Lowering the Lakes: The Environmental, Economic, and Recreational Impacts of Returning Lake Mendota to Historical Levels

by

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ABSTRACT

After extensive flooding in the Madison, Wisconsin area in August 2018, there have been calls by the public to permanently lower the largest body of water in the region, Lake Mendota, which has been artificially raised 5 feet by a dam, in order to prevent potential future floods. To investigate the practicality of lowering the lake, we first conducted a historical analysis of Lake Mendota's previous water levels in order to provide contextualization of our research. We then used geospatial modeling to produce maps simulating what would happen to Mendota's shoreline and navigable areas if the lake were lowered by 1, 2.5, or 5 feet from current average summer levels. These maps were then utilized in a series of interviews to facilitate discussion with several key stakeholders on the levels of Lake Mendota, as well as during a survey of the general public. We conclude that financial cost, navigability and accessibility, ecology, and potential effectiveness of future flood mitigation are the primary concerns in this issue, and that extensive future research and education of the public regarding the lakes is necessary before proceeding with any action.

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Introduction

Located in the heart of southern Wisconsin, the Yahara River system flows through the capital of Madison. The uppermost lake in the system, Lake Mendota, is an icon of the city and its nearly 600,000 metropolitan residents (Fig 1). The lake is the largest and deepest of the Yahara chain and has been heavily manipulated, both ecologically and physically, since the mid-1800s. The largest physical example of this manipulation is the lake's water level, which has been artificially raised about 5 feet since the construction of the first Tenney Park Dam. The result of the construction of this dam was a dramatic expansion of the lake's surface area, and considerable flooding of wetlands that once encircled the lake, which has contributed to a decrease in water quality and further exacerbation of nutrient loading.

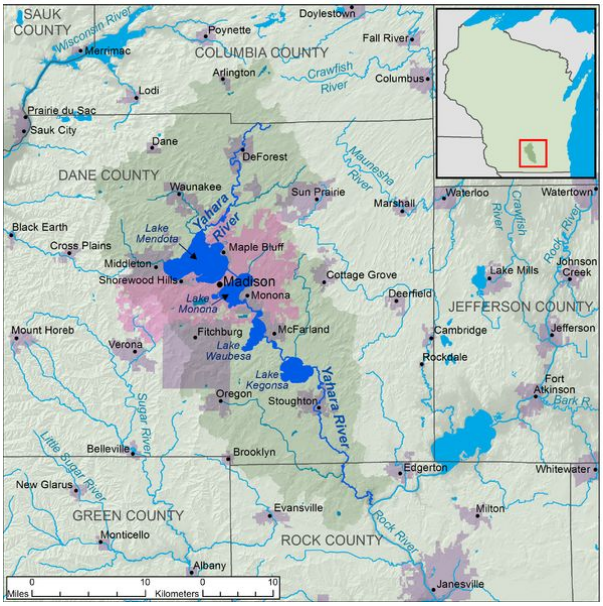


Fig 1- Lake Mendota and the Yahara River System.
Image Source: Tim Kiser, distributed by a CC- Attribution-Share Alike 3.0

On August 20th, 2018, the Madison area saw near-record rainfall with flooding all over the city. The chaos swept away cars, flooded homes and businesses, and closed roads for days. While most roads were opened a few days later, Lake Mendota's water level continued to climb for several days, which prolonged the lakeside flooding not only on Mendota, but the entire Yahara Chain of Lakes. This triggered several proposals by Madisonians to permanently lower Lake Mendota to historical levels to help prevent and mitigate future floods. If such a proposal were implemented, it would have many consequences aside from flood mitigation. Some of these consequences have the potential to be beneficial, such as the restoration of wetlands that are currently flooded, the expansion of wildlife habitats, and an improvement to lake water quality. That being said, there are also negative consequences to such a change. The many landowners on Lake Mendota would see a reduction in their property values, based on recent trends, and those who use the lake for recreational purposes would have a tougher time boating around. Public views of the lake would dramatically change as well.

Since much is at stake, our project consists of several parts: contextualization and historical research, modeling and spatial analysis, and public input and opinions. A historical perspective on how the lake appeared prior to the original dam's construction provides insights into how the lake may look after reducing the lake's water levels, as well as ecological consequences of such actions. Additionally, historical analysis of post-dam lake levels shows the politics behind water levels, how and why they fluctuate, and who would be affected, should the levels be lowered.

After a focused historical study of the lake, we performed analysis and modeling of the consequences of a 1-foot, 2.5-foot, and 5-foot reduction in the water level. Maps that model

these changes provide a visual way of understanding the immense degree of water loss. Some landowners may see little difference to their shoreline, and thus a comparatively small change in their experience of the lake. Other landowners, on the other hand, may potentially see their shoreline retreat hundreds of feet, which will greatly alter their interactions with Mendota. We used our maps to establish hard numbers in relation to what a reduction in lake levels would theoretically look like. The maps were also very useful for facilitating discussion with our interviewees and surveyees.

Our interviews were important for gaining public insight and understanding the stakeholders' concerns. In order to gauge the stances of these different stakeholders, we interviewed Dan Schultz and Sal Troia of the Yahara Lakes Association, Patty Prime of the Tenney-Lapham Neighborhood Association, Susan Graham and Dan Oele of the Wisconsin Department of Natural Resources, David Elsmo from the UW-Madison Hoofers Sailing Club, and John Reimer from Dane County Land and Water Resources Department. Each representative shared their opinions as well as the perspective of their group on how lowering Lake Mendota would impact them. Additionally, we conducted an open survey of passerby in Memorial Union to gauge public understanding and interest in this issue.

Historical Review

The story of Lake Mendota is long and complex. The lake was formed at the end of the last glacial period nearly 17,000 years ago (Mickelson, 1983). Originally much larger than it is today, post-glacial Lake Mendota covered much of the low areas of the Yahara valley. Over several thousand years, erosion on the watershed outlet eventually lowered the lake closer to

current levels. The areas that were once the post-glacial lake bed became the flat, low wetlands that surrounded pre-settlement Lake Mendota (Bean, 1936, 5).

As described extensively in Kannonburgs historical description (Kannonburg 1936, 17-20), before European settlement, the lake was in a mesotrophic state and was surrounded by extensive wetlands and sedge meadows along its shore. The lake's watershed was largely prairie, oak openings, and forest land (Joan 2001, 47). The Yahara river outlet was a slow and meandering stream that wound its way through an extensive wetland. During spring melts, the overgrown brush and grasses in the marshy outlet served as a temporary obstruction, and are theorized to have temporarily raised Mendota's levels 2 feet above Lake Monona's. That being said, for the most part the two lakes were naturally at the same elevation (Kannonburg 1936, 17).

In 1846, the Wisconsin territorial legislature authorized a dam and mill at the outlet of the lake, and by the next year James Farwell, a future governor, purchased land around current day Tenney Park and constructed the Farwell Mill. Since there was no natural drop in water elevation between the lakes, the only way to create enough water power to run the mill was to artificially create an elevation drop by raising Lake Mendota via a dam, which consisted of an earthen embankment and spillway, along with the aforementioned flour mill. As a result, Lake Mendota's water levels were raised about 3 to 3.5 feet to the top of this first dam ("Fourth Lake Again", 1866). By raising the lake's water levels, extensive swaths of shoreline wetlands and meadows were flooded around the lake, which dramatically expanded the lake's size, especially on the northern shore. Since the artificial raising of Lake Mendota occurred before most white settlement of the area, the pursuing development of Madison and the lakeshore occurred nearly exclusively with these artificially high waters. This may explain the common modern-day

misconception that the lake's current water levels are natural even though they are, in fact, heavily manipulated.

This crucial dam, which dictated the lake's levels, underwent several changes through the decades. Lake levels for this period were largely unregulated and as a result are unknown, but they likely varied with each successive dam. In 1866, a large spring flood burst the dam open, causing extensive flooding down the Yahara chain and into the city of Madison as well. Although some Madisonians pleaded to remove the dam permanently, it was soon reconstructed ("Fourth Lake Again", 1866). Several decades later in 1894, the mill was rebuilt after having been burned down in a fire. Unfortunately, the mill owners soon encountered rough financial times in an era where coal power rendered a water-powered mill unnecessary (Kannonburg 1936, 19). The city of Madison purchased the property shortly afterward in 1896 and constructed a new dam with navigable locks (Kannonburg 1936, 19). From this point onward, lake levels were managed by a public power as opposed to a private interest. The result was two-fold. First, lake levels were now managed for recreation as opposed to industry, and second, lake levels were now a public issue. That being said, after the city built the new lock and dam system there was no direct order from a public agency dictating what the lake levels should be. At the time, it was simply recorded that the lake had its waters "artificially raised 3 ½ feet by a dam at the outlet". (Scheuber 1916, n. page). Concurrent photographs suggest this water level is correct (Fig 2, Fig 3).

Direct litigation over the water level was set by the State Railroad Commission in April of 1931, which mandated that Mendota be 849.8 feet at its maximum, and 849.40 feet on

average. Therefore, from 1931-1980, the lake was ordered to "not be maintained in excess of 4 feet higher than the level of Lake Monona" (Wisconsin DNR, 1979). Concurrent photographs show this management of water levels in practice (Fig 4).

In 1958, the current lock and dam system on the outlet of the lake was constructed, consisting of two 12-foot gates and a navigation lock (Tenney Park, 2018). This new dam did not alter lake levels, as the legal orders to regulate the lake were already in effect.

Fig 2- Yahara River Dam- Outlet of the Yahara River. The ruins of the original Farwell Mill are on the right, suggesting this photo was taken before the city constricted a new dam, and after the original mill burnt down in the 1890s. Note the drop of water and the scale of the child. This suggests the dam had a head of about 3 or 3.5 feet.
Wisconsin Historical Society, Stanley C Hanks, Yahara River Dam, Image ID: 118022. Viewed online at https://www.wisconsinhistory.org/Records/Image/IM118022.

Fig 3 - Image of the original Tenney Park Lock and Dam in 1906. Again, judging by the scale of people and the drop of water, the head of the dam is around 3-4 feet.

Wisconsin Historical Society, Thomas Pelton, Tenney Park Locks, Image ID: 52198. Viewed online at https://www.wisconsinhistory.org/Records/Image/IM52198

Fig 4- Original Tenney Park Lock and Dam in the early 1950s. Judging by the water line and the boaters, we estimate the dam to have about a 4 foot head, which is in agreeance with the water level orders placed in 1931
Wisconsin Historical Society, Arthur M Vinje, Summer Scenes at Madison Parks and Beaches, Image ID: 108797. Viewed online at https://www.wisconsinhistory.org/Records/Image/IM108797

In 1979, the Wisconsin DNR established new water level orders in the "interest of public rights in navigable waters and to promote safety and protect life, health, and property". These

new orders, which are still in effect today, dictate that Lake Mendota be kept at a winter minimum of 848.2 feet, a summer minimum of 849.6 feet, and a summer maximum of 850.1 feet. During normal flow conditions, Lake Mendota is ordered to be "held within 4.9 feet of the level of Lake Mendota" (Wisconsin DNR, 1979) (Fig 5).

The long history of different lake levels on Mendota indicates that the water levels are never truly static. They are subject to the forces of nature, and to those that manage the Tenney Park Lock and Dam at the outlet of the lake. Thus, any future change in Lake Mendota's levels would not be new, as the lake's entire history contains variations in water levels (Fig 6). The water levels will surely impact the ecology, economics, and floodwater dynamics of the lake, all of which need to be considered.

ORDER

THE DEPARTMENT THEREFORE ORDERS:

1. The maximum level of Lake Mendota is hereby established at 850.1 feet, mean sea level datum.

2. The minimum level of Lake Mendota between the first spring runoff occurring after March 1 and October 30 is established at 849.6 feet, mean sea level datum. The minimum level of Lake Mendota between November 1 and the first spring runoff occurring after March 1 is established at 848.2 feet, mean sea level datum.

3. From April 1 through May 15 one of the taintor gates of the Tenney Park Dam shall be left open at least 0.3 feet. At all other times a minimum flow of at least 4 cfs shall be released.

4. During normal flow and low flow conditions, the level of Lake Mendota shall be held within 4.9 feet of the level of Lake Monona.

5. The above established levels and flow shall be adhered to as closely as possible by reasonable and proper operation of the Tenney Park Dam.

Dated at Waunakee, Wisconsin Jan. 18, 1979

STATE OF WISCONSIN DEPARTMENT OF NATURAL RESOURCES
For the Secretary

By Douglas Morrissette
Douglas Morrissette
Southern District Director

ccb

Fig 5 - Image of 1979 Lake Orders for Lake Mendota (WIsconsin DNR, 1979)

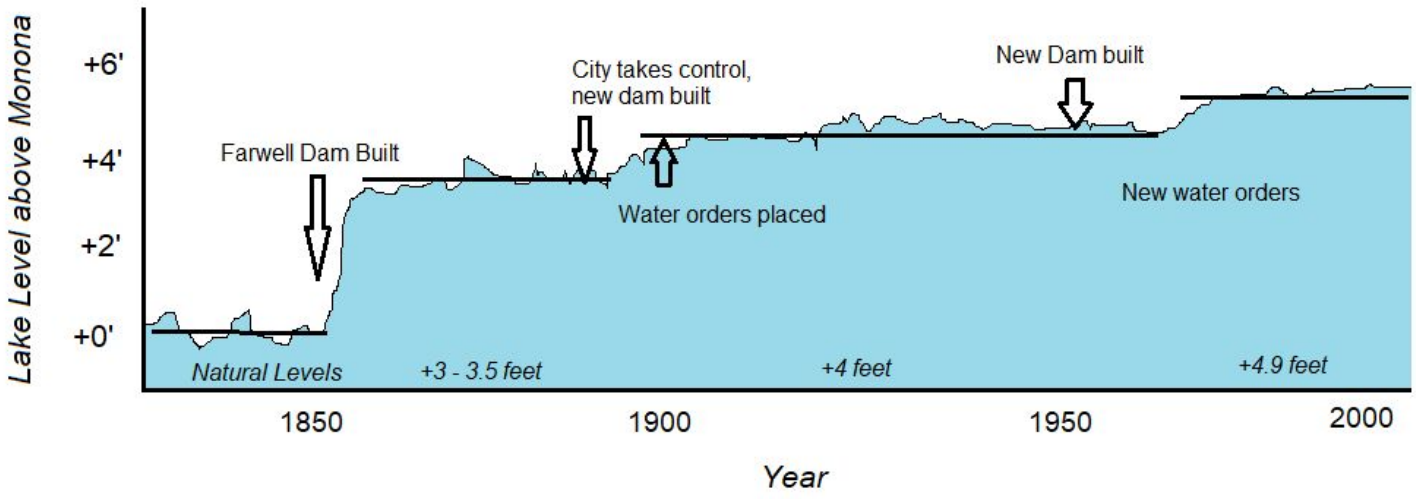


Fig 6- Timeline displaying theoretical water levels of Lake Mendota over time, according to historical accounts, photographs, and water orders (Created by Mike Smale in MS Paint)

Literature Review

In order to fully understand the potential impact that permanent water level reductions would have on Mendota, a review of previous research on the impacts of lowered lake levels on flooding, wetlands, and property values is necessary.

Floods

One of the central arguments for the raising of Lake Mendota and the operation of dams or other hydraulic structures is that the lake could act as a reservoir, holding floodwater and mitigating runoff from storms. Lake Mendota is the largest body of water in the Yahara watershed and is the northernmost of the four lakes in the system. Mendota receives runoff from agricultural land, as well as suburban and urban areas (Lefers 2005, 2). Being the biggest lake at the 'top' of the system, the current strategy has been to hold floodwater in the lake and let it

slowly drain down the river, thereby preventing (or at the very least minimizing) flooding downstream. Lake Mendota is adjacent to the Wisconsin capital city of Madison, which has continued to grow and urbanize, changing the area from land cover that used to previously slow precipitation through infiltration to impervious surfaces (Usinowicz 2017, 602). New construction and infrastructure reduces vegetative cover while adding asphalt, concrete, and other impermeable surfaces that don't allow water to infiltrate. The water is then forced to run off into drains, overwhelming stormwater management systems and overflowing retention ponds, detention basins, and the lake itself.

Beyond the increase in impervious surfaces such as roofs, roadways, and sidewalks, urbanization also results in changes in drainage networks and the compaction of soil due to construction, which further reduces sediment retention and infiltration (Usinowicz 2017, 602). At the outlet that connects Lake Mendota to the other downstream lakes, there is currently a dam and lock system designed to turn the lake into a detention basin or reservoir for the watershed during periods of heavy runoff or flooding (Lefers 200, 2). With the construction of the Tenney Park Dam, the lake level was artificially raised 4.9 feet, where it has remained through today (Sheng 2014, 5). This resulted in a change in the shoreline and the inundation of wetlands and marsh on the north side of the lake. Although it is foolish to assume flooding is new to the Yahara watershed, the potential for floods, especially 10-year and 100-year floods, have increased over time (Usinowicz 2017, 605). 10-year and 100-year floods are named as such due to the presumed frequency of such events, but they refer to the severity of the flood; the worst flood in 10 years, the biggest and most damaging flood in 100 years. Usinowicz also posits that the 'flashiness' or the ability of a watershed to react to a heavy precipitation event, has also

changed because of urbanization, with an increase in potential to flood, and to flood quickly (2017, 602). Flashiness can also be thought of as the speed at which a flood occurs, or that the system reaches the peak of its overflow. The general lag time for peak flooding on Lake Mendota is 1-2 days, but recent UW-Madison campus development, such as the West Campus Cogeneration Facility, has set longer detention plans of up to 7 days in order to better protect against future floods (Lefers, 2005, 10). Recent flooding has led some to question whether the artificially high lake level has been contributing to the damage, or if it is continuing to serve a purpose for the community by stabilizing fluctuations.

If the dam system were to be removed or substantially altered, Sheng suggests that the re-emergence of wetlands and shoreline vegetation could function just as well as, if not better than, channel constriction from hydraulic structures (2014, 19). Vegetation slows the flow of peak discharge, similar to how a dam slowly releases overflow downstream. The lake has been maintained at this high level for a number of years, and another concern is the erosion of existing wetlands and changes in shoreline shape, which has been seen to happen at other artificially raised lakes (Lorang 1993, 497). As with oceans, most lakeshores can tolerate slight changes in water level, with wetlands experiencing various changes in inundation annually, as well as during drought and flood years. The regulation and maintenance of lake levels focuses wave energy at a fixed level month after month and year after year, which erodes the shoreline faster and carves out wetlands (Lorang 1993, 495). The worry is that if the dam constricting the lake was removed, that the shoreline would be too far eroded for successful wetland re-emergence. With this study we plan to analyze the extent of wetland retreat and the potential degree of flood mitigation that would be brought about due to its return.

Wetlands

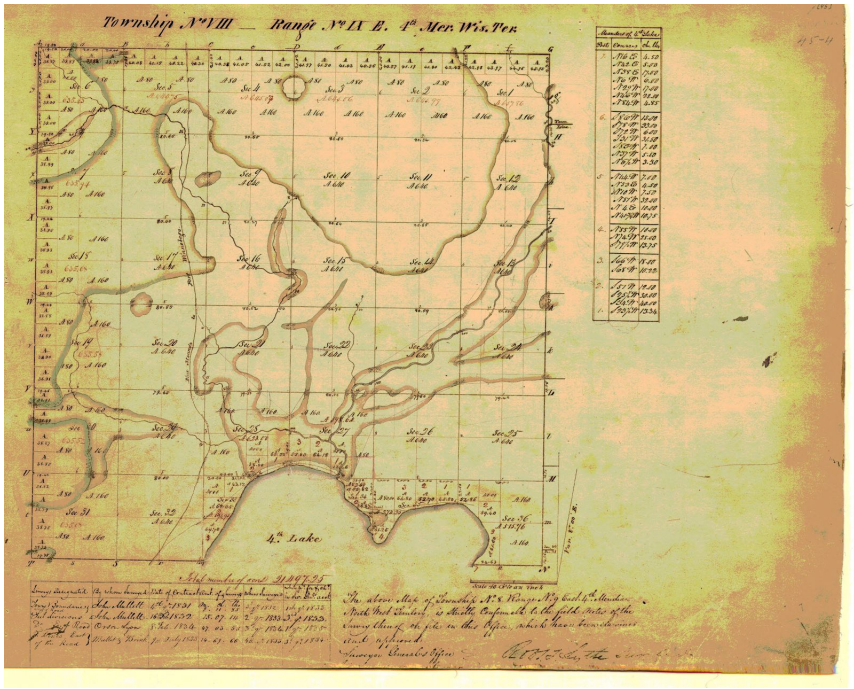


Fig 7- Original Land Survey of Northern Mendota (1838). Note the extensive wetlands and wet prairie. From Wisconsin Board of Commissioners of Public Lands, and the University of Wisconsin Board of Regents, Accessed via Fair Use

Historically, wetlands lined Lake Mendota, providing a home for diverse aquatic organisms, natural flood regulation, and nutrient cycling to the lake. The rapid expansion and development of the Madison area, as well as the construction of the Tenney Park Dam, caused the wetlands that once played an important role in the ecosystem to vanish (Fig 7). Wetlands may not be viewed as a useful space by some people, especially those who want to develop said area, but the role the wetlands play in our ecosystem cannot be easily replaced. Perhaps the lack

of respect of wetlands stems from the fact that many people do not know what a wetland exactly is. Made up of the words 'wet' and 'land', the easy deduction to be made is that it is just land that is wet and stays wet. But this raises questions. What about seasonally flooded areas that have all the qualities of an expected wetland? Would lakes and rivers be considered wetlands too? (Batzer 2014, 1). To answer these questions, we need a better definition for wetlands. According to Darnold Batzer and Rebecca Sharitz, whose definition was influenced by the U.S. Fish and Wildlife Service, wetlands are "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" (2014, 1). A simple definition like that does not cut it though. They also state that wetlands must have at least one of the three following attributes: (1) the land periodically supports predominantly hydrophytes (plants that grow in or on water); (2) it is predominantly comprised of undrained hydric soil; or (3) the land is covered by shallow water at some point during the growing season each year (Batzer et al. 2014, 1). The definition given by Batzer and Sharitz makes the distinction between wetlands and land that may have wetland qualities much clearer.

The impact humans have had on wetlands can be easily seen throughout the world, and especially in our home city of Madison. The rapid expansion of Madison and its surrounding area, as well as the construction of the Tenney Park Dam, had a huge impact on those wetlands which dramatically reduced total plant mass. (Nichols 1994, 225) "These changes altered habitat, changed water clarity, were directly toxic to plants, removed plant biomass or reproductive structures, or were caused by the introduction of exotic species" (Nichols 1994, 242). Nearly all of these changes were either directly or indirectly caused by humans. A sudden rise in the water level after the construction of the dam engulfed the wetlands that once surrounded Lake

Mendota, and those benefits of nutrient cycling and flood mitigation the previous wetlands had on the ecosystem were lost. The newly flooded area that we see now as the outer edge of the lake would soon be lined with boat docks, lifts, and shoreline erosion resistance techniques, pleasing those who choose to live there but disturbing the wetlands. Urbanization and expansion of the area created a great demand for lake front property and all the recreational activities that come with it. Boaters, fisherman, and landowners have what they need to enjoy the lake, but at the cost of the local ecosystem.

Plant life and diversity of species was especially impacted due to the raise in water level after the construction of the Tenney Park Dam. The water levels were altered, cultural eutrophication occurred, power boating increased, and shorelines were developed with little knowledge or concern about the impact to plant communities. By looking at historical accounts of plant life from 100+ years ago and comparing that data to what we see today, Nichols et al. noticed a significant change in vegetation. “Present vegetation is less diverse and less extensive, produces less biomass and is composed of more disturbance tolerant species than it was 80-100 years ago” (Nichols 1994, 225). The alteration to wetlands around Lake Mendota is not easy to notice because of the large time frame it occurred. The reality is that the local ecosystem was altered over time and had to adapt to the new conditions of the changing lake. Fluctuations weeded out the plant life that was too fragile or only fit for certain conditions, and the result was a more ubiquitous distribution of disturbance tolerant species. If the lake is returned to historic water levels or dropped significantly, some of the fragile plants that were lost over time would need to be reintroduced by us, and barring an intrusion of invasive species, a lowered lake level gives us the opportunity to emulate pre-dam vegetation.

However, lowering the lake alone will not bring back all the plant life that was once there or instantly restore the wetlands that stood. Emily Stanley and Martin Doyle conducted a study in 2003 that looked at what is left after the removal of a dam and the complete draining of a reservoir. While not quite the same as simply lowering the lake water levels, we may see many of the same trends. First, when the water level is decreased, riparian vegetation along reservoir margins may eventually die due to the water table decline (Stanley and Doyle., 2003, 17). Vegetation that was once thriving in the riparian zone now can't survive in the conditions they are thrown into. The death of all this vegetation loads the soil with nutrients for plants that come after them. The extensive, bare, nutrient-rich sediments of the former impoundment provide a substrate that may favor weedy, nonnative plants. Once established, nonnative weeds may inhibit the establishment of native species, thus reducing plant and animal species diversity (Shafroth 2002, 709). The plants that rebound quickly are those that grow rapidly and in large quantities. Unfortunately, many of these types of plants are invasive species. "Initial plant colonists of sites characteristic of former reservoir bottoms (bare, moist, nutrient-rich, with a depauperate seed bank) tend to be weedy plants with typical ruderal traits such as rapid growth, high levels of seed production, and effective dispersal mechanisms. This group of plants may include a relatively high fraction of invasive, nonnative species" (Shafroth 2002, 707). This makes the restoration process very important if the lake is lowered. Steps would have to be taken if we want to reintroduce the once-present native vegetation to the area around Lake Mendota. This would include the distribution of hearty native vegetation that can survive and populate the area.

In order to keep a healthy distribution of organisms, the newly organic-rich soil must not only have a diversity of plant life, but the created wetlands must be interconnected to improve

the habitat for animals. For example, wetland habitat is used by amphibian adults for mating as well as their offspring to complete their metamorphism from eggs (Zamberletti 2018, 119). Fragmented wetlands do not allow for a wide dispersal of amphibians into the necessary wetland habitat for breeding and hatching, and may therefore limit the success of the population, as opposed to interconnected wetlands of the same total area. This unfragmented and interconnected chain of wetlands can be referred to as a 'wetlandscape', where organisms, and especially amphibians, can thrive. Lowering the lake level would increase the total wetland area around Lake Mendota, but if we want to maximize the positive environmental impact, we must make sure these wetlands are interconnected and stay that way. "The wetland-restoration scenario showed greater positive effects on the amphibian population when the restored wetland belonged to the high Indegree class (higher connectivity)" (Zamberletti 2018, 123). As we have seen from historical maps (Fig 7), wetlands once nearly encircled Lake Mendota. If the lake is restored to historic levels, we will likely see wetlands appear in similar regions around the lake. To ensure the most positive impact on amphibian life, it is imperative that these wetlands all be connected. Fragmentation of the emerged wetlandscape will need to be kept to a minimum, which likely would be tough to achieve. Landowners around the lake will likely want to clear areas for boat docks and other recreational purposes without a knowledge or concern with wetland interconnectedness.

As stated earlier, human intervention is the one main cause for the change in local ecosystem around Lake Mendota. The construction of the Tenney Park Dam followed by an artificial raising of the lake level virtually erased the whole wetlandscape that once existed (Fig 7). The observed impacts were seen as a decrease in total density and diversity of both plant and

animal life (especially amphibians). Just as we needed something as significant as human intervention to cause the colossal changes we see today, we need significant human intervention to restore the area to its natural state. This starts with lowering the water levels and placing an importance on wetland restoration. Connectivity and diversity within a newly formed wetlandscape must be a main focus if the lake were to be lowered, otherwise Lake Mendota may never fully realize a restored and healthy natural state.

Property Values

Another of the key issues at hand is the effect that the water levels of Lake Mendota and the Yahara River system as a whole have on property values in the region. In its current state, heavy rainfall can cause the system to overflow, flooding parts of eastern Madison. A perk of lowering of Lake Mendota is an increased area to act as a reservoir in order to prevent this urban flooding from happening. As it stands, however, these urban properties are decreased in value by the flood risk associated with them. On the opposite end of the spectrum, properties along the Mendota lakeshore are currently valued very highly given the popularity of the lake for recreational purposes such as sailing or water skiing, and the proximity of the lake to urban areas. A lowering of the lake level would likely lead to the growth of lakeshore wetlands and a decrease in area of navigable water for recreational boating. Is there a population that is disproportionately affected by either scenario, and is there a happy medium that would be beneficial for both groups? In the case of land located in areas that have a known risk of flooding, the property values are almost always impacted. A recent flooding event will have a larger impact on property value than just an assessed risk of flooding. (Ebbwater consulting,

2014) The parts of Madison that saw flooding in late August are sure to see decreases in property value across the board, and with a new flooding event on the books, the areas in risk of flooding are being mapped out and updated. What does this mean for residents and landowners? The biggest issues are the loss of equity for homeowners and landlords and, by extension, lower rent prices. This puts low income Madison residents in a bad spot, as the most affordable housing in the city becomes the areas with the highest risk for flooding and property damage. A lowered Lake Mendota would provide the City of Madison with a greater ability to control the flow of water through the Yahara watershed and keep residential areas dry.

However, a lowering of Lake Mendota would have a wide variety of impacts on the area, namely the value of lakefront property. A relevant example is the lowering of Lake Koshkonong, which is located in southeastern Wisconsin. Lake Koshkonong is a natural, shallow lake that has its water level controlled by a dam. It is also one of the most populated lakefronts in the area, with over 400 residences lining its shore. In 2005 the DNR issued an order requiring the owner of the dam to lower the water level, and the result was a loss of roughly 10% of the aggregate value of all the lakefront homes. A lake residence on Lake Koshkonong was worth $20,000 less than a comparable home on any other nearby lake. There was also a notable reduction in business activity and a significant reduction in the tax base of surrounding towns (Kashian, 2015). In a 2015 study of Lake Koshkonong and the links between various lake variables and property value, it was noted that lake level directly correlates to property value. Generally, the more feet of lakeshore a property has, the more valuable that property is. When the water level

lowers, the lake gets smaller and the footage decreases. Another point raised by the study was that water quality also has a significant impact on the value of lakefront property. An example of this effect is the property values of Lake Geneva, a clear watered, spring fed lake in southeastern Wisconsin where lake houses have been selling for an average of $4 million. Less than 5 miles away, Lake Como is shallow and muddy, and a home on its shores will run a potential buyer roughly ¼ the cost of a Lake Geneva home (Johnson, 2018).

An oft-overlooked element of lake property value is the proximity of the property to wetlands. A study conducted in Minnesota in 1996 explored the proximity of houses to different wetlands and whether or not it had an impact on the property values. Interestingly enough, residences within close proximity to open water wetlands actually sported higher average property values than those that were not located by wetlands or were located near forested swamps.

These studies have some implications for property values around Lake Mendota, should something be done about the water level. The obvious impact would be the loss of shoreline, which would decrease property values around the lake if Lake Koshkonong is an accurate example. This would likely be the largest source of backlash on such a project, as homeowners associations and other property holders would object to this loss of value.

Conversely, in lowering the water level there is an opportunity to recoup some of the cost involved in decreasing the footage of shoreline. Trends have shown that water quality has a large impact on the value of waterfront property. In its current state Lake Mendota is highly eutrophic,

and algae blooms run rampant to the detriment of shoreline cleanliness and water quality. In the event that water levels are lowered, the once abundant wetlands in the northern portion of Lake Mendota would regrow, acting as a filter for fertilizers and other nutrients in the water and decreasing the frequency and size of algae blooms. This would dramatically improve the quality of the lake water, and lead to an improvement in property values.

This of course raises the questions as to how these new wetlands would affect property values. The aforementioned 1996 study showed that property values increased with proximity to open water wetlands. If that research is still valid, it would be another positive point for lowering the lake, however, the study didn't cover properties that went from having no wetlands in close proximity to having wetlands grow in. It stands to reason that landowners and potential buyers could be unhappy with these new wetlands, so it can't be said for certain whether this would be a boon for value or another detriment.

In either scenario, whether it is leaving the lake as it is or lowering the water level, there are people who stand to benefit and people who lose out on money in the form of property value. Within the current scenario, one could make the argument that this is a case of environmental injustice. Low-income landowners and renters are currently being forced to deal with less desirable property and a flood hazard that could result in further property damage or loss of life. The only reason for this injustice is so that wealthy landowners can have more desirable property on the lakefront, and so the City of Madison can bring in more tax revenue from tourists who wish to use the lake for recreational purposes. As in all walks of life, a case could certainly be

made for compromise. Lake Mendota currently acts as a large reservoir, one that can be overwhelmed should enough rainwater enter the system. A reduction of water level, not necessarily to natural levels, but by at least a few feet, could improve the lake's ability to store rainwater without flooding the downstream Yahara watershed, and would greatly mitigate the risks of flooding in urban eastern Madison. Such a reduction in water level would certainly lower property values along the Mendota shoreline, but the amount wetlands that could regrow would improve the water quality and help recoup some of the lost value.

Methodology

Our research consists of two main aspects: geospatial analysis and modeling, and research on public opinions. The first part, geospatial analysis, is to create maps of what a lowered Mendota would look like, as well as to provide hard numbers on potential lake size in each water scenario. These maps and associated numbers were then used as reference material and as a conversation-starter for the second section of public opinion. Because the question of lowering the lake involves a great deal of speculation on what may happen, without these maps, our public opinion research would be based only on speculation and hearsay, as opposed to some form of agreed upon reality of what may happen. Additionally, maps are known to be excellent facilitators of discussion. Since lowering Lake Mendota is inherently a public discussion and a public issue, we found it necessary to include the second portion of public opinion. This section involved two parts: interviews and a survey.

In order to create these maps of for the first part of our research, we needed accurate lake bathymetric data, which came from the most recent and highest definition maps we could obtain. Since we are primarily concerned with shallow depths of the lake, we found that the 1981 bathymetric survey map of Lake Mendota had the finest counter interval near the shore. By using a digitized form of the original map, we constructed a triangular irregular networks (TIN) of the lake bottom. Then, we created contour features from the TIN at water depths of interest so simulate the lake shoreline under the water level decreases (0', -1', -2.5', and -5'). We also created contour features at depths 3 feet below the simulated lake level decreases (thus -3', -4', -5.5', and -8' respectively) to select areas of Mendota that would be considered non-navigable were the lake to be lowered. We chose 3 feet to be our benchmark of "non-navigable" depths, since this is a widely-accepted depth needed to safely plane a recreation motor boat. Finally, these contours were converted into features and used to create numerical estimates on lake level decreases, as well as a total of 12 maps (Fig 8) – one for each water level simulation for the entire lake, for a zoom-in of the UW shoreline, and for a zoom-in of the Tenney-Lapham Neighborhood shoreline.

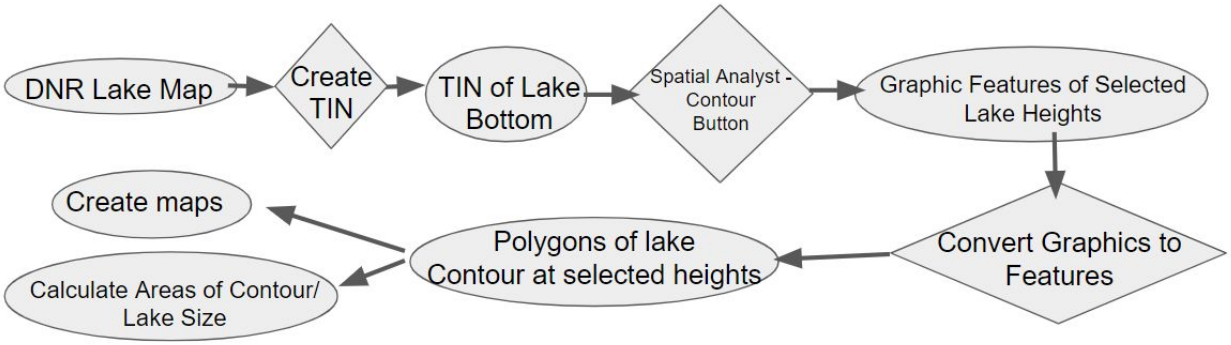


Fig 8 - GIS workflow to create output maps and lake size estimates. Created by Mike Smale in MS PowerPoint

After we have modeled the lake at current levels, 1 foot, 2.5 foot, and 5 foot reduction levels, we interviewed several stakeholders about how the changes would affect them, using the maps to facilitate discussion and help illustrate what the changes would look like from different areas. Specifically, we discussed the reduction with the Tenney-Lapham Neighborhood Association in order to gauge how property value might change and how residents would feel about it. Additionally, we interviewed representatives of the Yahara Lakes Association to see the concerns and opinions of lakeside property owners and recreational users of the lake on water levels. We also spoke with the manager and head coach from the University of Wisconsin-Madison Hoofers, as they frequently use the lake for activities, and their sailing division recently received funding for a new dock, the plans of which would certainly be impacted with drastic lake changes. We interviewed several people at the Wisconsin Department of Natural Resources about the management of the Cherokee Marsh area to the north of the lake, as well as what pieces of re-emergent shoreline have the potential to become wetlands, the management of fish within the lake, and their opinions on the success of various flood mitigation

strategies. Lastly, we spoke with the assistant director of the Dane County Land and Water Resources Department to understand the county's stance and current management plans. In addition to interviews with stakeholders, we were also interested in the thoughts and perspectives of the general public. Our null hypothesis was that the general public was unaware of the Tenney Park Dam and the artificially high lake level, but that after viewing our maps they might understand more about Lake Mendota and have opinions about changes. Memorial Union, situated along the southern coast of the lake in the heart of campus, is frequented by both the student and staff population of the university as well as the general public. We surveyed visitors about their knowledge and use of Lake Mendota, as well as their recommendations for the lowering of the lake levels if they had any. This allowed us to gauge public understanding on the issue of lowering Mendota's levels, and provided us another lens through which we could view the lake levels issue - through the non-stakeholder.

GIS Simulations and Analysis

The usage of a digitized contour map of Lake Mendota proved to be successful in creating simulations of water drawdowns. These simulations included maps for the entire lake, as well as the selected neighborhoods of Tenney Park and the UW Campus, under the four different circumstances of lake level as discussed earlier. The maps revealed the most tangible consideration of lowered lake levels - the shoreline and lake depth itself. It is important to note, before expounding our findings, that there may be inaccuracies within our simulations. The lake bathymetric data was used to interpolate between the known and measured contour depths of Lake Mendota, such as 0', 3', 5', and 10' depths, to find the unmeasured contours, such as '1,

2.5’ or 8’. However, this interpolation may be slightly flawed in certain locations where the shoreline features a deep drop into the lake. Where this occurs, the interpolations preformed to create these maps may be skewed to show a greater retreat in shoreline than would happen in reality (Fig 9). For example, shorelines such as the Memorial Union Terrace feature a concrete drop into 2 or 3 foot deep water. Moving farther out, the water depth gradually decreases to 5 feet. In our maps, the lakebed is simulated to be a constant, continuous slope between the shoreline and 3 known contour line of 3 feet. In reality, the shoreline may drop down into water directly at the shore, and then slowly taper to 3 feet. Thus, a 2.5 foot reduction at a steep, rip-raped, or artificial shore, such as the Memorial Union Terrace, would not cause a 10 foot retreat in the shoreline; it would simply lower the lake to the bottom of shoreline drop. Additionally, submerged rocks and other fine-scale features are not considered in the simulations. It is important to keep this in mind and take such simulations as estimates, not as exact measurements.

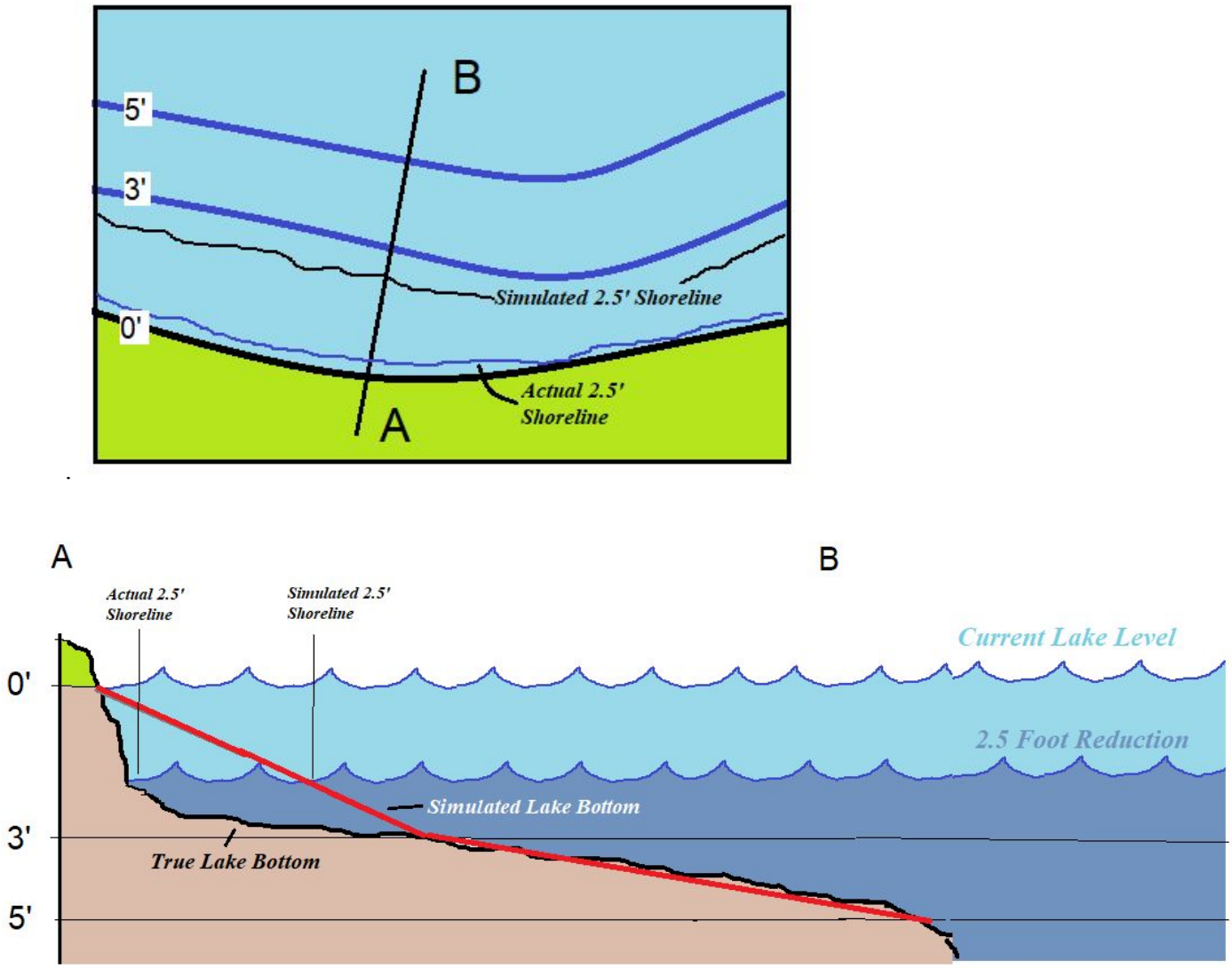


Fig 9 - Diagrams explaining the possible inaccuracy of near-shore shoreline retreat (Created by Mike Smale in MS Paint)

Moving on to our findings for the various scenarios, at a simulated reduction of 1 foot, a minor portion of the lake bed would become exposed, mostly on the western shore of the far northern side of the lake as well as University Bay (Fig 10). This reduction constitutes a minimal 1.18% decrease in lake size (Fig 11). Boat navigable areas, defined as lake areas 3 feet or less,

would decrease 4.47% from the status quo, largely due to the current shallow bay on the northern shore decreasing to depths just shallower than the navigable 3 feet.

At a 2.5 foot reduction, the lake would decrease by 2.74% of its original size, and navigable area would decrease by 7.86% of its original size (Fig 11). In this simulation, navigable areas on the northern bay are dramatically reduced to shallow depths of less than 3 feet, and several islands are re-exposed in the northern bay (Fig 10).

Lake Mendota would experience the most dramatic decrease in size if water levels were lowered by 5 feet. At this point, large swaths of open water in the northern bay would become exposed lakebed (Fig 10). A similar outcome would be seen at University Bay near the UW-Madison Campus. The total area would decrease by 9.72% of the lake's current size, adding up to 1.5 square miles of exposed lakebed (Fig 11). Areas navigable by boat would also decrease by 11.96% of their original size.

These simulations display several important considerations with respect to lowered lake levels. The first consideration is shoreline retreat, and what amount of retreat we could expect to see from different reductions to water level. 1 foot and 2.5 foot decreases would be minor water level reductions, the implication being that the lake may be lowered by these amounts without a considerable loss of shoreline. The greatest retreat of lake shoreline at a 2.5 foot reduction would happen near the inlet of Dorn Creek, where the shoreline would retreat by about 650 feet (Fig 10). The rest of the lake would not see this dramatic of a shoreline decrease, and in areas such as the UW-Madison Campus, we could expect as little as a 10 foot retreat in shoreline (Fig 10). That being said, under a full 5 foot reduction, the lake would experience a significant size reduction. The shallow northern bay of Lake Mendota would retreat about 4000 feet from the

current shoreline. In some residential areas, such as Tenney Neighborhood, the lake would retreat about 580 feet (Fig 10).

Another consideration is that there would be a dramatic decrease in navigable waters for boats on the northern stretches of the lake, even at a minor reduction of 1 foot. Much of this area is only just shy of our semi-arbitrary threshold of 3 feet, and shallow draft boats would have few issues traversing the area, but the fact remains that the majority of pleasure craft would be unable to use this part of the lake as they currently do. This is particularly troublesome, considering the large marina on the far northern tip of Lake Mendota near the inlet of the Yahara River. Accessibility to the marina by larger boats may be a concern under these shallow simulations. It is evident that each simulation produces a unique set of alterations to Mendota, and an equal reduction of the water level across the whole lake would pose different ramifications to different stretches of shoreline.

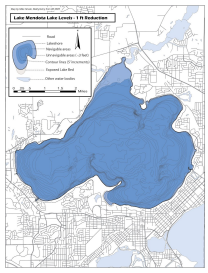
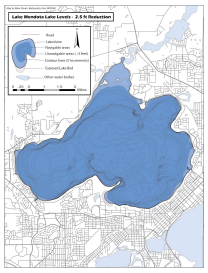
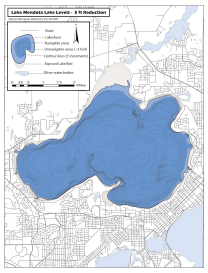
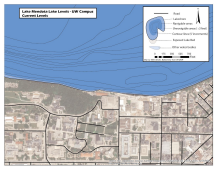
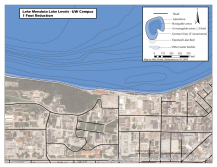
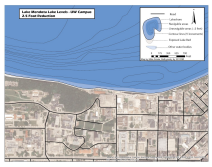
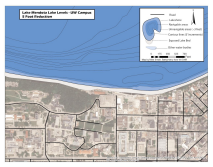
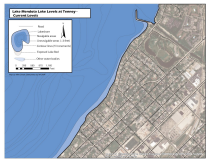
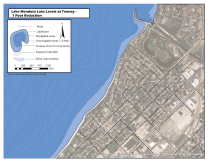
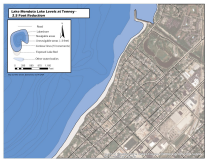
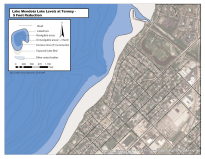
	Current Lake Levels	1 Foot Reduction	2.5 Foot Reduction	5 Foot Reduction
Entire Lake				
Campus Area				
Tenney Park				

Fig 10 - The Output Maps of Simulated Lake Level Decreases

Projected Changes in Lake Mendota	Total Lake Area (Acres)	Navigable Area (<3')	New Littoral Habitat (Acres)	% Change in Lake Size
Current Levels	9587	9271	0	0.00
1 Foot Reduction	9475	8856	112	-1.17
2.5 Foot Reduction	9324	8541	263	-2.74
5 foot Reduction	8655	8161	932	-9.73

Fig 11- The Estimated Size of Lake Mendota, Lake Navigable Areas, and Exposed Lakebed (aka New Littoral Habitat), Under the Various Lake Level Decreases

Interviews

The Yahara Lakes Association (YLA) is comprised of dues-paying members that live near Lakes Mendota, Monona, Waubesa, and Kegonsa. The organization focuses on advocating for issues that affect lakefront property owners (About YLA). Many YLA members were impacted by the flooding that occurred in late August, and stormwater mitigation and flooding prevention has become an important concern. In their November 2018 newsletter, the YLA outlined their recommendations and questions for discussion to Joe Parisi, a Dane County Executive who is heading a technical group that is working jointly with an advisory board from the Department of Natural Resources (Newsletters). During our interview, current president Dan Schultz and president-elect Sal Troia elaborated on the process to determine their suggestions, as well as the main concerns and expectations of their members. They emphasized that a 5 foot reduction to historic levels did not seem reasonable or feasible, and that water level reductions in general may not help prevent future flooding. They instead emphasized that other measures, such as dredging the lakebed, cutting aquatic weeds at pinchpoints, working on increasing flow rate, and changes in management of the entire Yahara dam system, could perhaps be a feasible and effective solution to future flooding (Appendix A). To Dan and Sal, a large part of any solution included the cost - financial, personal, or otherwise - on stakeholders. There would be costs incurred with any solution, but the discussion of flood prevention is not just a matter of what people support doing, it's what people support funding (Appendix A). "It's a matter of trade-offs, and it's a public opinion trade off as well" said Dan, pointing out that whatever change occurs will affect not only the communities around Lake Mendota, but the downstream

lakes as well, further supporting their argument that lake levels are only one piece of an effective management plan (Appendix A). Furthermore, Sal emphasized the need to have hard, concrete numbers and models to effectively address the question of preventing future flooding because without that, everything is merely speculation (Appendix A).

Patty Prime is a representative of the Tenney-Lapham Neighborhood Association that we spoke to regarding Lake Mendota levels. As someone who speaks for the residents in her neighborhood, the main takeaway from her interview was that nearly everyone wants Lake Mendota lowered. Property owners on the lake, as well as those further inland, were affected by the flooding in August 2018, and regardless of where they live, they are susceptible to more flooding if they are on the isthmus. For the sake of protecting themselves, the residents generally take a position that favors lowering Lake Mendota because they see the lake as a reservoir (Appendix B). With less water in the lake, more water can be held during heavy rainfall to protect their property, homes, or businesses. Since most residents are aware that there is a dam on Lake Mendota that regulates lake levels, they are also aware that it can be manipulated in order to lower the lake. According to Patty, a flood in the 2000s brought up this issue as well. Homes and businesses were flooded, similar to the flood in August 2018. Patty recalls a memory she had talking to one of her friends as they watched the water over a set of train tracks fluctuating. She said it was like "the lake was breathing on our necks" (Appendix B). Soon the flood passed, and over time, interest in the lake level throughout the community fizzled out (Appendix B). When the flood in August 2018 hit, it sparked conversation again regarding the levels of Lake Mendota. An issue that hasn't fizzled out, according to Patty, is the issue of water

quality. Lake Mendota's algae blooms have been a problem for years, and she believes that it is a growing concern for residents near the lake. (Appendix B)

One great point that Patty brought up regarding changing property values is that prices could go down if nothing is done to the lake. (Appendix B) With flooding being a main concern again in the community, potential buyers or builders in the neighborhood may be wary of moving their family to, or starting a business on the isthmus. Buyers may second guess their decisions as flooding in the past has proven very destructive in the area. Buildings must be built to a new, higher flood protection standard, which may be too costly for some. (Appendix B). Patty brought up a great point on the idea of individual costs vs. community benefits. Many residents that live right on the lake in the Tenney-Lapham Neighborhood use boat docks that will likely have to be moved outward following a drop in lake level. While the individuals with property on the lake may have different costs from those on the isthmus, lowering the lake benefits the greater community flood mitigation. (Appendix B) If the lake level is lowered, the community could potentially save millions of future dollars in the very likely event that we someday get another rainfall like that of August 2018.

We also interviewed David Elsmo, who works with the University of Wisconsin-Madison Hoofers Sailing Club as their manager and head coach. He also sits on the board for the Mendota Yacht Club, and was able to give us a perspective on how recreation was impacted by the flooding this past August. He brought up the economic costs the University and Hoofers experienced as a result of damage to their buildings and decking, particularly following a 3 ft surge from the north that wrecked boats and had waves hitting the windows along the lower level of Memorial Union (Appendix D). Practices for the Sailing Club and races for the Mendota

Yacht Club were also negatively affected by the flooding. The no-wake policy implemented post-flood prevented the safety boat from being able to follow behind the Sailing Club during practices, with the team has been affected from the date of the flood up until about two weeks before the interview, and the season for the Yacht Club was shortened due to this no-wake (Appendix D). While a lower lake level may have mitigated the extent of the damage, David also pointed out that people might not be able to enjoy the lakes as much. Social costs have to be considered in any lake proposal scenarios, and David asserted that "If you lowered the lake five feet, you'd totally destroy people's ability to enjoy the lake. Because unless you own property on the lakefront, you can't get a boat in there...even the boat launches we have...are no longer effective" (Appendix D). In addition, lack of public enjoyment could lead to public apathy towards the health of the lakes and lead to cuts in funding, and "Then you have a city with two of the most beautiful lakes in the midwest that nobody can play with" (Appendix D). Our maps demonstrated that a severe drawdown would greatly reduce boat navigability, especially on the north side of the lake, and this issue of accessibility came up repeatedly during our interview with David. The University has also been building new docks and infrastructure for the Hoofers, including the Tong Family Marina, which has been designed to be more durable and withstand big surges (Appendix D). David said that while the old docks were permanent and anchored, the new docks will float, thereby avoiding issues with fluctuations in water level, and the plan for the new infrastructure used the summer average on the DNR's order in the designs (Appendix D). The club then has flexibility with regards to changes in the level of the lake. David mentioned that lake levels lowered 1 foot below the summer minimum would not affect the club, but a 2 foot reduction may cause some issues (Appendix D).

Another stakeholder is the Wisconsin Department of Natural Resources (DNR). While not in direct control of the lakes or the dam at Tenney Park, the DNR works closely with Dane County to manage the lake levels, and is ultimately the state agency that creates water level orders for the county to follow. Susan Graham works in the division of environmental management in the field of water quality, and is part of a group from the DNR that is working jointly with a technical committee from Dane County to assess flood prevention options. She spoke to us regarding the impact lowering the levels would have on the lake ecosystem, primarily on the issues of phosphorus loading and shoreline/wetland erosion as well as flood mitigation. While lowering the lake might not have a significant effect on eutrophication since much of the phosphorus is from internal circulation, Susan pointed out that lower levels could provide an opportunity to restore wetland areas surrounding the lake that would become exposed, creating diverse native communities on a larger scale (Appendix C). This would require some management, through seeding and other methods of control, in order to prevent the proliferation of invasive species, but could be a chance to rehabilitate riparian habitat. In response to the idea that the whole Yahara Lakes system be lowered and share the consequences - positive and negative - Susan explained that if flood mitigation was the goal, lowering all the lakes would have little effect (Appendix C). Because Lake Mendota is the largest and the first of the chain, it has the greatest capacity to hold water. All of our interviewees noted that over a lake the size of Mendota, even a one foot reduction is a lot of water. This additional capacity may not stop flooding for precipitation events like 100-year storms, but it may prevent flooding for 10-year storms. The balance between expenses for flood prevention and costs of flood damage again

came up, with Susan noting that we know that storms, and therefore floods, will continue to occur.

The Wisconsin Department of Natural Resources also manages the wildlife of the lake, which includes monitoring spawning habits and stocking fish each season. Dan Oele, a fish biologist with the DNR, brought up that Lake Mendota is a heavily managed system as far as water levels go, and the natural seasonal pulses of rain that used to occur every spring and create temporal spawning habitats have ceased due to water order restrictions (Appendix E). The shallower, warmer areas along the shoreline to the north are the best for spawning, because fish rely on thermal cues and often spawn in areas with higher quantities of macrophytes (Appendix E). A lake level reduction of 5 feet then would greatly impact this habitat, especially along more tapered shoreline. Yet, Oele pointed out that fish are highly adaptable, and could likely cope with changes such as a 1 or 2 foot drawdown, but that "if you lose one of those key (shallow) habitat areas you're going to have less amount of space for the same amount of fish" (Appendix E). Another point made was how managed Mendota, as well as the entire Yahara system, is heavily managed and stocked system for fish. If most of fish are stocked in the lake, then perhaps a reduced spawning habitat may not be a large concern (Appendix E). But, some species, such as Northern Pike, do maintain a strong natural breeding population in the lake, and would certainly be affected with major water drawdowns more than others. Finally, Dan discussed that the current water orders were set by a county organized Water Level Task Force with the intent to balance ecological needs, landowner opinions, and the flow rates of the lake system, the latter of which Oele acknowledged was like "draining an Olympic swimming pool with a McDonald's straw" at times (Appendix E).

Our last interview was with John Reimer, Assistant Director at the Dane County Land and Water Resources Department. He works closely with the county and the DNR, and is responsible for the lake level management. The two options that the county is currently exploring for flood prevention are adaptation and mitigation: adaptation would be a change in the process of managing the lake, including changes in reactions to conditions and a possible lowering of the lake, while mitigation in this sense focuses on alterations to the watershed, increasing the flow of rivers, and preparing for floods by dredging, pumping water, building levees, widening bridges and clearing chokepoints (Appendix F). A technical committee has been formed in order to evaluate the costs and benefits of these options, and develop the strategy moving forward for Lake Mendota's management. Among the cost considerations for lake management include the maintenance costs and longevity of measures such as weed harvesting and dredging, which has not been utilized as a strategy as of yet (Appendix F). John pointed out that the Yahara lakes are managed as a system, and so any decision that the committee comes forth with will need to have weighed the consequences to all of the lakes and the communities that surround them, and quantified these impacts (Appendix F). Currently the dams are wide open, so "if we decide to lower it [Lake Mendota], the models show the other lakes rise - it's [the water] got to go somewhere. It just doesn't magically go out the bottom like pulling the bathtub plug" (Appendix F). Flow rates of water through the system is the critical factor regarding flood mitigation. While lowering Lake Mendota might benefit the communities immediately adjacent, the other lakes will be affected, potentially with more flooding and slow-no-wakes, and Reimer suggested that "...the solution is limited by the flow you can deliver through the system" (Appendix F). There are also issues associated with using Lake Mendota as a storage reservoir to hold back

floodwaters. If the primary purpose of the water orders is for maximum storage, there arises the issue of water levels bouncing up and down, impacting wetlands and lakefront properties due to increased fluctuations (Appendix F). All of these perspectives are being considered by the technical committee, and will report on their recommendation in the coming months.

Surveys

We conducted surveys in Memorial Union in order to gauge public knowledge and opinion about the artificially high lake level and the proposals to lower Lake Mendota. We split up in two groups and tabled inside der Rathskeller and in the main hallway of the first floor, offering cheese curds to those who stopped to take our survey. The survey was comprised of a set of questions about the taker's knowledge of the lake levels, and then a second set of questions about the proposals that participants answered after viewing our maps. 48.39% of the 31 respondents said they knew that Lake Mendota's water level is artificially high due to the dam at Tenney Park, with 51.61% saying they did not know. After looking at the maps, 19% said they would be in favor of a full 5 ft reduction, 48% were in favor of a 2.5 ft compromise, and 70% supported a 1 ft reduction, while only 5% supported maintaining the current lake level set by the DNR water orders (Appendix G). In addition to the survey responses, the maps stimulated discussion with the respondents, who showed curiosity in the project and often stuck around after completing the survey to ask questions. Most people we surveyed asked "what are the benefits of lowering Lake Mendota?" or "why do they want to lower it?" (Appendix G). This reflects a general lack of knowledge about the ongoing issue of Mendota's lake levels. This is not to say they did not understand the issue once explained. In fact, many participants expressed interest in

our research, and often wanted to know more, asking other questions such as "when was the (Tenney Park) dam built and why?", "what would this to Lake Monona?", and "what reduction level are they thinking of doing?" (Appendix G). All these follow-up questions display a genuine interest in the question of a lowered Lake Mendota. Others would relate the question of lowering the lakes to another well-known issue on Mendota, algae blooms, asking questions such as "what would this do for Blue-green algae" (Appendix G). This shows a general concern for the health and recreational usefulness of the lakes. Indeed, the public may not have a complete knowledge on the issue, but there is a genuine interest and concern about Mendota's level and health once learned.

Future Research

Future research endeavors on this topic could more comprehensively measure the actual effectiveness of lake levels to mitigate flooding, using models and simulations to show various flooding scenarios, as well as show the potential impacts on the lakes farther down the Yahara system. More research could also be done on the places that limit flow out of the system, and management strategies to reduce or eliminate these chokepoints. Modeling of the impact of water levels on wetland erosion would also be beneficial to understand the effects of changes in Lake Mendota on the Cherokee Marsh, as well as the backfilled wetland areas across the isthmus and surrounding the lake. A more wide-ranging survey of lake users would be useful to better estimate public knowledge and opinion, and would preferably encompass citizens from all over Dane County. Lastly, ground-truthing of map results could make our projections more accurate, as well as a high-definition survey of the shoreline in order to better model possible navigation hazards and address issues of simplification off of the shoreline.

Discussion and Conclusion

All of the interviews have touched on lake levels as possibly being part of the solution to flood mitigation, but usually in tandem with other supplementary measures. Almost all parties interviewed, but especially the Wisconsin Department of Natural Resources, referenced positive environmental benefits to the lake and surrounding wetland ecosystem as well, especially with the compromises in lake level reduction. However, although a full reduction would provide the greatest area for restoration of wetlands along the shoreline, such an extreme would be detrimental to fish spawning habitats. Overwhelmingly, the discussions kept coming back to costs - to the city, to the county, and to the communities on the lake. The costs to the county to alter dam management and to institute new procedures to prevent pinchpoints and increase water flow out of the system repeatedly came up as concerns, as well as the costs to lakefront owners who would need to extend their piers out farther in order to be able to plane their boats. Conversely, there could also be costs to communities from not lowering the lake and implementing flood prevention measures; street closures and traffic delays due to backed up storm drains, water damage to basements, houses, and businesses, and debris washed up on lawns, parks, and roadways. Who would pay for prevention measures, or how costs would be distributed equally across stakeholders or communities was also a recurring concern. In general, our interviews and survey results show a willingness or acceptance by various parties to have Lake Mendota lowered by 1 foot, granted that the water level reductions are doable, cost-effective, and helpful in mitigating future flooding. Many stakeholders also emphasized that other mitigation strategies should also be implemented in addition changes in lake level management.

The history of Lake Mendota and its ever-changing water levels is long and varied, from the installation of the first mill to the current predicament facing the adjacent city of Madison today. There is no question that the Madison region will continue to grow and urbanize, and lowering the lake is only one option to mitigate flooding. With these environmental benefits in sight, we cannot forget the economic and social aspects of sustainable decisions, and how communities will be affected by any action taken, whether that be full return or no change at all. The problem has been dealt with before, and will likely be addressed again in the future under similar circumstances as climate change continues knock at the door. Conversation and analysis on this matter is critical, and we should not allow ourselves to be as foolish as those who wrote on lowering Lake Mendota to the Wisconsin State Journal in 1866: "The present danger (of flooding) having passed, the whole affair is likely to sleep until old Neptune again wields his trident over half of the city provided the present (dam) is removed" ("The Fourth Lake Again" 1866). We cannot wait for Neptune to act yet again for the implications of flooding and flood management to be fully reconsidered.

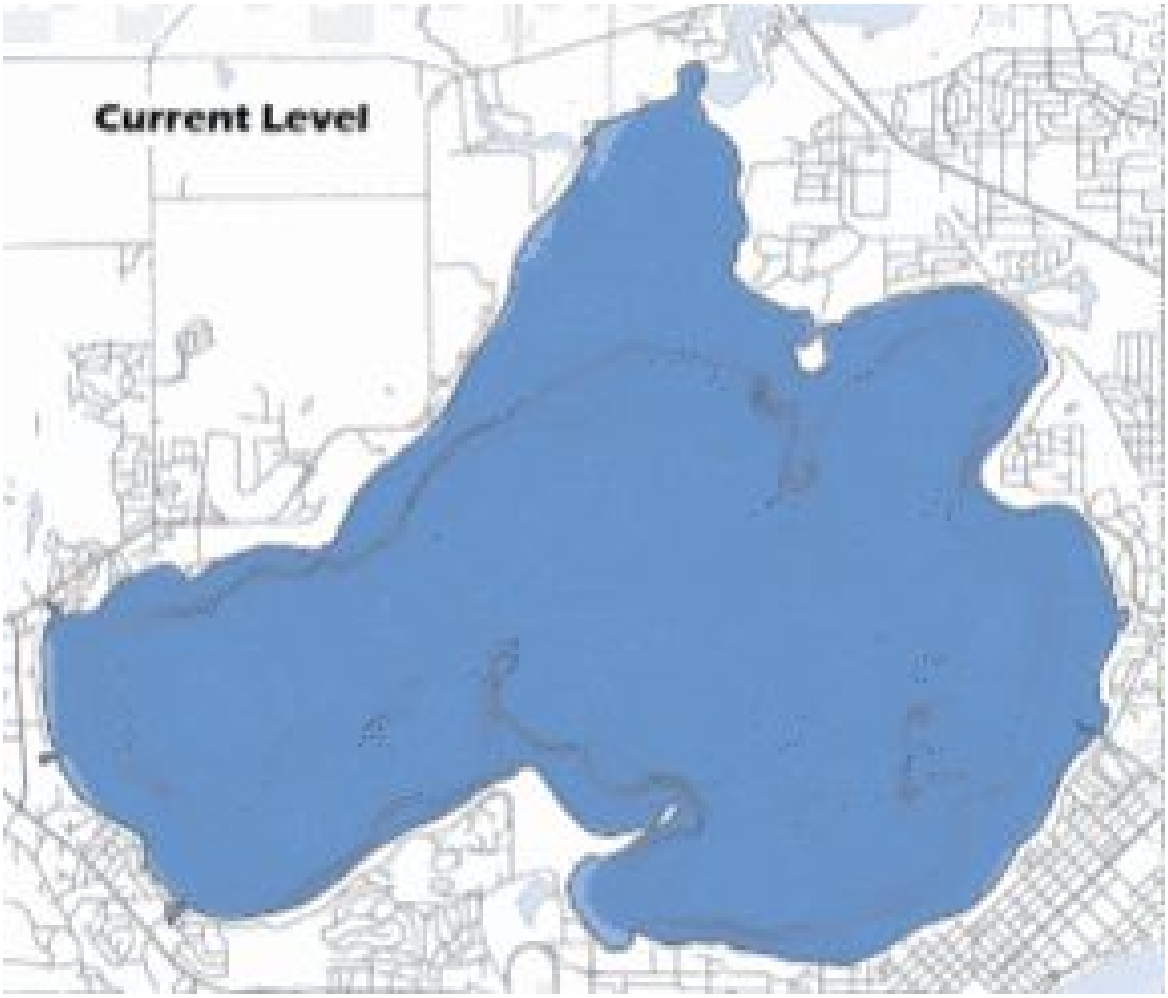


Fig. 12 This is an animated representation of lake level change.

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Appendix A - Yahara Lakes Association Interview

Dan Schultz and Sal Troia, The Green Lantern, McFarland, WI, 11/14/18 8:00AM

Analog note-taking and voice recording

- Lathrop's op-ed
    - Working on flow rate as solution to flooding
    - Technical committee will be looking at managing lake levels, but will not be likely to lower, just different techniques in addition to other flooding solutions
    -
- Costs (financial, personal, etc)
    - Is a solution to the flooding expensive? How much are people willing to put forward for a solution? Is Mendota a cheap fix?
    - What do you support doing is really what do you support funding
    - 5 foot reduction is not reasonable
    - Can we share the costs of flood mitigation by lowering all the lakes?
    - Costs of dredging the northern side of lake in a 1 foot lowered senario to allow access to marina.
    - Costs of adding navigation markers
    - "It's a matter of trade-offs, and it's a public opinion trade off as well. So ultimately, the historical 5' drop trade-off, no; the impact of that is vs the benefit has got to stop somewhere."
- Sympathy
    - Damage of flooding vs shoreline owners
    - "With that view, which is easy to say without knowing, you say 'well, goddamn it why can't they just spend the money and put a few more pier sections out there'. You know, it's the same thing with people complaining that their piers are washing away, 'spend some money, get some higher legs'. But when you're talking about shoreline you've moved your shoreline out 150 feet or something, that's a different deal. Or when your talking about this area over here (points to northern side of lake) and that's where it gets to be (the question of) 'what's the fair balance?'"
- Modeling and Knowledge
    - "It's such an emotional thing… what's the cost of doing all that stuff (to me)...Asking everyone what they think, you'll get an option from almost everybody based on whatever limited knowledge they are. I'm hopeful this group (the county) will move it from opinions to a (scenario where people can say) "ok we've looked at it, this is the impacts of this, of that (etc)". Some will be a social cost to people, but a lot of its going to be an actual dollar cost to it. The better

point is to do a survey of what people think after people actually get a full hearing of the issue".
    - "The best thing to do is evaluate this, and put real numbers on costs, and go with that"
    - Point of people not being well informed on issue
    - Raw, real numbers must be taken into consideration
- Logistics
    - Brought up issue of being even able to get a foot of water out of mendota, will downstream constraints even allow for the water to exit the system
    - Lowering Mendota may be part of Multi-part solution of flooding mitigation, but depends on costs.\Brought up difficulty of changing DNR orders at all, but raised prospects of the county being able to maintain lakes at lower edge of summer minimum instead of in the middle between max and min
- Water Quality
    - Lowered levels may affect the lake, but negligibly. More concerned about P inputs from agriculture and erosion
- Maps
    - Generally were impressed by the novelty of the maps, "I've never seen these maps before"
    - Did not actually change stance or opinion
    - "There's less of an impact with a 1' reduction on the shoreline (where the lake is built up) than I actually thought".

Appendix B - Tenney-Lapham Neighborhood Association
Patty Prime, Colectivo Coffee, Madison, WI, 11/14/18 10:30AM
Analog note-taking

Neighborhood encompasses 3200 units, with approximately 300 dues-paying members in association
Many of the units on the lakefront are single family, about 100
People live on the Isthmus for two reasons: it's close to downtown, and close to the lakes.
In the last five years, major developments in the neighborhood are up 50% in the number of units

Public Opinion

- Significant number of residents know about artificially high level
- Nearly everyone wants Mendota lowered
- In the 2000s, the flooding then raised the issue of lowering Mendota, but fizzled out. Now it's a much larger issue and there is larger conversation about it
- See the lake as a reservoir to hold back H2O

.

Property Values

- They may be slightly affected if the lake was lowered, but what if the lake was *not* lowered?
  May be larger drop in value. No new person wants to live in a flood zone
- Difficult/expensive to get flood insurance
- Raised topic of James Madison Park wetland demonstration, and asked what would people
  rather have, a wetland or water (or flooding)
- 50% increase in number of units in past 5 years from development, raises issues of flood prevention/preparation for newer infrastructure.

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Cost

- Yes there will be a cost, but we need to consider the community cost vs the individual cost
- Motorboats might be affected? Otherwise was not too concerned, as she did not own a boat

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Water Quality

- Addressed leaf litter and agriculture as the main issues for water
- Neighborhood cares greatly about water quality

Appendix C - Wisconsin Department of Natural Resources
Susan Graham, WDNR Service Center, Fitchburg, WI, 11/19/18 3:00PM
Analog note-taking and voice recording

Question 1: Effects on eutrophication

"Phosphorus is the driver of eutrophication"

Phosphorus gets into lake Mendota in three ways:

- External sources
- Shoreline erosion
    - Was an issue when the lake level initially rose
    - Stable now from people building on the lakefront
    - Wetlands are still eroding (not so much University Bay)
    - If water levels were decreased, new bank/shoreline would be formed
    - Decrease in water levels would <u>not</u> decrease erosion
- Internal circulation
    - Eutrophication would not go down, but internal circulation would decrease from the upper area of the lake that would be exposed

Question 1 conclusion: Little to no effect on eutrophication

Question 2: Effect of lowering Lake Mendota on flood mitigation

- Lake Mendota is very large, it is obvious that even a small reduction in lake level would vastly reduce flooding

Question 3: Cherokee Marsh Erosion

- Graham is self admittedly biased on the matter
- Cherokee Marsh started eroding when water level rose
- Less erosion if water level is lowered
- Natural shoreline vegetation (cattails) would not be lost, it would just move with the waterfront

Question 4: (Response to Sal's ideas) Possible to lower all lakes?

- Mendota is at the top of the lake system, and is the one place in the system with an existing point of control over water levels (Tenney Dam)
- Would make little sense to lower all the lakes (make all lakes and communities share the costs

Question 5: Citizen lake monitoring program

- Originally only monitored water clarity
- Expanded to cover chemistry
- Started from need for good quality data
- Citizens who live near remote lakes can monitor them without the DNR having to cover everywhere at once

Question 6: Necessary to seed new shoreline?

- Graham thinks it would be an interesting opportunity to do so

- Cheaper option would be to leave it alone
    - This would lead to invasion of weeds
- Overall a chance to build diverse native communities

Question 7: Who decides if a new order for water level comes down from the DNR?

- NOT the DNR
- A formal request must be submitted with specific water levels
- Was a request a few years ago, but was not formatted correctly and wasn't re-submitted

Appendix D - UW-Madison Hoofers Sailing Club
David Elsmo, UW Hoofers Office, 11/27/18 10:00AM
(Also sits on the Mendota Yacht Club Board)

Water history/flooding

- 'Lake level was pretty easy to work with. Drought was never an issue.'
- Hoofers have seen record low/high in last 50 years

Economic Costs

- 3 ft. surge from north wind- wrecked boats, waves hit the windows in lower level of union
    - North wind kept things pushed against shore
    - Flooding in building, fall nor'easter blew boat up into the building
- "If the lake had been held at it's actual required height, it wouldn't have been an issue." - referring to standard summer levels
- Couldn't get volunteers together fast enough to take apart piers when Aug 20th rains hit
- 'All our decking, got carried away...going to get replaced next season so we just threw it away.'
- Business affected during flood- nobody wanted to go downtown because it was a hassle
- "If we could reasonably lower each lake's level a little bit and that creates more benefit but the people saying five feet..., the whole north side is swampland. I don't think there's four feet in those (northern areas of Lake Mendota)."
- The creation of all the marshland on the north side would be an issue
- "It's not dropping Mendota five feet and everyone else is fine, it's the other lakes will come up too, and the surrounding neighborhoods...they'll be wiped out."
- The potential release of water by lowering the lake may affect downstream neighborhoods
- Economic component makes it seem very improbable
- All marinas and 95% of recreation are on the north side- most affected economically if lake lowered 5 feet
- Dredging would be a nightmare- where to dredge and where to leave be?
- 100s of 1000s of dollars would be lost in renovations- plan would need to change
- The state is the largest stakeholder in the lake levels (from the UW and the state park).
- "I think that reasonable heads will prevail in this conversation. The university is monitoring it… because they are such huge stakeholders, they will get involved in the conversation if it goes outside the realm of a reasonable drop in lake levels"
- "I would think a foot lower than what their overage is would be obtainable"

Social Costs

- No wake after floods- no safety boats can keep up with sail/row boats- no safe sailing

- ‘Once the lake got to the 100-year floodplain, all the lakes go no-wake. Can’t go above idle speed. Our boats can go way faster. So to keep up with sail boats our safety boats would need to go up to 20 miles per hour to keep up.’
- Affected in a safety sense
- Affected from flood all the way until two weeks ago
- Mendota Yacht Club (sailboat racing) takes 3-4 hours to set race course/speeds- lost half of race season due to no-wake
- Affected skiing and fishing on the lake- huge loss in recreational activities
- “People just weren’t on the lake this year.” “People tend to freak out or go hard left field.”
- “I don’t think we need a drastic reduction, I think we need a lake level to account for what there is (flooding). Having a reasoned reduction in lake level to allow for a easier drain on the system makes total sense. It is my opinion that if the lake was a foot lower than what is was when we got that rainstorm we would have been able to draw the lake up safely and eventually draw it down without flooding Monona. So I don’t think a foot on either side of that is unreasonable, but I hear people talking about bringing it back to its natural levels...I don’t know where to begin with that conversation”
- Destroys people’s ability to use the lake unless they live on it- boat ramps would have to be redone or updated
- “If you lowered the lake five feet, you’d totally destroy people’s ability to enjoy the lake. Because unless you own property on the lakefront, you can’t get a boat in there. So you’re talking, even the boat launches we have, the public launches, are no longer effective.”
- Lack of Public enjoyment leads to public apathy leading to cuts in funding for care of the lake
- “Then you have a city with two of the most beautiful lakes in the midwest that nobody can play with”
- People on the east side would have beaches, may want that/find it desirable

Environmental benefits

- High water helped fish population- predatory fish now closer to shore. Unique
- 5 foot reduction- marshland good for ecosystem
- 1 foot reduction may increase weltand in University bay

Infrastructure-

- Old docks were permanent, low water didn’t cause many problems except for one rock
- Plan for new infrastructure is at summer average based on data minimum - what’s the lock is supposed to be keeping the lake at/DNR order
- New docks will float, avoiding problems with minor fluctuations
- A crane is being put into place 6’ deep boats in the water - current crane can not do that
- Crane built specifically

- Club has some flexibility to changes
- 1’ reduction wouldn’t change much
- “2 feet from where their supposed to be keeping the lake, then we’re gonna run into some issues.”
- New design of docks are meant for the ocean so can withstand big surges
    - Climate change and erratic weather patterns call for more durability
- “I’m hoping that they’re (the county) starting to think about the frequency of the storms (concerning climate change)

Appendix E - Wisconsin Department of Natural Resources

Dan Oele, WDNR Service Center, Fitchburg, WI 12/2/18 3:00PM

Fish biologist, at DNR works with Dane, Rock, and Green counties

- Evacuate impact on fish and fish habitat
- Review construction projects around lakes/bodies of water
    - Ch 30 permit for new dock project at UW
- Monitor fish (species, age distribution, etc.) mostly game fish
- Stocking
- Regulation - creation and modification
- Outreach for school groups, anglers (Muskies Inc.)
    - Southwest Trout Unlimited
- UW tie, Center for Limnology - share data, but otherwise don't work together (separate interest/goals in research)

"**Could you talk about how water level reductions might impact fisheries (on the lake) if at all?"**

Madison chain is interesting

- Water level are maintained
- Isthmus used to be wetlands
- "So it's already a heavily managed system as far as water levels, and that's to protect (indistinguishable) and property.
- "In a pristine environment, you'd seasonal pulses of rain, and that would send pulses and flooding down chain" creating temporal spawning habitats for fish
- Northern Pike have sticky eggs to go to substrates of flooded areas
- "Have lost natural spring pulse of several feet in some cases. In absence of that we have been doing stocking and evaluating the natural reproduction of Northern Pike"
- Different groups (Monona Terrace) have paid to have lakes stocked
- Mendota's got a lot of steep shoreline that wouldn't be as impacted as the shallower/tapering shorelines

Expansive bay area to north will be full of milfoil, water celery and other emergent plants etc. (with 1 foot reduction that would likely be lost)

- Shallow, warm, good for spawning (fish have thermal cues)
- "Those two areas, the River mouth (on the northern side of the lake) and University Bay are some of the more tapering shorelines that are full of macrophytes that are good for spawning"

Study of game fish

- Heavy focus on species of game and panfish (northern pike, walleye, large and smallmouth bass, white bass, yellow perch, bluegill, black crappie, channel catfish).
- Don't do a thorough job on looking at non-game fish.

- "Our focus is often relegated on where our funding is coming from, from hook-and-barrel fishermen and hunters who purchase licenses and related gear, so that money is directly put back into those programs" (Pittman-Robertson Act)

"Sounds like Lake Mendota is heavily managed. If a lot of the fish are being stocked anyways (as opposed to natural spawning) do you think lake levels would really make a difference?"

- "Northern pike would definitely have an impact on the lower water level scenario"
- Negative effects to fish, they are very cued into depth and changes to habitat
- "If you lose one of those key habitat areas you're going to have less amount of space for the same amount of fish"
- "I think there will be a fisheries impact at any one extreme of your drawn-out scenarios would have an issue
- "If that's a 2' or 1 foot drawdown, that might not be detectable vs a 5' (reduction), that might be more severe"
- Fish are highly adaptable and could likely cope with some changes but the social question of whether we want to promote and proactively support self-sustaining populations of fish or move towards completely stocked systems is a large complex questions that would need to be considered

How/why is lake maintained?

"Do you think water levels, and how they're maintancened are based off of fishery needs, or recreation?"

- Document from Water Level Task Force by the county
- "Water levels were set as a grand compromise between local ecology, the fishy habitat needs, riparian landowners who wanna put their boats in, and the ability of the system as a whole to put water through"
- All those issues were discussed and attempted to balance with the current water levels
- Examples of drawdown impacts on other species: Hibernating turtles and frogs in shallow areas would die in winter if draw-down situation is too quick, so timing and rate is important
- Pro-con list in Task Force document

"Do you know if the fishing groups have any concerns about the water levels"

- Doesn't have calls from anglers on lake levels
- Heard on Lake Koshkonnog - got calls about boat access
- "Would expect to hear folks concerned about fish habitat if a plan materialized with a severe drawdown. Those groups would coalesce around preserving boat access and fish habitat"
- Skipper Buds and million-dollar boats in the north side
- "I'd suspect that a 5' drawdown would get major pushback from this group (the northern boats)"

“Some people have highlighted how dredging and weed cutting is an answer to improving flow. How would that affect fisheries?”

Flood mitigation strategies

- Want to keep water on north side of lake, so no cutting weeds north of lake
- Get rid of water (increase flow) out of pinch points
- Dredging good idea
    - Substantial sediment deposition at railroad and bridge posts
- “The weed cutting has been sort of a hot button issue”
- “I’m very supportive, especially in emergency scenarios of cutting and removing water out of the system as fast as we can. Holistically, it gives me a bit of heartburn, especially as a fisheries person to have those rivers, highly impacted as it is, are good fish habitat”
- Cost, loss of habitat are both considerations
- “Whole point here (points to northern side of map, little bit of peninsula) ...pretty sure it’s gone”
- Little peninsula of is gone, eroded

“Any issues of maintaining current levels?”

- Year was unique
- “Draining an Olympic swimming pool with a McDonald’s straw. That’s just the hand we’ve dealt ourselves as far as the system”
- As far as fisheries are concerned, the current levels work ok, as far as some of the more migratory fish that are seeking out places with (water) inundations”
- Inlets and outlets still function well as spawning
- Mendota is still ranked high (3rd or higher) as far as size class in number of large pike
- More likely to detect changes in our regulations (of size, limits, and such) than form water levels

Any Comments?

- Talks going on, informal
- Broader societal shift. “Look at Milwaukee County where the idea of the Milwaukee (kinnikinick) river was to get the water out as fast as possible. Slowly we’re coming around to ‘maybe a hardscape on the landscape isn’t the best thing to do.’”

Appendix F - Dane County

John Reimer, UW Extension Building, Madison, WI, 12/6/18 10:00AM

"Currently the county is looking into lake level management (in light of) the flooding. Could you explain the process/timeline of what any substantial change would look like? Specifically, any report, leading to cost benefit analysis, and then actually proceeding...to a DNR order?"

- 2 options for flood mitigation:
    - Adaptation- "Sayi we want to lower Lake Mendota; that's on the adaptation side. We're just adapting the way we manage the lakes"
        - react to conditions, lowering lake mendota, (removing dams?)
    - Mitigation- " It's really mitigating our flooding. Weather it be doing stuff on the watershed side so there's less water coming in, or it's mitigating to make the rivers bigger so you can flow more water out"
        - preparing for flood- dredging (doesn't last), pumps (use electricity), levees, widen bridges, clear chokepoints, etc.
    - "Our group (the County department) is looking at that adaptation side, which includes lowering Lake Mendota… another way is 'let's just remove all the dams', what does that do?"
        - One scenario is taking out all dams, but dams usually buffer flooding, so it may make flooding worse
    - Group is also looking at mitigation side, looking at removing chokepoints
    - "I don't think we're saying one solution or the other, but what we are putting together is a report that says 'what are the benefits to these different options"
- Dane county owns 4 dams, Tenney, Babcock, and Lafallete\
- "The downstream dams on Babcock and Lafallete have been wide open since 2016"
- "Our strategy of operating the lake is operating them together"
    - If Monona is a foot over, Mendota will be too
- To say we want to lower one lake means we're going to have to impact other lakes downstream because that water's got to go somewhere"
    - Maybe would benefit Mendota, but of course would impact other lakes
- Rainfall - doesn't happen predictably
    - "Having lake mendota lower, what is that going to benefit when the rainfall doesn't fall on it"
- Put together pros and cons of mitigation and adaptation strategy
- "Our plan is that report is going to be done February 1st"
- Then goes to "Task Force" - a body of members on the county board and some mayors
    - With report "what do they want to do for recommendations of policy? Do we really want to put all of our money together and dredge the rivers, for example."

- Looking at water level orders, flooding is one piece to consider, alongside economics, all the pieces associated with lake levels"
- From our perspective that (consideration of all the issues in lake levels) a DNR issue, because they're the ones that set the orders. They would go through the process of trying to quantify what are the impacts of fisheries, economics, or slow-no-wakes, what does it mean for our community. They're the ones that put that together"

"Here's the maps of the simulated lake level decreases. Thoughts or comments or opinions?"

- Points out where marins is on map (north side of lake)
    - "What you're doing here is impacting the economics of them (the mariana) unless you dredge it, but what's sustainable about dreading this part (of the lake)"
- Did something similar in the past
- "When you do something like this, the boating community or the property owners are the first ones to be impacted by this, so what can you quantify for them, and what it means for them...for this one home owner, what's the average distance that someone's going to have to put a dock out, what's that going to cost them"
- "What's the impact of navigation?" Since fine scale of actual rocks are not included in maps, "now those rocks are going to be exposed"
- How far does dock need to be to be able to get boat accessibility

"Recently the recent article in the Isthmus highlighted the issue of system flow as the primary concern as opposed to lowering Lake Mendota. So, would lowering the lake have any measurable storage capabilities to mitigate downstream flooding?"

- For example, Kegonsa went 7" above the 100 year mark
    - All the rain fell on Kegonsa
    - Reduced the flow from mendota to help out the lower lake, but they still flooded
    - Highlights the issue of where rain falls
- Dams are wide open, so "if we decide to lower it (Lake Mendota), the models show the other lakes rise - it's got to go somewhere. It just doesn't magically go out the bottom like pulling the bathtub plug"
    - Benefits mendota, but other lakes are affected, maybe with more slow-no-wakes, maye more 100 year levels
    - "Basically the solution is limited by the flow you can deliver through the system"
- Not hitting summer targets as it is for all the lakes
    - "To say 'we want to lower it a foot', are we just saying a magic or fictitious number in our head? Because we still manage all the lakes together"

"Would lowering the lake only be an option in a low-rain senario or a drought?"

- "That's the time you can do it, is likely then"
- However, "maybe as you said before, it's a combination of things. If we dredge the lower rivers and we can move more water out, then maybe we can move more water from Lake Mendota and lower it"
- But currently lowering the lakes, without allowing flow-through would most likely cause more flooding
- Monona flooded this year because water was let out of Mendota, and Monona couldn't get rid of it via the downstream lakes

"Several other groups proposed lowering all the lakes. Is that a) doable and b) manageable? '

- "Look at these last two years; the (lower) dams have been wide-open year-round. And we weren't at summer max. So it's again about putting the orders out there give people a false sense that we can do it. If the dams are wide open, it's the natural system and what it can deliver.
- Not hitting summer min/max as it is, so how to expect to hit those if it were lowered
- Too low is also a problem though
    - "A drought year is just as bad if not worse year than a wet weather year, at least from a property owner's perspective, right? Their boats are all stuck on their boat lifts, they can't get out and enjoy it...the fishermen can't get into their fishing spots (in the backwater areas)"

"Going to Tenney Dam specifically, one of the issues I've heard is that the dam is not meant to be topped (and flow over). Would a lowered lake have avoided that problem?"

- Dam can actually be topped
- Issue of the dam over the summer was that "over that period they were calling for *lots* of rain, and we just kept on missing them. The concern was 'if we do fill up really high on Mendota, we don't want to put an overburden amount of load on the gates, so then we would have to open up the gates even more, and the downstream would get even worse."
- Lucky we didn't get the rain, and we were able to move a lot of water out of the system by that time. - "We kind of lucked out"

"Would lowering the lake even solve that potential risk of the dam being overburdened?"

- Brought up that lowering lake Mendota will treat it as a storage reservoir
    - Lets just say we could magically get the lake down 3 feet.
    - Now it's like a storage. Water will bounce up and down
    - Impact on wetlands, lakefront property.
    - Maybe it's a benefit for the flooding from a storage perspective, but from a use perspective of people's docks, say someone puts their dock out and (the lake)

> fluctuates 3 or 4 feet, and their boatlift, or even its the fishermen, or the rocks are exposed..or the wetlands which might dislodge since it's fluctuating so much….there's other perspective to consider"

"Cutting and dredging the rivers would probably be a constant maintenance cost. Do you think that cost will be a major consideration? As in, altering lake levels is essentially "free", but the maintenance cost of the mitigation might not be".

- It's likely
- "Weed harvesting budget in the past 10 years has pretty much doubled. We're getting two more harvesters next year, so we'll then have 13 in our fleet It's roughly a million dollar budget, so we're pretty committed to this."
- Weed harvesting also helps the property owners in certain areas
- Never have dredged the rivers, so "longevity will be an interesting question: how long does it last us. Is it 20 years? Do we over-dredge so that it'll benefit us for an additional 10-20 years?
- Pumps, which use electricity

Alex: "Can you describe the public response you get on the app"

- -App: Remote control of gates on dams for fast and easy control
- More for the timeliness, management side to benefit the public
- "If we get a rain event on friday, I'm not waiting until Monday when staff is in to make a change. I can make that change in seconds,

Appendix G, Survey Data and Notes
11/28/18, Memorial Union, 3:00PM-6:00PM

"What's the benefits of lowering the lake"
Why is 5 feet the max?
"Fuck the rich people"
When was the dam built and why?
What are the ecological benefits of lowering the lake?
Would lowering the lake do anything about blue green algae?
I think this is interesting but I don't know much about it.
What do you mean by lower?
What would this do to lake Monona?
Where would the water go?
What level reduction are they going to do?

Most people we surveyed asked "what are the benefits of lowering Lake Mendota" or "why do they want to lower it". This reflects a general lack of knowledge about the issue of the lake levels. This is not to say they did not understand the issue once explained. Several people commented how the survey and what we explained was very interesting. Others said they'd like to know more, asking other questions such as "when was the (Tenney Park) dam built and why", "what would this to to Lake Monona", and "what reduction level are they thinking of doing?" All these follow-up questions display a genuine interest in the question of a lowered Lake Mendota. Others would relate the question of lowering the lakes to another Yahara chain issue, algae blooms, asking questions such as "what would this do for Blue-green algae". This shows a general concern for the health and recreational usefulness of the lakes.

Survey Cross Tabulation

		Did you know Lake Mendota's water levels are artificially high due to a dam at Tenney Park?		
		Yes	No	Total
Would you be in favor of a full 5ft reduction?	Yes	2	4	6
	Maybe	8	9	17
	No	5	3	8
	Total	15	16	31
Would you be in favor of a 2.5ft compromise?	Yes	8	7	15
	Maybe	7	7	14
	No	0	2	2
	Total	15	16	31
Would you be in favor of a 1ft compromise?	Yes	6	8	14
	Maybe	0	3	3
	No	2	1	3
	Total	8	12	20
Would you be in favor of maintaining current lake levels?	Yes	1	0	1
	Maybe	3	3	6
	No	4	9	13
	Total	8	12	20