

## **Introduction**

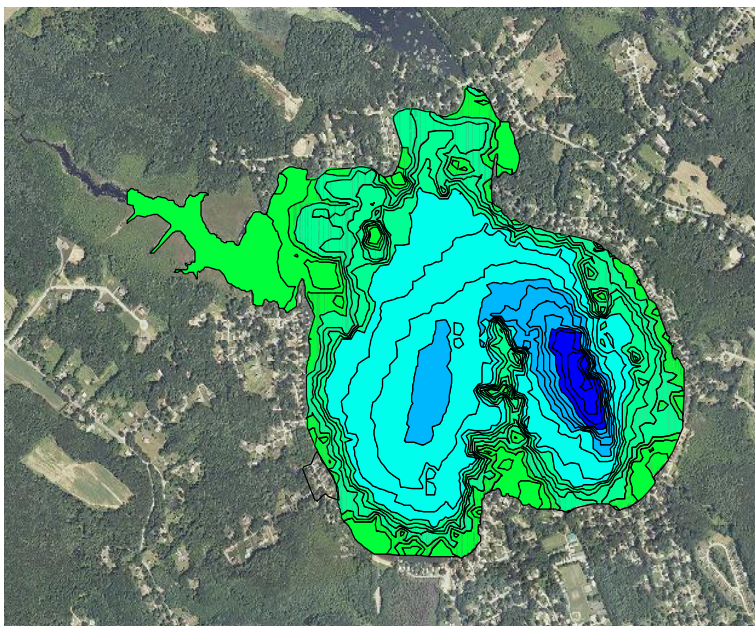
### **Geographic, Spatial, and Demographic Information**

Lake Attitash is a 360-acre natural lake split between the towns of Amesbury and Merrimac, Massachusetts. The lake provides a secondary public drinking water supply for the Town of Amesbury, following the primary sources of the Powwow River and Tuxbury Pond. In 1712, a dam was constructed on the northeast side of the lake with a purpose of raising the water level approximately three feet to maintain flow for the water-powered mills along the Powwow River.

Until the late 1800's, Lake Attitash was formerly named Kimball's Pond after a family that owned much of the surrounding area. With close proximity to the coast and Boston, Ma, the 30 mile radius population of 1,991,452 people includes the states Massachusetts, Maine, and New Hampshire.

### **Physical Water Body Characteristics**

Lake Attitash has a maximum depth of >10 m with a mean depth of 2.8 m. Variable in shape with frequent shoreline convolutions, the lake consists of one larger basin. The major inlet is Back River with a length of 3.7 km and whose confluence is located on the northwest shore. It is important to note that the outlet is also located on the north end of the lake, preventing water circulation throughout the entire lake.



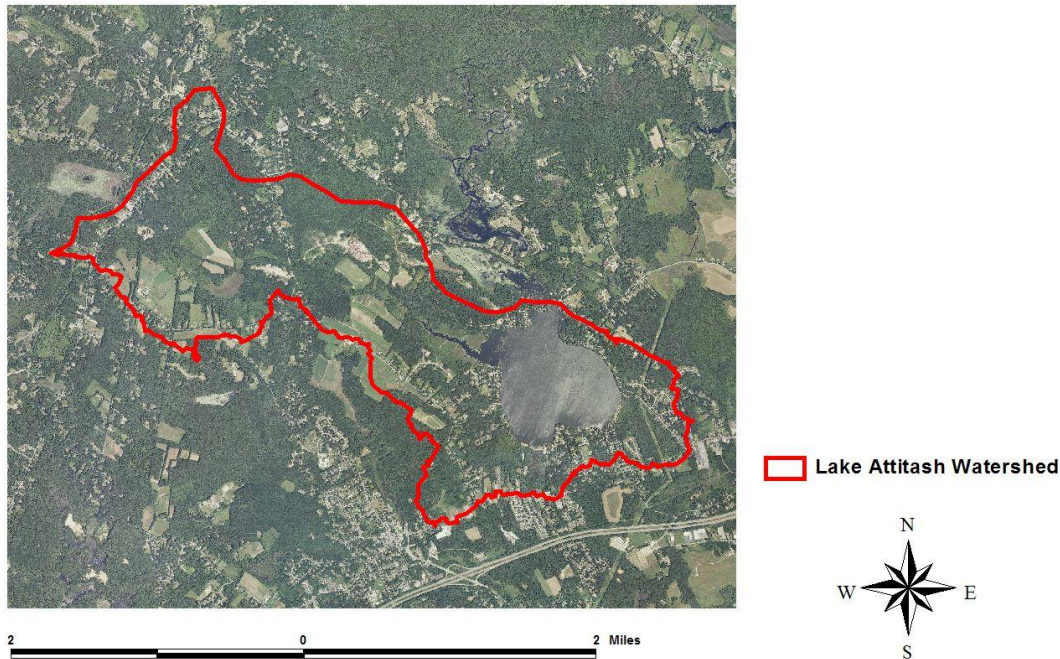
The shore-land area within the 250 foot high water mark surrounding the lake is 52.7 % developed, but of the remaining undeveloped areas, 24.6 % is considered wetlands, preventing development to occur on these lands in Massachusetts.

Approximately, 7.77 % of the shore-land is classified as impervious surfaces, which include driveways, roofs, and other hard-packed urban surfaces.

With a watershed of approximately 2,504 acres and spread over three towns (Amesbury, Merrimac, Newton) and two states (NH and MA), only 30.5 % of the land is developed.

Although the percentage of developed land is minimal, the relatively small watershed to lake ratio (6.8: 1) suggests that any slight increases in development would have detrimental effects of nutrient loading input into the lake.

## Lake Attitash Watershed



### Recreational Activities

With close proximity to the coast and the high density population within the surrounding area, Lake Attitash attracts a variety of recreational users. A public boat ramp located in Merrimac that is capable of accommodating nearly two dozen vehicles attracts a large number of high horsepower motorboats with restrictions limiting only the use of Jet-skis. A preliminary study performed by the Lake Attitash Association indicated a 60% powerboats: 40% sailboats/kayak comparison.

Lake Attitash parameters and habitat sustain a healthy population of warm-water fish species, which include Largemouth Bass, Chain Pickerel, Black Crappie, White Perch, Yellow Perch, Bluegill, Pumpkinseed, Brown Bullhead, and the Northern Pike (Mass Wildlife Survey). A management stocking effort was performed by the Massachusetts Fish & Wildlife to introduce a Northern Pike fishery into many of the larger warm-water lakes statewide. Northern Pike were stocked in 1979, 1985, 1986, and

1988. Recent samples from Lake Attitash suggest excellent growth rates and survival for this particular species, making it one of the best northern pike waters in the Northeast District.

Since the establishment of Camp Bauercrest in 1931, this recreational facility has provided younger children with many outdoor activities. Unfortunately, the recent discovery of cyanobacteria blooms in the lake has directed the camp towards building a swimming pool to provide an alternative solution for safe aquatic activities.

### **Lake Attitash Association: Past and Current Involvement**

The Lake Attitash Association (LAA) was established in 1993 as a non-profit organization to provide any person interested in improving and practicing responsible behavior the ability to help conserve the varying lake values. Mostly comprised of members from the lake community, they strive towards addressing concerns such as nutrient loading, water quality, invasion of aquatic weeds, and wildlife preservation.

Active residents on the lake have been monitoring water quality since 1978 providing more than 30 years of data. The proactive group has made several improvements on the lake such as obtaining a grant from the state to install a storm water drainage system and restrictions preventing the use of jet-skis on the lake. In 2003, an engineered aquatic filter barrier system known as a “gunderboom” was installed at the inlet of the Back River. The system filters “weed promoting” nutrients from entering the lake, while still allowing water passage. Currently, the association continues to monitor and test water samples for cyanobacteria on monthly intervals.

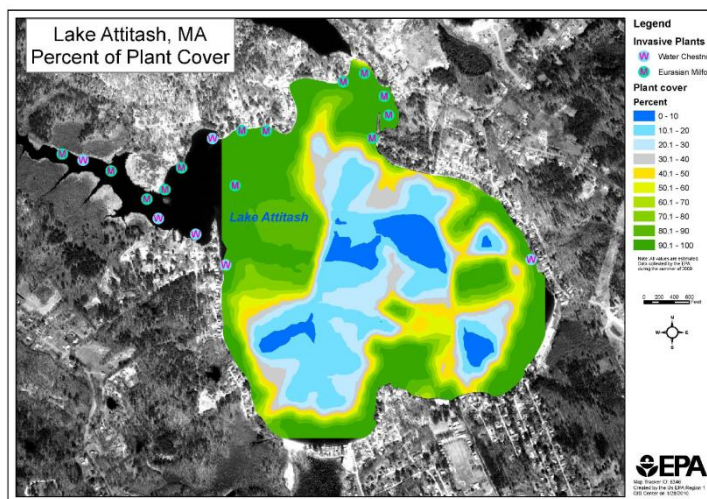
### **Water Quality Characteristics**

Through evidence of previous sampling by the lake association, their data has suggested a progression towards a more eutrophic lake with degrading water quality. Point and non-point sources have been identified throughout the watershed that have undoubtedly increased nutrient loading input into the lake. Numerous farms exist within the watershed, but agricultural runoff and a composting facility from specific operations adjacent to Back River and its wetlands are topographically structured to stimulate extensive nutrient inputs. Mulch storage and gravel yard facilities also exist within close proximity of Back River. Shore development surrounds the lake with the high density residential areas composed of secondary and tertiary waterfront residents. These residents may contribute relatively high levels of phosphorus associated with lawn fertilizers, car wash detergents, and other household supplies.

The input of excessive nutrients in combination with warm and slow circulating flows provides ideal water conditions for algal blooms. In the past years, increasing evidence of cyanobacteria blooms has alerted MA Department of Public Health officials to test the water quality, which resulted in the closure of public access to the lake due to the severity.

### **Aquatic Invasive Species**

Currently two aquatic invasive species exist within Lake Attitash. The more abundant is Eurasian Milfoil, which exists primarily around the inlet and outlet on the north end of the lake. The majority of this section is shallow and nutrient rich, providing proficient native and invasive macrophyte growth. The second invasive species, water chestnut is also found within the same area, although it is not as prolific. Future plans are in place in attempts to eradicate some of the macrophyte abundance through herbicides and winter drawdown.



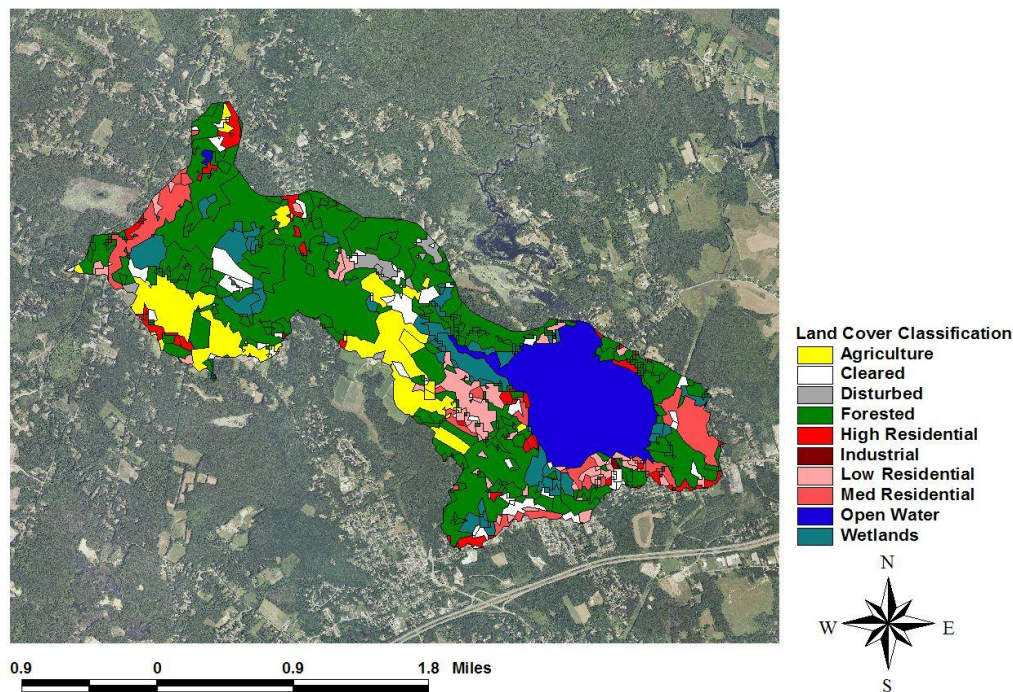
### **Comprehensive Lake Inventory (CLI)**

In order to determine what aspects of Lake Attitash's current status should be addressed as the main priority of this management plan, a Comprehensive Lake Inventory (CLI) was created as a foundation of information about the lake and the watershed. The information included in the CLI ranges from the physical and biological characteristics of the lake, to the laws and guidelines set in place to protect the watershed. Many resources were used to find this information. The Lake Attitash Association



was a wealth of knowledge when it came to both the historic and current characteristics of the lake. Much of the data collected also came from government sources such as the town halls of Merrimac and Amesbury, MA and Newton, NH. Other government agencies such as Mass Wildlife, the Department of Environmental Protection, the Environmental Protection Agency and the Department of Public Health also were helpful resources in the search for information. Biological characteristics of Lake Attitash were provided by data collected by volunteers with the lake association, as well as from the Center of Freshwater Biology with the University of New Hampshire. Some of the questions on the CLI are very specific as to the percentages of land area or population and this information was found using a computer program called Global Information Systems. This allowed for the manipulation of satellite images that were necessary for the data retrieval and calculations. Most of the data in the completed CLI has been crosschecked between multiple references to make sure that it is the most accurate and up to date information available. However, some of the data was collected from personal conversations with lakeside residents or town officials, which could make the information bias or open to dispute.

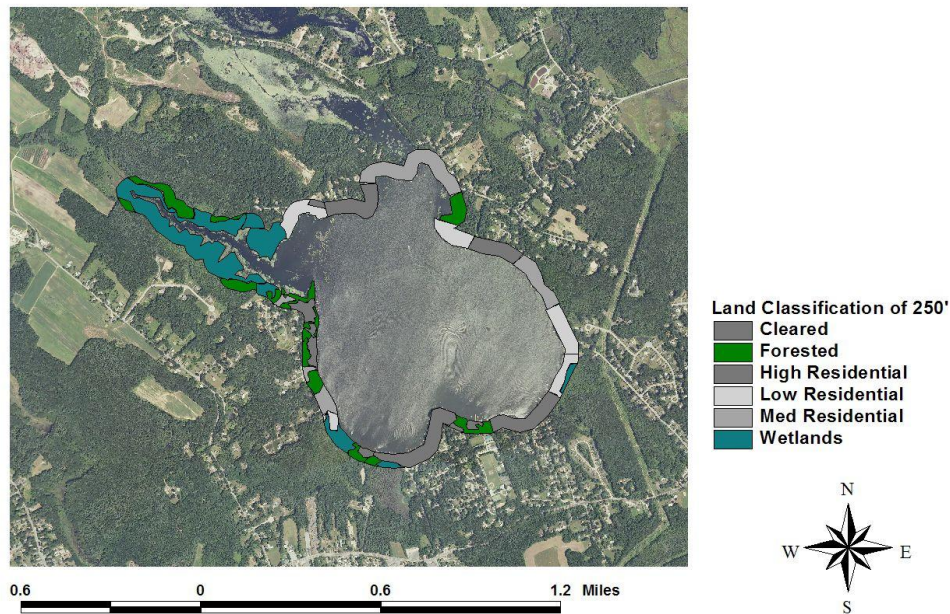
## Lake Attitash Watershed Land Classification



The inventory is organized in a way that focuses on the recreational value, any unique and outstanding value, along with the susceptibility to impairment of the lake. Each of these values is assigned twenty questions that relate directly to the main theme and the answers fall into a category

gaining a value between one and five. The final values are summed to get a score out of a possible one hundred. For this management plan a value for Lake Attitash has been determined for each of these three categories. The total recreational value of the lake was 46 which considering the amount of boating that occurs there in the summer months, it seems like a low value. Due to the large drop of recreation in the fall and winter months the annual average of recreational activities appears smaller. The lake also does not provide the ability for much out of water recreation, as the majority of the shoreline is devoted to residential developments. A score of 52 was found for the unique or outstanding value for the lake. This is a relatively low value due to the lack of unique natural features in the area, as well as the absence of distinctive habitats. Lakes that score high in this category are normally known for their rare geological settings or specialized habitats for rare species of animals, factors such as these would need to be protected as to prevent their further disappearance. Lake Attitash scored 68 out of 100 in the susceptibility to impairment category. This means that the lake is very vulnerable to any changes in the watershed; it also means that there are likely already multiple factors that are causing stress on the lake's ecosystem. High scores such as this are more common in shallow lakes surrounded by areas with a high population density. Since Lake Attitash scored so high in this category the main aspects of the management plan designed relate to environmental and physical features that may be adding stress to the lake.

## Land Classification of Lake Attitash Shoreland



### Issues of Concern

#### **Cyanobacteria**

Cyanobacteria, or blue-green algae, are single-celled organisms that occur in fresh, brackish and marine water systems, but thrive in stagnant, nutrient-rich waters. Cyanobacteria are filamentous and form algae mats on the lake floor with sediment and weed beds. As the mats grow throughout the summer, photosynthetic gases are often trapped within the mats, causing them to float toward the surface. This occurrence referred to as algae blooms generally occur in the late summer during consistently dry, hot and calm days. Cyanobacteria blooms can look like foam, scum or mats on the water surface of lakes and can be blue, bright green, brown or red and often looks like paint floating on the water (CDC). Cyanobacteria photosynthesize and thus require both nutrients and light in order to undergo this process. The control of cyanobacteria blooms is just one of the many reasons in lake management for the reduction of nutrient inputs.

### *Human health concerns*

Specific species of cyanobacteria produce toxins, which consequently raises concerns for their affect on animal and human health. Species within the genus of *Microcystis* and *Anabaena* exist in Lake Attitash, both of which produce the toxin microcystin. Microcystins are a hepatotoxin, which affect the liver. Microcystins have also been found to promote the growth of tumors. Under certain environmental conditions *Anabaena* also may produce anatoxin-a, which is a neurotoxin, toxins that affect the nervous system (Center for Disease Control (CDC)). Depending on the type of toxin produced and the type of water exposure (drinking vs. skin contact), cyanotoxins are known to cause a range of symptoms in humans ranging from skin irritation, stomach cramps, vomiting, nausea, diarrhea, fever, sore throat, headache, muscle and joint pain, blisters of the mouth and liver damage (World Health Organization (WHO)). People swimming in waters containing cyanotoxins may suffer reactions such as asthma, eye irritation, rashes and blisters around the mouth and nose.

These toxins remain within the cyanobacteria until they die in the waterbody or when they are ingested by animals or humans. Once cyanobacteria are ingested, the digestive juices destroy their cell walls, releasing the toxin into the gastrointestinal tract (Massachusetts Bureau of Environmental Health (MA BEH)). Because the toxins are not released until cyanobacteria dies, it is important to note that the toxin concentration in the water may rise for a period after the algae blooms have disappeared (MA BEH).

### *Microcystin threshold*

Currently, WHO has only set guidelines for the maximum concentration of microcystin that humans should be exposed to which is a maximum concentration of 1 parts per billion (ppb or 1 ug/L). There is a correlation between the number of cyanobacteria present in a water sample and the toxin concentrations in the water (WHO). Concentrations of cyanobacteria cells in drinking water above 50,000 cells/mL, suggest that microcystin levels exceed the maximum threshold set by the World Health Organization. Estimating the concentration of cyanobacteria cells is a commonly used method to determine if the concentration of toxins in the water could exceed set toxic levels.

### *Accumulation in fish*

Cyanobacteria are often ingested by aquatic micro-invertebrates that filter lake water. Larger invertebrates such as fish consume these zooplankton in their early juvenile planktonic stages, thus



indirectly accumulating the biotoxins. The accumulation of these toxins through the food chain should be noted by anglers who consume fish from lakes that suffer from cyanobacteria blooms.

### *Cyanobacteria in Lake Attitash*

In August of 2009, a group from the Center for Freshwater Biology (CFB) at the University of New Hampshire (UNH) identified cyanobacteria blooms in Lake Attitash that measured cell concentrations ranging from 62,000 - 350,000 cells/mL (UNH CFB). Because these cell counts exceeded the Massachusetts Department of Public Health (DPH)'s recommended levels of 70,000 cells/mL, warnings of the cyanobacteria bloom was posted from most of August into September (Amesbury Town Hall). The only known period of cyanotoxin testing was conducted by the Department of Public Health (DPH) in August 2009 while the lake was closed for high cyanobacteria levels (Yandell, 4 May 2010). The DPH tested for the toxin microcystin as it is the most common toxin that is tested for in freshwater. (MA BEH). The DPH did not measure any microcystin in the tested lake water samples during the three week sampling period

The high probability that cyanotoxins exist at unhealthy levels in Lake Attitash is especially concerning because it is used as a supplementary drinking source for the town of Amesbury. The town of Amesbury draws down Lake Attitash each fall to prevent flooding and this water is diverted to the Amesbury Water Treatment Facility and used as a supplementary drinking source to the Powwow River. During the fall, cyanobacteria cells decay and release their toxins, coincidentally in time for winter lake drawdown. Besides the testing conducted by the DPH in 2009, no other tests currently measure cyanotoxin levels. The Amesbury Water Treatment Facility currently does not have its drinking water tested for cyanotoxins. The facility does however periodically conduct rough cell counts of cyanobacteria when blooms occur in the summer.

### *Water testing*

The WHO recommends that cyanotoxin testing be conducted when the cyanobacteria cell counts exceeds 50,000 cells/mL and since cyanobacteria cell counts far exceeded this concentration in August 2009, it is suggested that both the lake water of Lake Attitash as well as the drinking water of Amesbury be tested for cyanotoxins during the summer and fall. It is recommended that both integrated and surface water samples be tested biweekly throughout the summer and fall. During hot, dry and calm conditions, especially during periods of cyanobacteria blooms, testing should be conducted at more frequent intervals.

One option for Lake Attitash to have their water tested for microcystin is through a program with the Center for Freshwater Biology (CFB) at the University of New Hampshire. The CFB is offering a microcystin testing program for interested lakes for the summer of 2010. Each sample will cost \$40 to process and provide a full analysis of the sample.

To fund testing, the Lake Attitash Association could apply for a grant with the Massachusetts Department of Environmental Protection (DEP). The Clean Water Act Section 604(b) grant program is offering competitive grants to municipalities and regional planning agencies to support watershed or sub-watershed based point and nonpoint source assessment leading to the determination of the nature, extent and causes of water quality problems. The town of Amesbury could look into applying for this grant or one like it to help fund this important testing program. More information about this grant and other grants offered by the DEP can be found at the Massachusetts Department of Environmental Protection website.

### *Managing cyanobacteria*

Excess phosphorus from point and non-point sources suggests large increases in cyanobacteria blooms. A reduction of nutrient loading input into the lake will coincidentally affect the concentration of cyanobacterial cells. In addition to the reduction of nutrients, there are other experimental control methods of cyanobacteria such the use of phosphorous-binding compounds (copper, aluminum, or calcium) or sediment oxidation to reduce the amount of phosphorous available to cyanobacteria on the lake floor (Holdren et al. 2001). However, due to the large expenses and the lack of unknown effects, we do not recommend any of these experimental options at this time.

There have been numerous studies on the removal of cyanotoxins from drinking water and it has been found that the process of ozonation is the most effective in destroying cyanobacteria and removing microcystins. However, these treatments were not always found to be sufficient during periods of blooms or when high organic load is present (Hitzfield et al. 2000). In addition, the Amesbury Water Treatment Facility does not currently use this form of water treatment technology.

## **Nutrient Loading**

### *Lake Drawdown*

An alternative method includes a lake water level drawdown, which typically occurs in the later fall for multiple reasons. Lake drawdowns are typically performed in preparation for ice shelves that fluctuate in height levels throughout the season dependent on precipitation as well as spring runoff and

snow melt. The drawdown allows a lake basin to absorb more water during the spring floods when rainfall and runoff create an abnormally high water table. Fortunately, a fall drawdown can also perform as a management method to control the spread of aquatic invasive macrophytes as well as nutrient loading.

Many aquatic invasive macrophytes inhabit the shallow littoral benthic regions of lakes. Lake drawdown has the greatest direct affect on the littoral region as this area will be exposed to dehydration and the harsh winter conditions. Previous studies of drawdown suggest positive results on inhibition of Eurasian Milfoil distribution, mainly due to the extended period of exposure to winter weather conditions (Goldsby & Bates, Stanley et al.). With the correct time period and depth of drawdown on a lake, further distribution of Water Chestnut may also be regulated. The life period of this species within a specific waterbody is important, as the offspring produced as seeds have evolved to survive extreme climate changes. They will remain viable in the sediments until conditions are ideal to begin growth.

Drawdown removes a large volume of the lake water, thus flushes out suspended particulates and nutrients within the water column. This rapid water level decrease may have positive effects on removal of excess nutrient abundance in the lake, thus decreasing probabilities of cyanobacterial blooms in the spring.

Lake drawdown is a viable management tool that may prevent a number of lake related issues, but the environmental impact may have detrimental effects on the lake community. During drawdown, the littoral benthic community is exposed to dehydration and winter conditions for an extended period of time. Exposure to these large areas of sediment may lead to erosion through waves and high winds, which are common occurrences of winter storms. The erosion will wash away the organic matter that is vital to the native macrophytes and micro-invertebrate communities. The littoral region serves as an important breeding community as well as providing ideal habitat for juvenile organisms where food and protection from predation is abundant. The destruction of this habitat will undoubtedly lead to a decrease in the young of the year organisms, thus affecting future populations. Dissolved oxygen becomes a limiting factor during extremely cold winters when ice depth is high. The aquatic macrophytes in the littoral region provide much of the oxygen for the organisms during the winter months, but even these macrophytes die during the season increasing carbon dioxide and minimizing oxygen. Seasonal trends of oxygen concentration unquestionably decrease throughout the season and with the depletion of photosynthetic organisms in the littoral zones, high fish kills will occur. It is important to evaluate the negative and positive attributes to determine the most beneficial decision for the lake.

After researching solutions towards the removal of aquatic invasive species, the most economically viable method of management is hand-pulling. This method specifically targets the invasive species without the removal of other native macrophytes that are beneficial to the entire community. The plants are uprooted by hand and preferably removed to reduce the amount of biomass.

### *Phosphorus Budgeting*

This process allows researchers to determine the input of phosphorus into the lake each year. This service can be provided by research laboratories such as the Water Resource Research Center at the University of New Hampshire. Phosphorous budgeting is a relatively expensive procedure, but with the help of volunteers to take regular samples, the costs are reduced substantially. In order to determine the total input of phosphorus per year, the total water input must be determined. The nutrient input of the Back River (the main inlet) would be measured, as well as that from the wetland at the southwest corner of the lake. Both of these inputs have proven to be major sources of phosphorus. Previous water quality tests, from the summer of 2009, show a reading of 119.0 µg/L at the mouth of the southwestern wetland, and a reading of 59.3 µg/L at the mouth of the Back River. These high levels of phosphorus provide evidence that the nutrient loading into the lake is a major source of current problems. The storm water runoff as well as any other input sources into the lake will be measured for phosphorus content and also added into the calculation. Creating a phosphorus budget will provide more evidence as to the main sources of nutrient loading into the lake, which would allow for a more targeted solution to the problem. If the results prove that the input and output of the phosphorus in the lake does not correspond, this will prove that the lake is being affected by internal sources of phosphorus. This may cause a larger gap of time before any improvements are seen from a decrease in external phosphorus sources.

### **Outreach**

After speaking to the members of the Lake Attitash Association it was clear that they were doing a very successful job at reaching out to the residents who live directly on the lake. They expressed a desire for the new management plan to include an educational plan that was directed toward the residents in the secondary and tertiary residential layers around the lake. It is very important for all of the residents in the watershed to understand that they have an impact on the health of the Lake Attitash ecosystem. Other people who use the lake for recreation purposes also need to be educated as to the repercussions of their actions on the lake. Due to the use of Lake Attitash as a secondary drinking water source it is especially



important for the residents of Amesbury, MA to understand that the health of the lake affects the health of their entire town.

Currently Lake Attitash is exhibiting high levels of cyanobacteria, which increase in the summer months to toxic levels. As stated above the water filtration systems in most towns, specifically the town of Amesbury, MA, have not been proven to have an effective means of filtering the cyanotoxins out of the drinking water supply. The residents of Amesbury have the right to be educated about what health hazards they may be exposed to by ingesting drinking water from such a polluted source. The use of educational workshops, pamphlets and bulletins it will be possible to educate a greater number of people in the area about the health risks of the lake water and what they can do to minimize their impact.

In order to encourage a larger number of people to be concerned about the lake it is important to show them why an unhealthy lake can affect their lives. A brochure regarding the effects of water quality on their drinking water is a good way to start. Creating an informative brochure is a great first step to getting the attention of residents who have never before attended a lake association meeting, and are not very involved with the town. The key is to use a title that peaks the interest of the reader and gets them to take the time to look at the beneficial information and tips inside. An example for this specific issue is “Where does your drinking water come from?” or “What’s in your drinking water?”. The figure shown on the right is just one example of an eye catching design for a pamphlet. Inside the brochure there should be lots of helpful information explaining the dangers of cyanotoxins, where they come from, and what the Lake Attitash Association is doing to limit the increase of toxins in the lake. Outreach resources such as these are not only a good way to send out information about the lake, but also about the association itself. This may encourage more of the watershed residents to join the association, and learn more about how they can help the lake.

Educational workshops are another important way to get information out to the public. These workshops should focus on small topics that help the residents reduce their effect on the lake in small easy steps. Lawn care is a great topic to start with. It is a large factor in nutrient loading for a lake’s ecosystem and can be minimized in easily. This topic is also one that will easily relate to many of the residents in the watershed. A seminar on lake friendly lawn care would include discussing non-



phosphorus fertilizers, and the construction of buffer zones for the lakeside residents. Fertilizers are a problem that is often addressed with the public but in order for it to be successful you must provide the audience with all of the necessary information. It is important to explain the destructive effects of nutrient loading, and how it leads to the eutrophication of the lake and can be a cause of toxic cyanoblooms. It is important to mention that just because someone does not live directly on the lake that does not mean that the runoff from his or her house is not affecting the lake. Once they understand why normal fertilizers cause damage, it is important to provide them with information about an alternative fertilizer. This information should include where you would find it, how to know if it is phosphorus free. Adding information about price differences between the phosphorus-free fertilizer and the more commonly used version will also help them understand that the cost is not drastically different. It is even possible that by talking to your local provider they maybe willing to team up with your Lake Association to give members a discount. Buffer zones can also be addressed in this workshop. The Massachusetts Department of Environmental Protection has many resources stating suggested guidelines for the size and composition of buffer zones. During a workshop it is important to provide not only visual representations of what the people should be doing, but also a take home resource for them to look back at when they begin to put the knowledge they learned to work. Supplying the targeted group with a reference to take home with them, not only are they less likely to forget what was said, but they may also share the information with friends or neighbors that did not attend the class.

Informational workshops can be advertised for through the Lake Association, as well as with help from the public libraries, the Board of Health, and the town selectmen. By getting these other groups involved in your efforts it draws in a different demographic of people who you may not have previously thought to target. Public Libraries are often a great resource to use for function or in dispersal of information. The Town Selectmen are a valuable contact to use for support in your efforts or in order to get information about your educational workshops and the Lake Attitash Association into the town meetings. These meetings are often broadcast on public television channels, which provide a larger audience for your message to reach. Both the towns of Amesbury, MA and Merrimac, MA have public access stations, which are willing to work with nonprofit groups to broadcast informational meetings or workshops to the public in the corresponding towns. Not only does this allow for larger audiences, but it also catches the attention of people who would not normally get involved in an educational workshop of this type. In order to focus on the youth in the area it is also possible to get involved with local schools or Camp Bauercrest to organize a day of fun, educational activities for a younger age group. The local high

schools may be especially important to contact so that students in the biology, biodiversity, or environmental science classes, who would be especially interested in this subject would have a chance to participate in the workshops or data collection.



Another public outreach option is to install a kiosk at the public boat ramp. This would provide both the town and the Lake Attitash Association a place to post information about lake health. On the bulletin board information could be posted regarding cleaning boats before entering the pond, as well as safety rules and regulations for lake users. This is also a valuable space to display a schedule of upcoming events concerning the lake, such as meetings or seminars that would be of interest to those who frequent the lake. Warning signs referring to the health of the lake, for cyanobacteria blooms or mercury levels could also be posted in this kiosk. It would be best to purchase a kiosk that has a glass cover with a lock so that it is weather proof, and to ensure that the information is safe from any acts of vandalism.

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