wetlands. It is also likely that beavers have been, and will continue to be very active in the impoundment. As it is beyond the scope of this study to quantify these changes, it can only be stated that beavers are active in the impoundment, and could play a part in maintaining the wetlands if the dam were removed.

The decision to remove the dam would be founded on the importance of restoring natural riparian conditions, the possibility of a beaver maintained dynamic wetland system, and the costs of repairing the historical dam in the future. In many ways these considerations are equally, if not more important, than conclusions about potential wetland losses due to dam removal. While this study provides insight into a new ecological component of dam removal, one that has not been properly researched in the past, the decision to maintain or remove the Advocate Dam should not be made based solely on wetland analysis. Future research into the removal of the Advocate Dam should focus on the potential of a dynamic beaver maintained wetland, fish habitat above and below the dam, fish passage, and alternative fish passage methods. Many of these issues are the focus of NEIHP research, and they will produce a much more comprehensive study of the feasibility of removing the Advocate Dam.
Conclusion

The removal of the historical Advocate Dam would result in the loss of the majority of the impoundment wetlands. If the dam were removed, the water level would drop 1.5 m, which would mean the isolation of water flows to what was the once the former river channel. The current wetlands, which are composed of a variety of wetland types, including aquatic bed, emergent, scrub-shrub, and forest, would shift to a forest dominated riparian system. Approximately 73% of the current wetlands would be replaced by upland communities. This loss could be minimized if beavers become more active in areas above the dam, which is highly likely if the dam were removed and water levels were lower. Future research should focus on the potential of beaver maintained wetlands. The decision to remove the Advocate Dam will have to weigh these potential wetland changes against the benefits of increased fish passage, river connectivity, and the return of a natural flow regime.
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