Community Responses to Water Quality Decline in the Lake Mendota Watershed

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Geography 565
December 16, 2014

Abstract: Land use and land cover (LULC) are critical factors in determining the water quality of surrounding water bodies. Although the mechanisms are different, both urban and agricultural LULC increase the quantity of runoff directly entering nearby hydrological systems as well as increase the phosphorus, nitrogen and chloride content of the runoff. Lake Mendota in Madison, Wisconsin receives runoff from both urban and agricultural LULC, accelerating lake eutrophication and severely degrading its water quality, evoking a response from the community. To understand this response, researchers analyzed archival photos, conducted interviews with the major stakeholders and collected surveys on the knowledge and engagement in best management practices (BMP's) of residents on the lake. Their findings highlight the long history of LULC around Lake Mendota and the currently disbanded efforts to improve the lake's quality, evident in the public's low awareness of water quality issues and the major stakeholders segregated efforts. All of the stakeholders turn to the emerging nonprofit sector to consolidate efforts and increase communal outreach to create one common coalition working towards improving Lake Mendota's water quality.

Introduction

The land around Lake Mendota has undergone extensive changes since the early 1800's. Water quality has long been associated with many variables, the most important being land-use and land-cover (LULC). Two of the most influential types of LULC that affect water quality are urban and agricultural development. LULC associated with urban areas entails a conversion of natural vegetation to impervious surfaces. Agricultural LULC involves the clearing of vegetation and disruption of topsoils. Urban and agricultural LULC significantly increase water runoff or overland flow to water bodies during storm events. This overland flow and runoff delivers high volumes of pollutants, particulates, and nutrients to enter the local lakes and water bodies. Water quality begins to suffer due to water salinization and eutrophication with increased pollutants, particulates, and nutrients getting into water bodies. This process of LULC change, increased runoff, and subsequent declines in water quality, establishes a narrative that concerns the entire community inhabiting the watershed surrounding Lake Mendota.

As the landscape continues to evolve, the importance of maintaining healthy lakes and water bodies needs to be stressed more than ever so that this valuable resource remains available to future generations. There are many stakeholders that are involved with management practices and all of the stakeholders must remain accountable for their actions. The University of Wisconsin-Madison, City of Madison, agriculturalists, regulatory institutions, researchers, local non-profits, and Madison residents each play an important role in educating and implementing best management practices to protect Lake Mendota in the present day and in the future. The goal of this research is to discover how LULC change led to a decline in the water quality of Lake Mendota and what the communal responses to this decline are.

Site Setting

Madison, Wisconsin is a city famous for its many lakes and has a rich tradition of making them an integral part of the city. The biggest, and arguably most famous, of these lakes is Lake Mendota, which is known to many as "the most studied lake in the world."

Lake Mendota is a eutrophic lake located in Dane County, Wisconsin. Its 35.2 kilometers (km) of vast shoreline are home to the cities of Waunakee, Middleton and the capital city, Madison, a metropolitan area of about 570,687 people. Various types of development including high density urban, low density urban, and agricultural land affect Lake Mendota by altering sediments, water chemistry and aquatic ecology. The total surface area of the lake is 3,985 hectares (ha) with an average depth of 12.7 meters (m), for a total volume of 505 million meters cubed (m^3), making it the largest lake in the Yahara Sub-Watershed. This sub-watershed is a 603 km^2 drainage basin within the Rock River Watershed, comprises most of southeast Wisconsin (Lake Mendota 2014). The water entering Lake Mendota primarily comes from urban, suburban and agricultural land-use types (Lefers, et. al 2005, 2), with 53 percent cropland and 21 percent developed as of 2008. The remaining 26 percent of land-use in the watershed is comprised of undeveloped land (Betz and Genskow 2012, 3). Figure 15 in appendix I shows an updated land use map for the Lake Mendota Watershed as of 2012. Each individual land-use within the watershed influences Lake Mendota and its health in the present day.

To understand Lake Mendota in its current state, it is important to know the deep history of its formation and settlement. Stream erosion and the resulting topography set the stage for the creation of the Lake Mendota basin some 40,000 years ago, at which time there were no lakes or swamps. Glaciation during the last ice age resulted in a drastic transformation of the area due to the large amounts of sediment deposited by the Wisconsin Glacier, damming the stream flow and creating the lakes (Bean 1936, 8). The overall effect was the creation of a beautifully blue, oligotrophic [low in nutrients and unable to sustain much life] lake, known today as Lake Mendota (Carpenter 2006, 236). Lake Mendota is a glacial lake that formed roughly 15,000 years ago. Originally part of the pre-glacial Yahara River, the area that is now Lake Mendota used to be much larger in size, covering all of the modern isthmus of downtown Madison and the city of Middleton (Yahara Waterways 2014, 16). Lake Mendota looks much different in its current state, making it necessary that researchers analyze the factors that have caused Lake Mendota to change over time.

When the first European settlers arrived in the 1830's, they came upon Lake Mendota as a clear-watered lake, surrounded by wetlands and dense forests. By 1840, Europeans already significantly transformed the area, which included the clearing of land for agriculture and urban settlement growth. In 1880, Lake Mendota transitioned from an oligotrophic to a eutrophic lake, noted by the change in water color from blue to green and the observed large scale fish die-offs from algal blooms (Carpenter 2006, 237). These trends of land use and land cover change continued over the next hundred years to create the modern landscape of Lake Mendota.

Literature Review

Introduction

Land-use and land-cover (LULC) change directly affects surrounding hydrological systems, including but not limited to lakes. Human activities and land-use types, along with their associated land-cover, have a profound impact on the quantity and composition of runoff in a hydrological system. Chemicals used in urban and agricultural settings alter the chemical composition of runoff into surrounding lakes. Scientists have observed how these subsequent changes to the nature of runoff are one of the primary determinants of declining lake water quality. The loss of aquatic system functions associated with declining water quality elicits many responses from a variety of actors and organizations who are concerned with maintaining the health of local lakes. Thus, land-use and land-cover changes negatively impact the water quality of surrounding hydrological systems by altering the chemical composition of the run-off entering lakes, spurring various local responses and practices.

Water Quality and Non-point/Point Pollution

Before delving into the volumes of research about the numerous relationships between land-use and land-cover and water quality, it is important to clearly state how water quality is defined in this research project. In general, water quality is an all-encapsulating word used to describe the state of any kind of hydrological system (i.e. river, lake, sea, stream). Researchers have measured a plethora of factors (both chemical and state variable) that promote and degrade the health of water systems including but not limited to pH, temperature, suspended solids, chlorides, trace metals, phosphorus and nitrogen. Each of these factors poses a unique threat to water quality, but for the sake of this research, eutrophication and salt concentration will be the main area of focus when determining water quality because they are heavily associated with common human practices. Since the objective of this project is to identify how changing landscapes have changed Lake Mendota, the only hydrological systems we are interested in are lakes. Water quality is therefore defined as the level of eutrophication and salt concentration within a lake, with higher levels of eutrophication and salt content meaning lower quality (Nielsen et al. 2012, 1187; Novonty et al. 2008, 132). In understanding lake water quality, the factors most important to this research project are phosphorus, nitrogen, temperature and chlorides.

The pollution of water bodies occurs through two primary ways: point and nonpoint source pollution (Appendix I, figure 16). A broad definition of nonpoint source pollution is any sort of pollutants that "diffuse" through the surface and have no direct entry point into the water. The Environmental Protection Agency (EPA) defines non-point source pollution as any source that is not defined by the "point source" definition in the Clean Water Act of 1987. In contrast, point source pollution is loosely defined as pollution that directly enters water bodies at one specific location. The Clean Water Act defines point source as "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture" (Ongley 1996, 5). This research will concentrate on both nonpoint and point sources of pollution that affect Lake Mendota's water quality.

Defining LULC

In order to analyze the changing composition of lake water and its quality, it is critical that the importance of surrounding LULC change is understood first. Land cover is a measure that combines both the overall appearance of the surface landscape including its use, seasonal variations, and cultivation while land-use accounts for the demands of humans, influenced by political and economic variables. Together, LULC creates a unique land type and with it, changes the physical and chemical processes of the immediate environment (Gregory 2009, 409; Wolter et al. 2006, 607; Niehoff et al. 2002, 82). This includes physical and chemical changes to hydrological systems as it dictates the amount of runoff and level of soil erosion (Lee et al. 2009; Sun et al. 2014, 285; Mohammed 2010, 97). Research has shed new light on the interconnectedness of land-use types and water quality within their watershed, suggesting that water quality is heavily dependent upon the land-use types within the watershed (Sun et al. 2014, 285; Amin et al. 2014, 120; Tong 2002, 377). Thus, the type of land-cover associated with urban and agricultural land-uses are critical to understanding the process of physical and chemical changes to hydrological systems.

Urban LULC

As urban LULC increases with population growth and industrialization, it is important to adequately understand how it physically and chemically alters hydrological systems. The increase in impervious surfaces is a phenomenon closely tied to urban LULC. An impervious surface is any surface that does not allow water to be absorbed into the ground. Instead, it forces the water to accumulate and drain, or runoff, directly into a surrounding water body. Common impervious surfaces are asphalt pavement, concrete, and rooftops. As urban areas grow, buildings, homes, streets, sidewalks, parking ramps and other impervious surfaces replace native vegetation and soils. These types of natural land cover play a key role in protecting water quality because they filter out excessive nutrients, like Phosphorus, before they enter nearby water bodies. This conversion from pervious to impervious land-cover drastically increases the amount of runoff entering nearby water bodies after any type of precipitation or storm event. One study found that increasing amount of impervious pavements resulted in a 65 percent higher rise in lake levels after a rainfall in 1995 compared to one of the same volume in 1937 (Wolter et al. 2006, 608). Impervious surfaces also absorb much more solar radiation than vegetative cover, making them much hotter. During precipitation events, this heat is transferred to the runoff, making it warmer than normal when entering a lake (Goonetilleke et al. 2004, 31; EPA 2003, 1).

Thus, urban LULC change replaces the amount of natural environmental filters with impervious surfaces, increasing the amount and temperature of water directly emptying into a water body.

Greater volumes of water directly entering a water body become more of an issue when it is matched with increased chemical use and pollutant emissions, which are also associated with urban LULC change. Areas of high urban development see increases in physical contaminants, called suspended solids, such as metals and rubbers associated with commercial and residential waste, as well as chemical pollutants such as deicers and fertilizers constantly applied to roads and lawns for routine maintenance (Tong et al. 2002, 377). Of the many pollutants, Phosphorus (P) and Nitrogen (N) are two of the most common urban bi-products and are often cited as having the greatest impact on water quality because they are nutrients that induce lake eutrophication. Lawn fertilization, construction, pet waste accumulation, and lack of proper sewer systems are all urban activities which produce excess amounts of P and N immediately available to enter the environment (Carpenter et al. 1998, 560-564). Both P and N are water-soluble elements easily dissolved in rainwater and effectively transported by the wealth of impervious surfaces associated with urban development. Research concludes that P loads in lakes are highest when surrounded by land cleared for urbanization; a study by Detenbeck et al. in the Minneapolis/ St. Paul metropolitan area found phosphorus levels in lakes were 50-100% higher within urban watersheds (Soranno et al. 1996, 874; Detenbeck et al. 1993, 40). Urban LULC change introduces a variety of pollutants to its immediate environment through various human practices which rely on heavy chemical usage, especially, but not limited to P and N.

Urban LULC not only facilitates the deposition of P and N into surrounding lakes, but also chlorides. Urban areas with cold and icy winter seasons heavily rely upon chlorides to make streets and sidewalks safe, but with the onset of spring, the ice melts and the vast amounts of road salt used dissolve and drain into surrounding lakes, spiking the chloride to unprecedented levels. Research shows that urban lake salinity levels are undoubtedly higher than non-urban lakes, with urban concentrations ranging from 10-25 times higher. The origin of this salt is highly contested. Some scholars debate that the most common source of chloride in urban areas comes from home and commercial water softeners, while others claim that it is from road salting. Those who blame road salt, point to the cyclical nature of the salt concentrations, with spiking concentrations in the spring, but this does not account for higher yearly chloride averages (Novotny et al. 2008, 130). Regardless of how the salt enters urban lakes, what is important to know is that it does, and its presence poses further ecological damage.

One of the largest debates surrounding urban runoff is the "first-flush phenomenon." "First flush is highly dependent on the precipitation intensity as well as the duration of precipitation. "First-flush" is when runoff officially begins, typically within the first hour of rainfall, and is believed that the pollutant load is most concentrated at this time. While "first-flush" does recognize the importance of runoff quantity, its main focus is the importance of the time of runoff creation for assessing water pollution (Goonetilleke et al. 2005, 32; Tong et al. 2002, 377). Not all experts agree on the importance of the "first-flush phenomenon." Opposing studies indicate that only 60-80 percent of storm events actually exhibit signs of higher concentrations of pollutants at the outset of a runoff event, indicating that the first-flush phenomenon may not be as important as previously thought (Hall and Ellis 1985, 271). It is also worth noting that the concentration of pollutants is insignificant in comparison to the total pollutant load of the entire runoff event, which ultimately has the greatest total effect on aquatic systems. Initial runoff can have very high concentrations, but may have a low pollution load when compared to the total pollution load for the entire runoff event (Barrett et al. 1998, 136).

The fact that there is a debate surrounding first-flush is important because this has serious policy implications for storm runoff management. If the importance of first-flush is overemphasized, then management policies may be overly concentrated on the initial portion of runoff, which could have serious implications if the majority of pollutants are entering runoff after the first flush.

Urban land-use makes anthropogenic chemicals like N, P and salt readily available and urban land-cover provides the perfect surface to carry these chemicals into nearby lakes via runoff. The resulting effect is larger amounts of chemically enriched storm water flowing into urban lakes. (Goonetilleke et al. 2005, 31). Across multiple studies and numerous researchers' conclusions, urban LULC negatively impacts the water quality of surrounding lakes by intensifying the P and N nutrient enrichment and the chloride content (Ren et al. 2003, 657; Sun et al. 2014, 272; Brehm et al. 2013, 114; Amin et al. 2014, 120; Lee et al. 2009, 80; Tong et al. 2002, 378).

Agricultural LULC

LULC change is not strictly limited to urbanization. A LULC change that affects water quality more than urbanization is agriculture, which is identified as the biggest contributor to nonpoint source pollution of water resources (Liu et al. 2013). There are multitudes of ways in which agriculture impacts water quality, but the main ones are: clearing, plowing, and irrigation. Clearing land for agriculture removes vegetative cover, reducing the amount of water that can be absorbed by the soil, creating more surface runoff. Tilling or plowing practices expose greater quantities of loose soils that can easily be eroded away by increased surface water runoff. In fact, one study found that soil erosion was twenty times higher in watersheds of primarily cultivated areas than watersheds with predominantly native vegetation (Cox et al. 2006, 55). The combination of agricultural land's inability to soak up water and the abundance of chemically enriched loose soils create the perfect conditions for enriched surface runoff after any given rain event, but irrigation practices make this process much more regular. Irrigating agricultural fields provides a constant source of water to pick up all of the loose soil and carry it to the nearest water body (Ongley et al. 1996). For this reason, there is a very large volume of polluted runoff that comes from agricultural LULCs.

Higher amounts of soil entering water bodies poses a threat to water quality on its own, but when these soils are chemically enriched, it poses an entirely different set of threats. As with any LULC, there are a host of chemicals associated with agricultural LULC. The evolution and spread of modern, intensive agricultural practices increases chemical fertilizers and insecticides in the environment, which contain P and N. These are such popular nutrients because they artificially enrich soils, providing agriculturalists the ability to grow more crops in less fertile lands. In fact, agriculture is the largest source of P and N loading in many lakes, contributing 83 percent and 42 percent of total P and total N respectively, in a study done on Danish lakes (Nielsen et al. 2012, 1188). This is because during rainfall events, the remnants of these fertilizers and insecticides in the tilled soil dissolve rain or irrigation water and are then easily washed into the nearest lake (Ren et al. 2003, 651; Ongley 1996). This phenomena has been intensively studied and many bodies of work conclude that agricultural LULC is heavily correlated with decreased water quality because of the in which it provides the perfect conditions for large quantities of nutrient enriched soils to enter surrounding lakes (Nielsen et al. 2012, 1189; Cox et al. 2006, 56; Liu et al. 2013; Sun et al. 2014, 285). Such findings are important to this research project, seeing as agricultural land is the most common type of LULC in the watershed surrounding Lake Mendota.

Wetlands

Wetlands are very important ecosystems that suffer at the hands of urban and agricultural LULC change. Often times wetlands are filled to allow for urban and agricultural development (Gannon and Turner). Conversion of wetlands to urban and agricultural LULC greatly impacts the surrounding hydrological system due to the loss in the ecosystem benefits provided by these unique environments. An ecosystem benefit provided by wetlands that is especially pertinent to water quality, is the filtering out of nutrients, such as phosphorus and nitrogen. The detrimental effects of these nutrients can be offset by the existence of wetlands (Acreman and Maltby 2011, 1347). Due to these important functions that are lost by converting wetlands to urban and agricultural land uses, it is a process that must be discussed when looking at LULC change's effect on water quality.

The Effects of LULC on Water Quality: Lake Eutrophication and Salinization

So far, this research has focused on the effects of LULC change in a relatively binary way, emphasizing urban versus agricultural. However, finding watersheds that are entirely urban or entirely agricultural are a rarity in today's world and an interesting debate about LULC change with regards to water quality is that the more diverse a watershed is, the worse the water quality. The idea is that a wider variety of LULC within a watershed exposes it to more pollutants and increases the ways in which these pollutants can enter the water. The major assumption, and what incites a great deal of criticism, is how scale is used to determine this. Many researchers agree that all results of analyzing LULC and its effects on water quality are subject to scale biases, highlighting the fact that results will change depending on how close or far the research is from a lake. Opponents argue that the idea of more varied LULC is associated with worse water quality is a result of scaling too far out, and does not effectively interpolate the effects of nonpoint source pollution closer to the water (Sun et al. 2014, 285; Honisch 2002, 293). It may be years before researchers settle this debate, but the idea that varying quantities of LULC changes the outcome of water quality helps put into perspective the environmental impacts of LULC change.

It is now clear that LULC directly impacts the lakes within their watershed, so the next focus is to look at the lakes' reaction to these LULC changes. Water quality was previously defined as the state of a lake based on the level of eutrophication and salt content within the lake. But how does having higher levels of eutrophication and salt diminish the quality of water? The answer to this question is long and the affects salt and eutrophication have on a lake are still studied and contested to this day, but the following examples are a few ways that these factors decrease water quality.

With the increase in both urban and agricultural LULC, along with their associated runoff, the most apparent effect to the water quality of water bodies is through accelerated eutrophication. Eutrophication is a process where water bodies receive excess nutrients that stimulate excessive plant growth. However, the increase in volume and nutrient loads of the runoff accelerates this process (Correll 1998, 262). The two most important minerals found in urban and agricultural runoff contributing to this accelerated eutrophication are phosphorus and nitrogen. The reason for these two nutrients having such an effect on this process is due to phosphorus and nitrogen being the two principal nutrients limiting and influencing the growth of algae and vascular plants in freshwater systems (Smith et al. 1999, 181). Just as farmers fertilize an agricultural crop in order to promote plant growth, the same is applied for the role of nitrogen and phosphorus in water bodies, essentially fertilizing the aquatic system, resulting in the promotion of aquatic vegetation (Smith et al. 1999, 181). The accelerated eutrophication of freshwater systems leads to direct negative impacts of these water bodies, as well as to the community and residents adjacent to them.

One of the most notable impacts eutrophication has on the water quality of a water body is the increase of algae and cyanobacteria, also known as blue-green algae, along with the general increase in primary production. The increase of blue-green algae is especially dangerous to residents and animals of the area, in that some cyanobacteria produce compounds more toxic than cobra venom (Smith et al. 1999, 182). This toxicity increase of water bodies is primarily the cause for beach closings and prompting media attention within local and regional areas. The high primary production, occurring usually in the summer and fall, leads to another detrimental impact eutrophication has on water quality. The higher frequency in algal blooms leads to the creation of thick mats on the surface of the lake or just below. Problems arise when these algal mats are formed faster than they can be consumed because they decrease the amount of penetrable light aquatic plants deeper in the water column are able to receive. This directly affects these plants' productivity, and subsequently oxygen production, decreasing the amount of readily available dissolved oxygen for the rest of the aquatic ecosystem (Mylavarapu 2008, 1; Correll 1998, 262).

The decreased dissolved oxygen within the aquatic system directly transitions into another negative impact associated with eutrophication. At some point the algal mats become so thick that they die off. Decomposition of the mats requires lots of oxygen, so much oxygen that the lakes become too depleted in dissolved oxygen, a condition known as hypoxia (Mylavarapu 2008, 1). Hypoxia negatively impacts the biological community and activity within the ecosystem because it decreases the survival rates of aquatic life. This results in major shifts in species composition at all trophic levels and subsequent food web dynamics within the ecosystem, as some fish species, such as carp, can tolerate and even thrive in low dissolved oxygen conditions, while other species struggle (Mylavarapu 2008, 1; Correll 1998, 262).

Other, secondary effects that eutrophication has on the water quality of lakes include reduced water clarity, decreases in the perceived aesthetic value of the water body, taste, odor, and water supply filtration problems, elevated pH, along with an increase in the probability of fish kills (Smith et al. 1999, 182). Along with the profound effects phosphorus and nitrogen have on the water quality of receiving waters, the over enrichment of these nutrients can result in losses of the aquatic system's component species, as well as losses of the amenities or services that these systems provide (Smith et al. 1999, 182).

Eutrophication has substantial economic effects due to the impairment of aquatic resources. Economic effects from eutrophication include the degradation of clean water for drinking, irrigation, industry, transportation, recreation, fishing, hunting, support of biodiversity, and sheer esthetic enjoyment (Carpenter 1998, 561). The economic cost therefore comes in forms such as further or advanced filtration of the water for such uses, loss of tourism due to unaesthetic and low biodiversity waters, or in the form of decrease property values of lakeshore homes due to this eutrophication.

There are many variables determining the level of eutrophication a lake experiences, especially influx of P and N, but an important accelerant is temperature. Temperature favors eutrophication by providing more energy (in the form of sensible heat) to the lake. Higher energy levels can sustain higher amounts of life, making it easier for the algae to multiply and develop large populations. Warmer lakes see more frequent and more intense effects of algal blooms (Smith et al. 1999, 183). Eutrophication is partly a function of a lake's temperature, which is why it is such an important state variable when assessing water quality.

Eutrophication is not the only mechanism for decreasing water quality. Increasing amounts of chloride effects lakes in an entirely different manner. First and foremost, chloride in high concentrations is toxic to all aquatic life forms. Once chloride enters a lake, there is no way of removing it because it dissolves in the water. Chloride will eventually settle to the bottom of the lake and deposit in the sediment, but this process occurs at a rate slower than the influx of chloride. Limnologists at the University of Wisconsin-Madison observed a trend of chloride concentrations in the urban lakes growing each year by 1.5 milligrams per liter and a similar study of the Minneapolis/St. Paul urban lakes noticed a yearly increase of 1.8 percent (Magnuson 2014, 4; Novotny et al. 2008, 143). Salting roads in the winter may keep humans safe, but as it concentrates in the surrounding lakes, it endangers the water quality.

As the chloride content of a lake climbs, the lake is put at risk. Higher inputs of chloride not only increase its concentration, but also increases the density of the water. Terrestrial lakes rely on lake turnover every year to mix the water column, which redistributes the dissolved oxygen and other nutrients amongst the various layers. Water dissolved with chloride is denser than fresh water and sinks to the bottom, creating a density gradient between the top and bottom of the lake. In small urban lakes with chloride contents high enough, lake turnover ceases or is heavily impaired, resulting in loss of biodiversity as oxygen disappears from the bottom of the lake and nutrients and any present pollutants separate to the top (Novotny et al. 2008, 132). Lake turnover is a critical process for most terrestrial lakes and extremely high chloride saturation can impede this process, devastating the water quality of the lake.

Eutrophication and an increase in chloride are both detrimental and damaging to the water quality of aquatic systems. The diversity of negative impacts associated with these two phenomena are not only limited to physical and chemical disturbances, but also economic and social as well. These impacts elicit responses from multiple actors through multiple management practices, ranging from large scale mitigating infrastructure to common household applications.

Management Practices

Due to the ever-changing land-uses within watersheds, human responses to mitigate the effects of these changes have become more important now than ever before. The increasing amount of impervious surfaces, as well as increasing volumes of runoff, pollutes water bodies faster than ever. The management of storm water can be defined by the prevention of detrimental effects runoff that may impact the environment. These management practices can be structural or non-structural as long as they reduce the negative effects of runoff on water quality. Examples of management practices include picking up pet waste, reducing fertilizer use, keeping storm drains clean as well as creating infrastructure to reduce runoff. Some broad management goals include managing the quantities of water that gets into water bodies, reducing the temperature of runoff and limiting the amounts of nutrients and other pollutants (Delaware 2005).

On large scale urban planning projects, such as with universities, managing the quantities of water getting into water bodies is a great way of limiting the amounts of pollution. This can be done through various methods such as creating retention/detention ponds and cisterns. There are two types of retention/detention ponds, which are known as wet and dry ponds. Wet ponds are regulated to keep a minimum depth of 3 feet for water and are designed specifically for storm water management. This type of pond only discharges water when the level rises above an outlet point, primarily during large rainfall events. The consistent storage of water in wet ponds helps sediments to settle which then improves the water quality. Dry detention ponds, are areas made specifically for storm water runoff to flow into. These ponds remain dry until rainstorm events happen and then dry up again after a certain amount of time has passed, usually 48 hours. The way these ponds regulate water quantities are through outlet structures that drain water, at a slow pace, to nearby waterways (Delaware 2005). Cisterns manage the quantities of water via filtering water into some sort of catchment tank. The sources from where catchment water comes from are primarily rooftops of homes and public buildings. The cistern tank then has a draining mechanism on the bottom that can release water at certain intervals or whenever needed (Dillaha 1985, 741). Cisterns are commonly implemented to mitigate the first flush phenomenon.

Regulating the quantities of pollutants and nutrients entering water bodies is just as important, if not more important, than regulating the quantities of water entering lakes directly. The use of fertilizers in both urban and agricultural areas has caused an increased need for limiting the pollutants that get into the lakes. Some of these management practices include bioswales, rain gardens, infiltration basins, and riparian buffers. Bioswales are landscape practices with sloped sides and an abundance of thick, natural vegetation that filter out contaminants and soak up nutrients. They are designed specifically to infiltrate storm water runoff and reduce sediment and nutrient loads. Rain gardens are another mitigation practice that are used to filter out pollutants. They are very similar to bioswales because they contain native vegetation that is used to infiltrate storm water. The difference between the two is that rain gardens are made specifically to collect storm water from impervious areas, which is why they are seen at individual households. Infiltration basins are areas designed to allow storm water to soak into the ground and recharge groundwater supplies at the same time. If designed correctly, infiltration basins are one of the most effective management practices for trapping pollutants. In order for infiltration basins to work as desired, they should be located away from areas with high water tables or high contents of clay, as these prevent efficient infiltration. Riparian buffers refer to vegetative areas that lie along the shorelines of streams and other water bodies (Delaware 2005). These are often the last areas to absorb storm water and filter out pollutants.

Reducing the temperature of surface runoff is another important mitigation strategy. Temperature is a very important variable that factors into the eutrophication of lakes and other water bodies. Practices that aid in the reduction of temperature include retention/detention ponds, bioswales and cisterns. Retention/detention ponds and bioswales reduce the temperature by providing an area for the water to collect and cool before it actually reaches the lake (Appendix I, figure 17). Cisterns reduce the temperature of water similarly, by holding the water in steel or concrete tanks before letting it drain to other areas.

Aside from investing large sums of money in these infrastructures, there are simple management practices local residents can adopt to reduce point and nonpoint source pollution and promote water quality, commonly known as Best Management Practices (BMPs). Adoption of BMPs is a popular tactic for solving the inherent problem of nonpoint source pollution, which is widely scattered and segmented. The most common BMPs are: keeping storm drains clean, mulching grass and leaves, picking up pet waste, reducing lawn fertilizer and reducing road salt use. Keeping storm drains clean reduces the amount of leaves, an abundant source of phosphorus, that enter the watershed via storm drains. Mulching grass and leaves ensures that they will not end up in a storm drain or eventually in a lake, but also acts as a natural fertilizer. Pet waste is fortified with phosphorus, and when not properly disposed of, will eventually end up in the nearest water body. Reducing lawn fertilizers and road salt reduces two major sources of polluting chemicals that can easily enter surrounding water bodies through runoff (Brehm et al. 2013, 113-115; EPA 2003, 1). The commonality between all BMPs, especially these, is that they are actions working to curb current anthropogenic habits of relying on pollutants and a general apathy towards what runs off into the storm drain.

The idea of BMPs is relatively new and therefore not many scientists have studied their adoption and implementation. There is no doubt that adopting them will improve water quality, but who adopts them is the question scientists have yet to answer. The adoption of BMPs started with agriculturalists forming area coalitions to limit and improve their community water quality, strongly emphasizing the notion that BMPs are to be adopted as a community. Now the focus is shifting to include residential urban dwellers, and with it, an unchartered social reaction. A study by Brehm et al. in 2013 surveyed over 2,300 residents living in an at risk watershed in Illinois about their knowledge and practice of BMPs. Their findings concluded that the biggest indicator of BMP adoption is education and familiarity with them, stating that each increase on a likert scale of familiarity resulted in 30 percent higher likelihood to adopt BMP's. Other findings included that people with higher incomes are more likely to adopt BMP's and that women are more likely to properly dispose of grass and yard clippings (Brehm et al. 2013, 118). Engaging a community to improve water quality relies upon the education of its residents about best management practices, and that if educated properly, they are much more likely to adopt them.

Methods

As previously stated, the watershed surrounding Lake Mendota is dominated by urban and agricultural land-uses, making the lake highly susceptible to large amounts of polluted runoff. Thus, the current literature surrounding land-use and runoff is very applicable to this site setting, but additional information is required in order to create a holistic representation of all the factors influencing Lake Mendota's water quality. On site photographs, archival research, interviews of all the stakeholders in Lake Mendota's water quality, and surveys of local residents will all contribute to a better understanding of the relationship between land-use, runoff, and water quality.

Photographs

On site photography around the lake will be a very important tool for capturing images of the real world concepts and examples frequently discussed in the literature. Images of the specific LULCs around Lake Mendota will provide a means for comparing similar LULCs discussed in the relevant literature. In addition, photographs will be vital in helping the reader to visualize the site setting being discussed and how LULC has manifested in the watershed surrounding Lake Mendota. Classifying LULC as simply urban or agricultural does not allow for a complete understanding of the landscape because there can be a great amount of variation between the urban and agricultural areas, even if they are in the same LULC category. On site photographs will provide a means for making this distinction in the final research. The interpretation of on site photographs also assist in conceptualizing Madison residents' relationship to Lake Mendota. This includes how residents interact with the lake and the practices they have personally adopted to promote improved water quality. All in all, photographs will be the bridge that connects key concepts in the literature to a specific real world location.

Archival Research

Archival research will also be a crucial aspect of the research because it provides a chronological timeline of changes to LULC and water quality. Maps and aerial photographs of Lake Mendota and the surrounding watershed will directly show the changes in LULC and perhaps even water quality over a very long time span. In this way, one can deduct where and when LULC change was occurring and compare this with the water quality at this specific point in time. This provides a very clear and visible link between LULC trends and changes in water quality.

Reactions From Stakeholders in Lake Mendota's Water Quality

Reviewing the relevant literature surrounding LULC, runoff, and water quality and also using archival research to see how these factors have changed over time will form a narrative of how LULC in Madison has lead to changes in runoff and subsequent declines in water quality, but one piece of the story is still missing that requires further investigation. The current reaction from the local community members to declines in water quality has not been adequately assessed. Interviews are critical to the research project in that they investigate complex behaviors and motivations, provide insights into the differing opinions, reveal common themes across interviewees, as well as fill the gap in knowledge that other methods are unable to bridge efficaciously (Dunn 2000, 103). Interviews of the various stakeholders in runoff management and Lake Mendota's water quality will give a well-rounded view of what each actor is doing to limit polluted runoff, whether it is effective, and how they are all working together. The University of Wisconsin-Madison administration, the City of Madison, agriculturalists, regulatory institutions, researchers, local non-profits and Madison residents are all the relevant stakeholders involved in the discussion surrounding runoff and water quality in the surrounding watershed.

The University of Wisconsin campus is situated on a very large portion of Lake Mendota's shoreline, and thus a very important stakeholder to interview. Discussions with University administrators will shed light on the infrastructure that they have in place to prevent polluted runoff from entering the lake. It will also help to identify how the university interacts with other local stakeholders. This will also be the main benefit provided by interviewing employees of the City of Madison who plan and implement policies related to runoff and water quality. Discovering the role agriculturalists play in preventing polluted runoff into Lake Mendota through interviews will also be crucial because they are essentially the only stakeholders managing runoff from agricultural LULC, which also makes up the majority of LULC in the surrounding watershed. This makes agriculturalists one of the most important stakeholders in the water quality of Lake Mendota. For this reason it will be very insightful to receive an account of what exactly agriculturalists are doing to prevent polluted agricultural runoff from entering the lake.

Researchers have also played a significant part in the community's response to LULC and water quality change. Extensive research has been conducted by faculty members of University of Wisconsin-Madison to assess runoff effects on water quality and what mitigation strategies should be used to prevent polluted runoff from entering the lake. Without this wealth of knowledge, it would be very difficult to understand which factors affect Lake Mendota's water quality, which would prevent proper policies from being implemented. For this reason, it will be important to interview a researcher to see how they are contributing to the debate surrounding runoff and water quality.

Local non-profits focused on improving Lake Mendota's water quality have responded strongly to these changes occurring in the surrounding watershed. The main goal of these organizations it to disseminate information about water quality and best management practices to the local community and to facilitate communication between the various stakeholders. They are also heavily involved in raising funds for water quality projects and research initiatives. Discussing with these local organizations about their goals and strategies will be important for understanding the relationships between the various stakeholders because they are the primary driving force behind encouraging communication amongst the many actors.

Interviews of local residents will provide the final piece for understanding local responses to water quality decline. Private residential properties also make up a very large portion of Lake Mendota's shoreline, making the practices of residents very important to water quality. Additionally, runoff from the properties of residents all over the watershed has the ability to affect the lake's water quality. Interviews would provide insight into whether or not residents have adopted best management practices and which practices are most common. Each other category of stakeholder also contains residents; so interviewing this group will also provide a very informative overview of the entire community's reaction to water quality decline.

Surveys of local residents will be the final research data gathering method. The surveys will focus on the best management practices adopted by local residents and their personal value of Lake Mendota's water quality. This will supplement resident interviews with statistics, which will give a more holistic representation of the community's involvement in best management practices to reduce polluted runoff into the lake. It will also allow for a geographical comparison of which areas and demographics are more receptive to adopting best management practices on their properties. The management practices discussed in the survey are leaf/grass clipping mulching, composting, building rain gardens, keeping storm drains clear, picking up pet waste, using rain barrels, and reducing fertilizer and road salt use (Brehm et al. 2013). Once again, since residents are members of every other stakeholder category, surveying them will give the best overview of the entire community's response to water quality decline.

Results

Introduction

The data for this research is a combination of archival sources, stakeholder interviews, photographs, and surveys of local residents within the watershed. The goal of archival data is to provide a visual record of LULC change around Lake Mendota depicted in maps and aerial photographs. Stakeholder interviews concentrate on identifying how each individual actor is promoting Best Management Practices (BMPs) to prevent polluted runoff from entering Lake Mendota. Interviews also help reveal the relationship between the various stakeholders. Personal photographs taken by the researchers are also an important aspect to the research data. Photographs will provide a current image of LULC around Lake Mendota. They also will provide a physical record of stakeholders implementing various BMPs. Lastly, survey data collected from residents will shed light on the opinions of residents regarding Lake Mendota and the role they play in maintaining its water quality. All of this data combined will provide a more holistic understanding of how LULC change has manifested around Lake Mendota and the community's response to the effects of LULC change on water quality.

Archival Data: Aerial Photographs and Maps

The primary function of archival data will be for a visual record of LULC change around Lake Mendota. LULC change and its effects on water quality are central to our research so it is important to establish that significant LULC change has indeed occurred. For this reason historical aerial photographs of the land around Lake Mendota and maps of the land surrounding Lake Mendota will make up the bulk of the archival data relevant to this research. Aerial photographs and maps are very useful because they allow a much clearer understanding of the extent of LULC change and what this actually looked like, as opposed to a simple written account of LULC change. The following photo's were taken from appendix I and can be seen again in this appendix located after the works cited section.

Figure 1

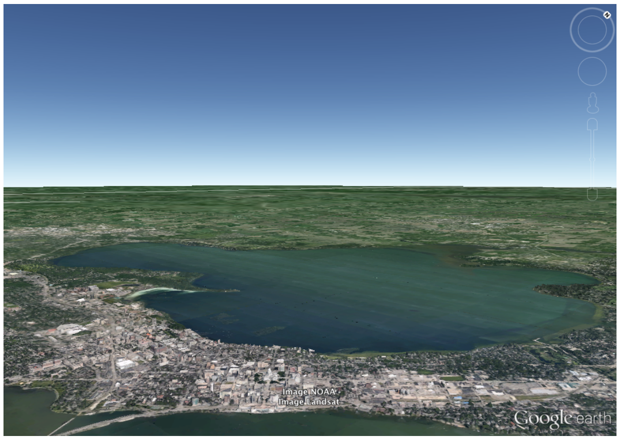


Figure 2

Figure 1 is a realistic and representative painting of the Madison area in 1908. It clearly shows how the urban areas of Madison are almost entirely confined to the isthmus, leaving much of land around Lake Mendota still heavily forested. Today, the urban areas of Madison have expanded greatly around the shores of the lake, increasing the total amount of impervious surfaces (Figure 2).

Figure 3

Figure 4

Figure 3 is another important photo that expresses how little urbanization/impervious surfaces there were in Madison a hundred years ago. Pre 1900, the lake is still mostly surrounded by forest. Present day, this area contains the band practice field, soccer field, parking lots and some forested areas within the campus. Again, the increase of impervious surfaces due to urbanization is evident by comparison of Figures 3 and 4.

Figure 5

Figure 6

Located on Observatory Hill, Washburn Observatory and the Director's house can be seen prior to the 1900's (Figure 5). The land is predominantly wooded along the lakeshore with little development. Today, this area contains student housing, parking lots, streets, and campus buildings making much of this land impervious pavement and susceptible to runoff (Figure 6).

Figure 7

The Conklin Ice House, located where James Madison Park is today, remained operational until 1936. Lake Mendota ice was in high demand before refrigeration was invented because it was free of pollutants and was considered thicker than surrounding ices. Through this image, it is revealed that the water quality of Lake Mendota was of much better quality than of present day.

Figure 8

This map again highlights how small the urban population once was in the Madison area in 1924, spanning only the isthmus and a small section west of the isthmus, but not reaching past Picnic Point. Maple Bluff, a well-developed neighborhood development today, is still a wooded area.

Figure 9 **Figure 10**

Figure 9 is a photo showing the Wisconsin Historical Society, Bascom Hall, Science Hall on campus in the 1920's. It can be seen that the majority of the shoreline along Lake Mendota is primarily wooded and undeveloped, whereas today it is much more developed and allows for more runoff (Figure 10).

Figure 11

Figure 12

Figure 11 is an aerial view of Eagle Heights in 1958 while the apartments were under construction. This photo shows Lake Mendota in the upper left hand corner with farmland surrounding it. Today, this area is primarily residential, with an increase in housing structures, but does maintain some of the trees and undeveloped area (Figure 12).

Figure 13 (top) and Figure 14 (bottom) provide an example of the intensification of agriculture within the Lake Mendota Watershed. Figure 13 is a photo from the Wisconsin Historical Aerial Image Finder from 1937. It shows how agricultural land is confined mainly to small fields. Figure 14 is the present day Google earth image of the same location. This photo shows large agricultural fields and the intensification of agriculture. The corporate farm in figure 14 shows the industrialization that occurred in the agricultural industry. Both industrialization and intensification of agriculture lead to increased storm water runoff and pollutants.

Stakeholder Interviews

Stakeholder interviews are another important aspect of the data pertinent to this research because it is a testament to the community's response to changes in water quality. Interviews are also useful because they reveal the relationships between stakeholders and how all the specific actors are working together to promote the water quality of Lake Mendota. All in all, this allows the audience to have a better understanding of how this community operates as a whole. Five interviews were conducted throughout the course of the research project.

The first interview was conducted with Gary Brown and Rhonda James who are part of the Campus Planning and Landscape Architecture department at the University of Wisconsin-Madison (Appendix II, Interview A). Gary Brown and Rhonda James supplied valuable information about the University's strategies for dealing with polluted runoff on Campus land. This first interview established a firm foundation for further research. Urban and agricultural LULC was identified as the primary factors affecting Lake Mendota's water quality. It is noteworthy though that the interviewees saw storm water runoff from urban areas as a greater threat than the runoff from agricultural fields. Gary Brown and Rhonda James are also of the opinion that water quality has improved, but that there is further room for improvement. This seems to be a common sentiment throughout the community. It is also important that during this interview there was mention of other community stakeholders, specifically non-profit organizations, and the role they play in promoting Lake Mendota's water quality. Obviously, the university recognizes the very important role non-profit organizations like the Clean Lakes Alliance play in uniting the community to address issues of water quality. While this was given from the University's own, and perhaps biased, point of view, it appears that they are doing a great deal to implement infrastructure and management strategies that reduce polluted runoff.

The second interview, conducted with Don Lukes, a local resident along Lake Mendota, provided personal accounts on LULC changes along Lake Mendota over a span of 30+ years (Appendix II, Interview B). He also demonstrated some of the best management practices he uses and how his neighbors have followed suit. Two of the BMPs that Don Lukes implemented included buffer strips of vegetation (Appendix I, figure 18) and a rock wall (Appendix I, figure 19) that helped to prevent erosion and filter out nutrients. The information obtained from Don Lukes will supplement the surveys for a greater understanding of how local residents and property owners have responded to declines in water quality. Don Lukes and his status as a long-term resident along the lakeshore was able to provide an insightful and historical account of how he, as a resident, has addressed the problem of polluted storm water runoff. Like other interviewees, he believes that water quality has improved greatly throughout his life in Madison. He also spoke about the need for greater coordination amongst stakeholders so that residents can cooperate on projects and hold one another accountable for not participating. This draws into question whether one can view residents as a cohesive stakeholder group because there is a great amount of variation between residents' interest in and willingness to participate in BMPs. Once again, the importance of non-profits is mentioned, specifically the CLA, in promoting communal actions that collectively address Lake Mendota's water quality. Don Lukes did express his concerns about both urban and agricultural runoff into the lake, but highlighted his fear of the possible negative effects that may arise from increased residential development along the shoreline. It was very insightful to see how Don Lukes had come to learn about BMPs and how he decided to implement them on his own. This is important because it shows the ways in which other stakeholders can encourage residents to adopt BMPs and that they are willing to do so if given the proper resources and information.

The next interviewee was John Magnuson, Emeritus of the Center for Limnology at UW-Madison (Appendix II, Interview C). John Magnuson and his background in limnology offered extensive information on the factors affecting Lake Mendota's water quality. He also stated his opinion regarding various responses to water quality decline throughout the community and identified areas for improvement. John Magnuson's testimony will be viewed as separate from that of the UW-Madison staff from the Campus Planning and Landscape Architecture because his point of view was given as that of a resident, academic, and researcher. John Magnuson, a retired zoology professor and former director of the Center for Limnology at the University of Wisconsin Madison, was able to provide insight into the current water quality trends and impacts on Lake Mendota. His long-term research and observations on Lake Mendota reveal the lake's stubbornness to change. Total phosphorus within the lake is decreasing, but at a slow rate, while chloride is increasing and up to 50 mg/L. John also noted how the ice cover of the lake is a month shorter than 150 years ago, a trend affecting the winter lake activities of the community. Parts of the lake that have experienced a greater change in water quality are the wetlands and shallow waters. Wetland change is due to an increase in chloride use from the University and City's winter salting, which negatively impacts the wetland's ecosystem services in the filtration of nutrients. Shallow water change is due to algae washing up onto shore, causing beach closing. John believes it is hard to change people's way of behaving when it comes to best management practices to ensure the improvement of the lake's water quality. He believes there needs to be a functional network including all responsible actors, as "it takes a village to raise a child, and a community to clean a lake." This is significant to our research in that this functional network idea has resonated and came up in a number of our conducted interviews.

Greg Fries, the City of Madison sanitary and storm sewer principal engineer was another useful source who gave an overview of what projects the City of Madison is undertaking to ensure Lake Mendota's water quality is upheld (Appendix II, Interview D). Like John Magnusson, Greg Fries also provided more insight into the specific pollutants and land use practices that are affecting Lake Mendota's water quality. Lastly, he was able to provide a more understandable explanation of the series of complex water quality regulations that the City must abide by. Greg Fries makes a valuable source because he is able to provide an account of the city's role in promoting water quality, which was almost never discussed by other interviewees.

Compared to other stakeholders, the city is confronted with many problems in regards to reducing polluted runoff and has to develop a very diverse set of strategies to deal with this complex problem. Despite all that the city is doing, Greg feels that their contribution to pollutant reduction (phosphorus) will only have a limited impact because of the lack of regulations placed upon agriculturalists. LULC devoted to agriculture produces about 70% of the phosphorus in the watershed and all the other areas contribute the remaining phosphorus. It is very difficult to make large reductions in phosphorus when there are no regulations placed upon those who also produce the most pollutants. This interview was also insightful due to the fact that the city coordinates with almost all of the community stakeholders. The most interesting interaction Greg discussed is the adaptive management plan that is being implemented by the City, CLA, and members of Yahara Pride. With this adaptive management scheme, the city looks to pay agriculturalists to develop strategies that reduce the amount of polluted runoff they are producing. This requires a very high amount of coordination and planning, which shows the ability of stakeholders to work together to pursue meaningful projects. Outcomes of adaptive management could be monumental because this is the first time this strategy has been implemented in the U.S.

The final interview with Paul Dearlove and Rachel Fossum of the Clean Lakes Alliance (CLA) provided information about non-profit involvement in the community response to the declines in Lake Mendota's water quality (Appendix II, Interview E). Since no agriculturalist offered to take part in an interview, Rachel Fossum's information is valuable to this research. Rachel Fossum coordinates between the CLA and members of the agriculturalist organization Yahara Pride, and was able to give insight into the strategies being developed by agriculturalists to limit the amount of polluted runoff from their lands. Paul Dearlove spoke of the operations of

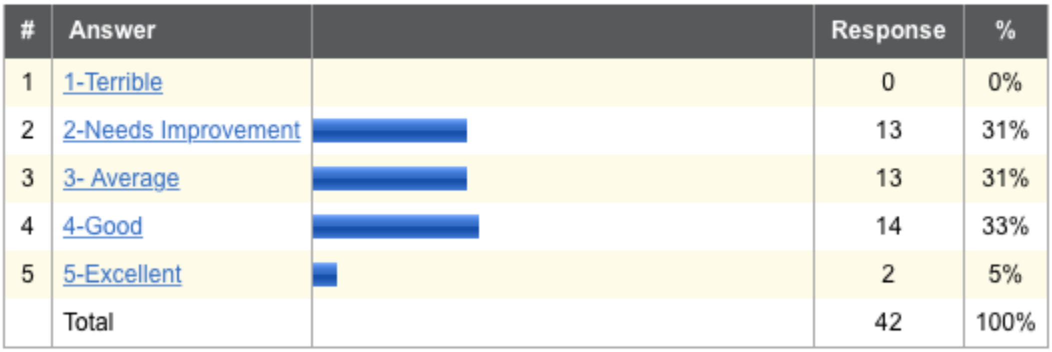
CLA and how their main goal is to create a dialog between the stakeholders in Lake Mendota's water quality, so that the entire community is able to work together to improve the state of local lakes. The interview of Paul Dearlove and Rachel Fossum of the CLA was extremely important to this research because of the way in which the CLA's mission single handedly encapsulates the community's response to declines in Lake Mendota's water quality. The information gleaned from this interview is also very applicable to this research because the goal of the CLA is very similar to the goal of this research, to assess the community's response to water quality decline and to find strategies for encouraging stakeholders to work together towards a common solution. CLA actively coordinates with nearly all of the stakeholders in Lake Mendota's water quality and one of their primary functions is to encourage dialog and collective strategies between the various actors. One way in which CLA accomplishes this goal is by being an intermediary between the City and Yahara Pride in order to ensure the projects success. After speaking to other interviewees, it is clear that they support the mission of the CLA and feel that it is making a very valuable contribution to addressing water quality decline. From the information provided, it seems that the work of the CLA can be expanded upon and that their work is the most feasible strategy for addressing water quality as an entire community.

Property Owner Surveys

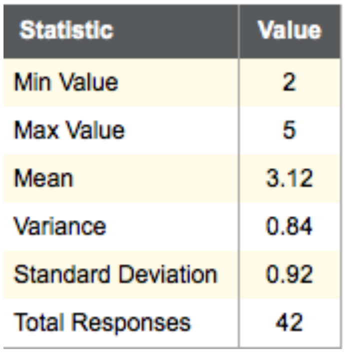
The survey questionnaire for our research project consists of four questions aimed at gauging how the residents of Lake Mendota view the water quality and their level of engagement with common BMPs. In addition, the surveys were intended to provide further analysis of the communal response to Lake Mendota's water quality decline. These surveys were distributed door-to-door in varying neighborhoods surrounding the lake. The overall goal of the survey is to provide a quantitative analysis of the attitudes the residents of Lake Mendota hold toward the lake. The majority of the questions asked provide nominal data of BMPs used. The ordinal data within the survey comes from Likert Scales asking residents to rate the water quality and familiarity with BMP’s. In total, 42 surveys were collected given the time and resource constraints. Aside from the 4 questions, the neighborhood where each survey was collected was recorded, so that a Fischer’s Exact test can establish the difference between neighborhoods knowledge and use of BMPs around the lake. Further analysis looked at the statistical significance between residents who said they are ‘moderately familiar’ with BMPs and their level of engagement.

Question 1: Please rate the quality of Lake Mendota:

Response totals:



#	Answer		Response	%
1	1-Terrible		0	0%
2	2-Needs Improvement		13	31%
3	3- Average		13	31%
4	4-Good		14	33%
5	5-Excellent		2	5%
	Total		42	100%



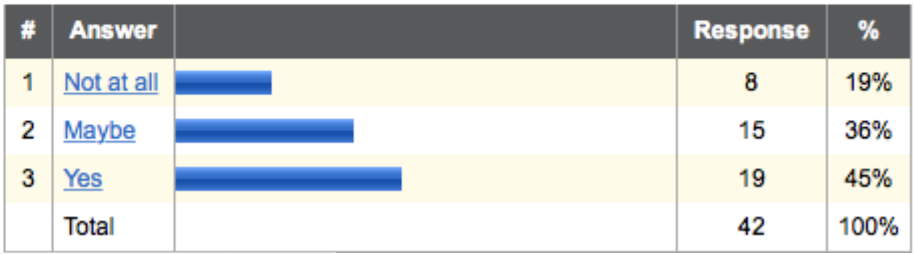
Statistic	Value
Min Value	2
Max Value	5
Mean	3.12
Variance	0.84
Standard Deviation	0.92
Total Responses	42

Question 1 results:

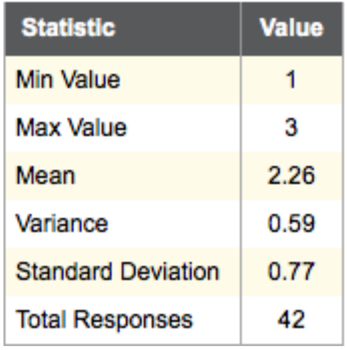
The mean value for the responses is 3.12, meaning that the collective attitude of the survey takers towards Lake Mendota water quality is that is it slightly above average, but not necessarily good. The mode of responses was 3 and 2, meaning the majority of people responded with ‘average’ or ‘needs improvement.’ Not one resident said that the water quality was ‘terrible,’ and 2 said that the water quality was ‘excellent’. With a standard deviation of 0.92 and a variance of 0.84, it is evident that most people feel the water quality is between ‘good’ and ‘needs improvement,’ with the results leaning towards ‘good.’ This data highlights the general attitude of the public that the water quality is ok, and not aware of the current poor condition of the Lake.

Question 2: Would you be willing to pay a small fee to make sure that Lake Mendota’s water quality was upheld/improved.

Response totals:



#	Answer		Response	%
1	Not at all		8	19%
2	Maybe		15	36%
3	Yes		19	45%
	Total		42	100%



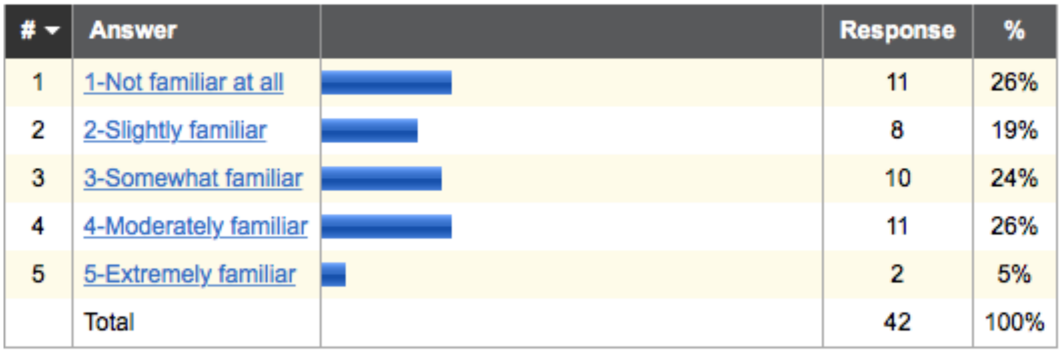
Statistic	Value
Min Value	1
Max Value	3
Mean	2.26
Variance	0.59
Standard Deviation	0.77
Total Responses	42

Question 2 results:

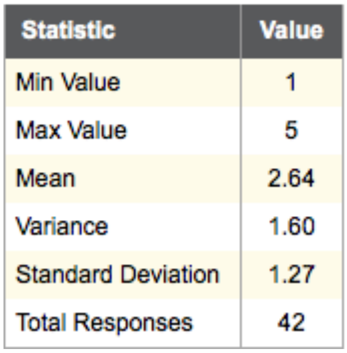
The mode was 3, meaning that most responses were indeed a ‘yes.’ With a standard deviation of 0.77 and a variance of 0.59, most of the responses were between ‘maybe’ and ‘yes,’ with only 19 percent of the respondents saying they would not be willing to pay a small fee. These results tell us that among the respondents, there is a general willingness to improve the water quality of Lake Mendota in a monetary manner.

Question 3: How familiar are you with Best Management Practices to protect Lake Mendota’s water quality?

Response totals:



#	Answer		Response	%
1	1-Not familiar at all		11	26%
2	2-Slightly familiar		8	19%
3	3-Somewhat familiar		10	24%
4	4-Moderately familiar		11	26%
5	5-Extremely familiar		2	5%
	Total		42	100%



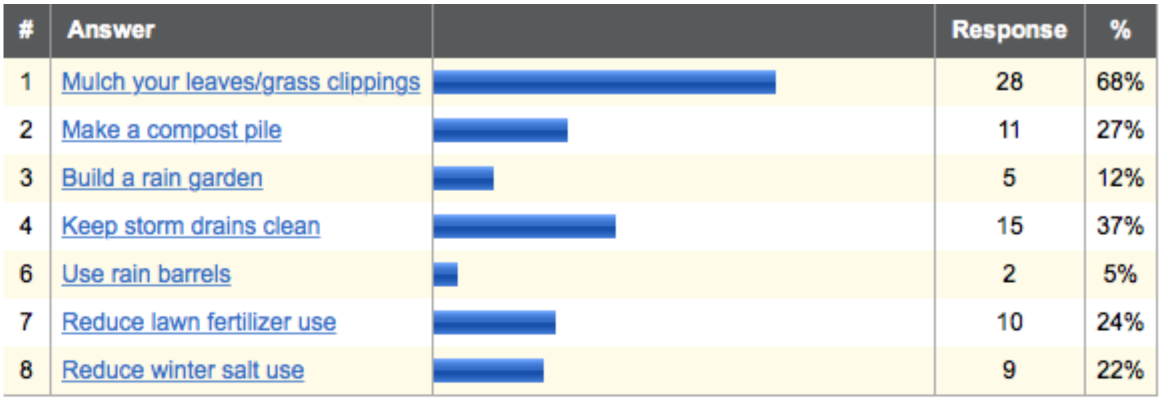
Statistic	Value
Min Value	1
Max Value	5
Mean	2.64
Variance	1.60
Standard Deviation	1.27
Total Responses	42

Question 3 results:

For this question, the mean response is 2.64, putting the level of familiarity just below somewhat familiar. The variance is 1.6 and the standard deviation is 1.27, showing that most of the responses are between the ‘slightly familiar’ and ‘somewhat familiar’ categories. The mode responses are 4 and 1, meaning that most people selected ‘unfamiliar’ or ‘moderately familiar.’

This gives the distribution of familiarity a negative skew, which is no surprise since the mode is 4, the mean 2.84, a variance of 1.47 and a standard deviation of 1.21. This highlights the varying nature of knowledge of BMPs, and that although there are people who say they are ‘moderately’ familiar with BMPs, the majority of people are only ‘somewhat familiar’ or less.

Question 4: Do you engage in the following activities? Please mark all that apply.



#	Answer	Response	%
1	Mulch your leaves/grass clippings	28	68%
2	Make a compost pile	11	27%
3	Build a rain garden	5	12%
4	Keep storm drains clean	15	37%
6	Use rain barrels	2	5%
7	Reduce lawn fertilizer use	10	24%
8	Reduce winter salt use	9	22%

Question 4 results:

Since this question is categorical, and the numbers assigned to each BMP are completely arbitrary, descriptive statistics do not help much in describing the data. Here, what is important to look at is how many people are engaging in various BMPs. From the 42 respondents, there were a total of 80 BMPs circled, meaning that the average resident engages in 1.9 BMPs. Mulching grass and leaves is the most common BMP, with the least being collecting storm water via rain barrels or a rain garden. The second most common BMP is keeping storm drains clean, with only 15 residents practicing.

Discussion

By comparing archival photographs with current day images, a clear record of both urban and agricultural LULC change in the Lake Mendota watershed can be established. This expansion of urban areas coupled with the intensification of agriculture has lead to an overall decline in the water quality of Lake Mendota since the arrival of European settlers in the mid 19th century. As the decline in Lake Mendota's water quality becomes more apparent, there have been a variety of responses from all the individual stakeholders in order to address the state of the lake. Our interview of all the stakeholders in Mendota's water quality, allowed for an assessment of the community response to water quality decline. By analyzing the various responses from stakeholders, it presents an opportunity to evaluate the extent to which they have all collectively responded to the threats facing Lake Mendota. Ultimately this will reveal what adjustments and improvements can be made in order to form a more unified and collective response to water quality decline in the watershed. Four common themes were present in all the stakeholder interviews: urban and agricultural LULC change pose a major threat to Lake Mendota's water quality, Lake Mendota's water quality is improving, agriculturalists are one of the greatest constraints on future improvements to water quality, and lastly that a collective response to water quality decline will be essential if water quality improvement is to continue. Property owner surveys of residents in the Lake Mendota watershed supplemented the information gathered in interviews and highlighted the needs for greater educational and informational opportunities to inform all the residents and stakeholders about water quality and what they can personally do to improve it. In order to fully understood the entire community's response to water quality decline and to form a more collective response, further research will need to take the form of more stakeholder interviews, property owner surveys, and water samples.

Archival record of LULC change that leads to water quality decline

Comparing archival photographs of the Madison area with current images confirms that urban LULC is increasing. Comparing Figure 5, a photograph of the Washburn observatory circa 1900 with Figure 6 (Appendix I), a current day image of the same area in 2014 exemplifies this trend of expanding urban LULC that has been occurring throughout the last century. In Figure 5, one can see that only one urban structure is present besides the Washburn observatory, and the land is still primarily woodland and grassland, with few impervious surfaces. Appendix I, figure 6, a current day image of the area acquired through Google Earth, contains significantly more buildings and impervious surfaces than figure 5 in appendix I. This captures the trend of urbanization, and an accompanying increase in impervious surfaces, that has been occurring in Madison for over a century. There is clear evidence that an increase in impervious surfaces leads to increased runoff and eventually water quality decline (Goonetilleke et al. 2005, 31; Ren et al. 2003, 657; Sun et al. 2014, 272; Brehm et al. 2013, 114; Amin et al. 2014, 120; Lee et al. 2009, 80; Tong et al. 2002, 378). Thus, one can assume that the increase in urban LULC exemplified in the progression from figure 5 to figure 6 (Appendix I) contributed to declines in Lake Mendota's water quality decline.

The urban LULC change map, appendix I figure 23, conveys the same trend of expanding urban areas by overlaying three LULC maps from 1904, 1959, and 2013, which demonstrates the extent to which urban LULC has expanded in Madison during the last century. It can clearly be observed that urban LULC continues to expand outwards from the Madison isthmus to a point where urban LULC constitutes a very large portion of the LULC immediately around lake

Mendota. In addition to expanding urban areas, the graphic shows where wetlands have been filled in for urban LULC since 1904. The filling in of wetlands for urban purposes is significant because wetlands provide important ecosystem services for watersheds, such as filtering out pollutants contained in runoff (Acreman and Maltby 2011, 1347). Since 1904, a sizeable amount of wetlands have been converted for urban LULC. This only exacerbates the negative effects on the watershed from expanding urban areas and increases in impervious surfaces, due to declining availability of wetlands to filter out harmful pollutants before they reach Lake Mendota. If this trend of expansion continues at the same rate as shown by the LULC change map, then the pressure placed on Lake Mendota from polluted runoff will only increase in the future. This could potentially be a significant obstacle that prevents further water quality improvement.

Archival and current image comparisons also reveal agricultural LULC trends around Lake Mendota. Appendix I, figure 13 from 1937 displays an area containing several agricultural fields accompanied by a scattering of small farm houses. The current day image of this same area, appendix I, figure 14, shows how these small fields have been replaced by larger agricultural plots. A small farm house in the center of the 1937 image has been replaced by a much larger industrial agricultural compound that houses more than 2,000 head of cattle. This coevolution of expanding fields and facilities demonstrates the intensification of agricultural that has been occurring since the arrival of European settlers. Many studies establish a clear link between the intensification of agricultural LULC and water quality decline (Nielsen et al. 2012, 1189; Cox et al. 2006, 56; Liu et al. 2013; Sun et al. 2014, 285). For this reason, the changes to agricultural LULC in the Lake Mendota watershed that is observed in these photographs undoubtedly contributed to an increase in the amount of pollutants entering the lake.

Declines in Lake Mendota's water quality can also be observed by comparing archival photographs with current day images. Appendix I, figure 7 of the Conklin ice house in 1912 show workers utilizing Lake Mendota's ice for refrigeration. At this point in time, the water was considered clean enough for consumption and to preserve food. Since 1912, changes in LULC have led to gradual declines in water quality to the point where images such as figure 20 in appendix I are quite common in the non-winter months. Appendix I, figure 20 captures algae washed up on the shoreline of Lake Mendota. This algae is a result of increased nutrients entering the lake from both urban and agricultural LULCs (Correll 1998; Smith et al. 1999). Algae has caused beaches on Lake Mendota to close, due to the harmful effect it has on humans and how aesthetically unpleasing it is. This stands in stark contrast to the 1912 image of the Conklin Ice House, where the lake was so clean that residents were able to use the ice for human consumption. With the current state of the lake, this would obviously no longer be possible.

Stakeholder Interviews: the Need for a Collective Response to Water Quality Decline

With this established record of LULC change and the subsequent decline in water quality, it is clear that Madison is confronted with a problem that needs to be addressed to ensure the health of the lake so that it can be used as a valuable economic, recreational and cultural resource far into the future. Unsurprisingly, stakeholders in Lake Mendota's water quality have elicited various responses to water quality decline and are striving to make improvements. Stakeholder interviews provide an opportunity to see the exact response from each party and the extent to which stakeholders coordinate with one another to address the problem. By looking at common themes amongst all various stakeholder responses, it also allows for a more holistic understanding of what common ground can be found between individual actors, so that they can work towards a more unified effort to improve the condition of the watershed. The common themes observed when interviewing stakeholders are that: urban and agricultural LULC significantly impacts water quality, all stakeholders incorporate some sort of strategy to reduce the amount of polluted runoff entering the watershed, water quality is improving, there needs to be more cooperation amongst stakeholders if water quality improvement is to continue, and non-profits will instrumental in formulating a collective response to the issues confronting the watershed.

Archival photograph and current day image comparison along with appendix I, figure 23 already confirms that urban and agricultural LULC have expanded and intensified in the Lake Mendota watershed. All the literature indicates that this has a strong effect on water quality, but due to the constraints of this research there is no way to obtain hard data that shows a direct decline in water quality in the watershed, outside of archival and current day image comparisons. The interviewees, all experts on the effects of runoff on water quality, confirmed that urban and agricultural LULC negatively impacts the lake. Stakeholders especially stress the importance of agricultural LULC and how this LULC is responsible for the largest contribution of polluted runoff in the entire watershed. Since all the stakeholders are aware of the impacts of specific LULCs on water quality, they have all adopted various strategies that look to decrease the amount of polluted runoff entering the watershed.

Most stakeholders concentrate on using both runoff infrastructures along with BMPs to reduce polluted storm water runoff from reaching Lake Mendota. The University of Wisconsin-Madison campus and the City of Madison are both utilizing new infrastructure to reduce the amount of urban storm water runoff in the watershed. For example, appendix I figure 17 shows a bioswale and appendix I figure 21, the education building green roof on the UW-Madison campus. Both filter out pollutants as well as reduce the water temperature of urban storm water runoff. The City of Madison has implemented infrastructure such as bioretention ponds, rain gardens as well as putting in more storm drains to alleviate pressure from other drains. Although governmental institutions are implementing storm water infrastructures, there are BMPs that other stakeholders enact to reduce the amount of polluted runoff entering Lake Mendota.

Stakeholders that are implementing BMPs include UW-Madison, the City of Madison as well as residents. UW-Madison is already making large contributions towards reducing polluted runoff with storm water infrastructure but they also implement leaf collection throughout campus. The leaves that get collected are then composted and used as fertilizer on campus or agricultural fields. The City of Madison also promotes a leaf collection program that comes several times during the fall season to residential areas (Appendix I, figure 22). The city also creates rain gardens and buffer strips to filter out pollutants as well as stressing the need to keep storm drains clean. Surveyed residents also indicated that they engage in various BMPs. These include building rain gardens, picking up pet waste, reducing salt and fertilizer use, keeping storm drains clean, mulching leaves/grass clippings and creating buffer strips (Appendix I, figure 18). John Magnuson stressed the need to use BMPs such as reducing salt and fertilizer use as well as a consistent leaf collection program. Through the various interviews, stakeholders hinted at BMPs that could be implemented and it appears that local residents are already implementing some of these.

Some stakeholders use education to show others how they can also reduce their contributions of polluted runoff. Education is key in having the entire community participate in BMPs that will help address the runoff and water decline problem. Every interview that was conducted mentioned the importance of the Clean Lakes Alliance (CLA) in educating the community. Don Lukes reiterated this fact by saying “a community and joint effort approach has increased, everyone has done good, especially the CLA by bringing various actors together." When a local resident, Don Lukes, was asked how he learned about BMPs and how to implement them on his own property he responded, "You just kind of learn by osmosis" (Appendix II, Interview B). Such remarks show that education is occurring throughout the community, but it is obvious that Lukes was forced to learn about BMPs very gradually and on his own initiative. This highlights a need for more educational outreach so that residents do not have to go to great lengths to learn about BMPs. In the end, this will ensure much higher participation in these practices. The interview with John Magnuson reiterated the need for educational opportunities through the CLA (Appendix II, Interview C). He singled out the list that the CLA created of 77 steps to clean the lakes and believes that this list should be condensed into 10-20 practices that the entire community can focus on, instead of a very broad list. Once again, this signifies the presence of educational materials, but they need to be improved upon with more focus in order to encourage greater participation from Madison residents. The Clean Lakes Alliance also recognized the need for educating people and this is evident in the interview (Appendix II, Interview E). "It all comes down to a lack of education. All of the ignorance and misconceptions and apathy can be traced to people simply not knowing enough. 9/10 times when the CLA is able to educate people about how to protect the lakes, they can get them to be supportive of it." All in all, stakeholders like the CLA are indeed educating the public, but the reach and accessibility of educational opportunities will need to increase in order to encourage more participation.

While these interviews show that all the interviewed stakeholders are in fact adopting strategies to improve the state of Lake Mendota, but it is clear that the response has been largely fragmented. Each stakeholder appears to be working in their own sphere of influence, with only a few examples of cooperation amongst stakeholders. The interview conducted with UW planning and management gave insight about how the water quality is actually improving and much of the credit for the improvement was given to non-profit groups educating people, such as the CLA (Appendix II, Interview A). Don Lukes stated that he has observed an increase in collective responses to water quality decline and that it has created very positive results (Appendix II, Interview B). This shows great promise, but John Magnusson clearly stressed that if improvement in water quality are to continue, stakeholders will have to find even more ways to come together to address the problem more collectively (Appendix III, Interview C). While there are examples of cooperation between stakeholders, it will need to increase in order to achieve the best possible result.

The various strategies of storm water infrastructure, BMPs, and education have led to an observable improvement in water quality, but more can still be done. For water quality improvements to continue, the interviewees stressed the need for more cooperation amongst the various stakeholders, especially with the agricultural sector. The agricultural sector is mentioned as the stakeholder that can do the most to continue water quality improvements. Greg Fries reiterates this idea because the agricultural sector is responsible for 70% of all the phosphorus that enters the lake. He understands that the 30% of phosphorus coming from urban land can be reduced, but that no real effect will occur until the major phosphorus contributor, agriculturists, improve their methods to reduce the amount of polluted runoff from their lands (Appendix II, Interview D). Greg Fries stated that the City of Madison looks to overcome this problem by implementing the adaptive management program. In short, adaptive management provides monetary incentives to agriculturalists to adopt responsible practices that reduce the amount of polluted runoff they are contributing into the watershed. This is the first time a program like this has been implemented in the U.S., and it is an example of one of the first major attempts at cooperating along side agriculturists to address the problem of polluted runoff. Gary Brown and Rhonda James agree that runoff due to agriculturists needs to be addressed because the other stakeholders have all implemented strategies while the agricultural sector remains primarily unchanged (Appendix II, Interview A). The adaptive management strategy that Greg Fries mentioned in his interview is the first step to getting the agricultural industry on board with the rest of the community, but even more stakeholders will need to cooperate with the agricultural sector to progress water quality even further.

In order to reach a collective response from all stakeholders to increase water quality, non-profits, such as the CLA, are the key. Paul Dearlove of the CLA stated "the goal of the CLA is to build a community of people to go out into their influence spheres and spread the word." (Appendix II Interview E). The role of non-profits in promoting a more collective response to water decline is essential captured in this quote. Rather than being directly involved in water cleaning projects, the CLA is much more concerned with bringing all the stakeholders together and to encourage cooperation amongst them. By doing this the CLA places the task of improving Lake Mendota's water quality on the entire community, who when working together, have much more resources and are much more capable of addressing the problem. As John Magnusson said, if future improvements are to be made, there will need to be a more unified response. The CLA strives to be the stakeholder to fill this gap.

Surveys

The overall goal of the survey is to quantify the residents of Madison's opinion about water quality issues, level of education about Best Management Practices as well as their engagement in them. In total, there are 42 responses, coming from a variety of Madison and Middleton neighborhoods to represent a variety of Lake Mendota's residents. Using descriptive statistics and Fisher's Exact Tests, the analysis of the survey results exemplify the need for more public outreach programs to promote education and increased engagement in BMP's.

The first question asked residents to rate the water quality of Lake Mendota (Appendix III, figure 2). Of the 42 respondents, none believe the water quality is terrible, but only 2 respondents marked "excellent." The mean response was "average," and low standard deviations and variances suggest that most residents feel the same way. This response mirrors the opinions of many of the stakeholders, especially Gary Brown and Don Lukes, in that Lake Mendota's water quality has improved, but could still be further improved.

The survey also asked residents to rank their familiarity with BMP's on a scale of unfamiliar to extremely familiar (Appendix III, figure 6). The most common responses were "unfamiliar" and "moderately familiar," with 11 each, but a mean of 2.64 and a standard deviation of 1.6, it is clear that most people are between "unfamiliar" and "somewhat familiar." Of the 42 respondents, only 2 said "extremely familiar." As a whole, the results of this question highlight another commonality of the stakeholder interviews in that there is a general lack of education amongst the public about BMP's. Both Paul Dearlove of the CLA and Don Lukes stressed the need for more public education regarding BMP's. Don Lukes is a man well versed in BMP's and almost every aspect of his property employs one, but when asked how he learned about all of them, he replied, "You just kind of learn by osmosis." The fact that Don Lukes is familiar with BMP’s through his own research reinforces the survey results, exposing a hole in the amount of public outreach regarding BMP education.

Along with asking resident’s familiarity with BMP’s, they were also asked to indicate which BMP’s they currently practice (Appendix III, figure 8). The most commonly practiced BMP is mulching leaves/grass clippings, with about 68 percent of the respondents doing it. One common explanation residents had for practicing this BMP is that their lawn mowers came with mulching capabilities and that it is much easier to mulch the grass/leave instead of bagging and disposing of them. The second most commonly practiced BMP is keeping storm drains clean, but only 37 percent of residents claimed doing so. Reducing lawn fertilizer and winter salt had response rates around 22 percent. The low response rates of reducing lawn fertilizer use, winter salt and keeping storm drains clean is especially critical because these are the BMP’s that reduce the most amount of urban phosphorus, nitrogen and chlorides entering Lake Mendota according to John Magnuson (Appendix II, Interview C). Magnuson also stressed the importance of collective responses, but low engagement amongst Lake Mendota residents currently bars any sort of collective action.

In an interview with Paul Dearlove, the Watershed Program Manager for the CLA (Appendix II, Interview E), he stressed the importance of public education in raising the level of BMP engagement, as well as general interest in Lake Mendota’s water quality. To test this idea, a Fisher’s Exact statistical test analyzed the relationship between resident’s level of familiarity with BMP’s and level of engagement in them (Appendix III, figure 9). The null hypothesis states, “people who are unfamiliar or slightly familiar do not engage in 1 or less BMP’s.” A p-value of .029 rejects the null hypothesis, suggesting that residents who are unfamiliar with BMP’s are less likely to engage in them. This stat highlights what Paul Dearlove said to be the biggest problem facing the public's engagement in BMP's and water quality issues, a lack of education. He believes that the only way to achieve a collective response is through education, and this survey analysis helps confirm this idea.

Further statistical analysis about the need for public education resulted in another Fisher's Exact test. This time, the null hypothesis was that there is no relationship between the residents who are familiar with BMP's and the residents who are unwilling to pay a small fee to improve Lake Mendota's water quality (Appendix III, figure 10). With a p-value of .112, it is not possible to reject the null hypothesis, making it clear that people are familiar with BMP's are not statistically likely to be unwilling to pay a small fee to improve Lake Mendota. This stat further highlights Paul Dearlove's and John Magnuson's idea that if the public was better educated about water quality issues, they would be more receptive to aiding the cause.

A survey size of 42 is not very big, and therefore any parametric statistical analyses would be making too many assumptions for the scope of this project. The non-parametric method (Fisher's Exact Test) is not as powerful as any parametric method, but still quantifies the ideas presented by the stakeholder interviews. Another potential source of error in the survey results comes from the fact that they were distributed in person, with face-to-face interaction between the surveyor and the respondent. This interaction introduces the possibility that the respondent gave answers that they presumed to appease the surveyors, known as the Social Desirability Bias (Parfitt 2005, 79). When distributing the surveys, there was a general feeling that most respondents exaggerated or falsified their familiarity with BMP's in order to seem more receptive to water quality issues. Even with the possibility that some residents were not completely truthful with their responses, there are a variety of answers and enough variance to provide descriptive statistics and nonparametric probabilities that describe the ideas put forth by the major stakeholders of Lake Mendota.

Future Research

To design and implement a research project in just over three months with no funding is a feat bound to limitations and leaves the opportunity for future research to be conducted. First and foremost, more surveys need to be collected. 42 responses is a very small amount of surveys for conducting any meaningful statistical analyses. If there was sufficient funding, it would ideal to send out a slightly longer (about 10 questions total) survey via mail. Possible new questions would ask where respondents get their information from as well as basic demographic information. Distributing the survey via mail would increase the response rate to one high enough to perform parametric statistical analyses as well as help reduce the Social Desirability Bias in the responses. Possible new analyses would include determining if there are correlations between socioeconomic status, gender or race and engagement in BMP's. Furthermore, distributing surveys around the entire lake would provide the chance to do neighborhood-by-neighborhood analysis to see if there is any difference in education and engagement amongst the many neighborhoods on the lake.

Further quantitative research would include collecting water samples. The most desired locations are the tributaries entering Lake Mendota, especially Six Mile Creek, Pheasant Branch Creek, Spring Creek and the Yahara River. Other sampling locations include the shorelines of the various neighborhoods across the lake. The samples would be analyzed for phosphorus, nitrogen and chloride levels, with the goal of establishing estimates of the quantities of pollutants the agriculturalists and residents are adding to the lake. The results would help better understand the role of land use and land cover in the decline of Lake Mendota's water quality.

The second area needing further research is the agricultural sector's response. One of the biggest themes in the interviews (with all stakeholders agreeing) is the large role agriculture plays in polluting Lake Mendota, contributing 70 percent of the phosphorus entering the lake. The stakeholder interviews lacked the perspective of the agriculturalists, and there is a dire need to interview with some agriculturalists. The exact number is hard to determine, but interviews with both agriculturalists within the Yahara Pride movement and outside of it are crucial to understanding the variety of opinions about water quality and their role in contributing to and mitigating the pollution of Lake Mendota.

There has also been a significant response to declining water quality from regulatory institutions such as the DNR. To gain a deeper understanding of what sort of regulations exist, who they apply to, and how well they are enforced, interviews with the officials of regulatory institutions will provide valuable research material. These regulations are very important to the water quality of Lake Mendota because they are enforceable laws, but they have little to no meaning if they are not properly enforced. Interviewing a regulatory institution, such as the DNR, would reveal whether an adequate level of enforcement is taking place.

All in all more data must be collected to accurately describe the communal response to Lake Mendota's water quality decline. More surveys will increase the types and power of statistical analyses. More interviews will represent all of the stakeholders' views, and not present a one-sided opinion. Water samples will provide more exact understandings of the nature of the lake's pollution. The many components of the proposed future research will correct the shortcomings associated with the current research and holistically tell the story of Lake Mendota's water quality decline and the communal response it sparked.

Conclusion

A lake's water quality is heavily associated with land uses and the coverage surrounding it. Urban land cover increases impervious surface area, reducing the land's ability to absorb and filter storm water and increasing the quantity of runoff directly entering the lake. Urban land use is heavily associated with a myriad of pollutants dangerous to aquatic health but some of the most harmful and plentiful pollutants include phosphorus, nitrogen and chloride, which are easily transported into the nearest water body via impervious surfaces and storm drains. Agricultural land cover removes native vegetation and increases exposed soils creating a perfect vesicle for storm water to easily enter a nearby lake. Agricultural land use relies on nitrogen and phosphorus to enrich the soils and promote crop growth, but when coupled with exposed soils, these chemicals wash into nearby lakes during any storm water event. Lake Mendota is plagued by the repercussions of both urban and agricultural LULC as its shorelines host the bustling Madison metropolitan area and is located in a watershed comprised of nearly 70% agricultural land use type. Together, the LULC surrounding Lake Mendota degrades its water quality, causing accelerated eutrophication and heightened chloride levels. This evident decline in water quality spurred a variety of responses from actors within the watershed. Understanding this response required examination of archival photos documenting the history of LULC change surrounding Lake Mendota, interviewing some of the major actors both contributing to the lake's pollution and those working to end it, as well as polling the residents of the lake about their responses to water quality decline. The results show that the current response is fragmented, with each of the major stakeholders only working within their own spheres of influence, inspiring little collaboration or coordination of efforts. This disjointed attempt is evident in the general public's lack of education about water quality issues, leading to a low level of engagement in BMPs to improve the water quality. All of the major actors agree that the only way Lake Mendota can be cleaned is through a collaborative effort amongst everyone within the watershed and to achieve this there must be cooperation from the agriculturists and more communal outreach to inform and involve the general public. John Magnuson said it best when he said, “It takes a whole village to raise one child, and it’s going to take a whole community to clean Lake Mendota.”

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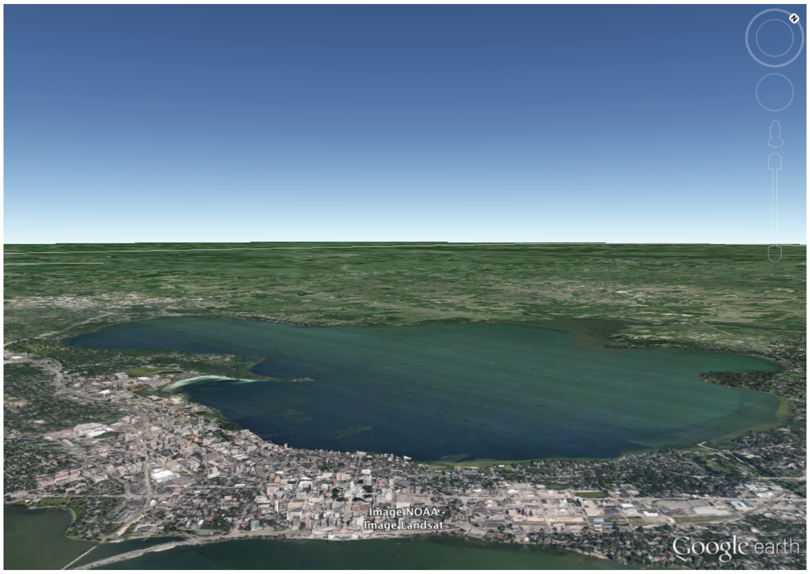
Appendix I - Photographs

Painting: 1908. H, Wellge. “Bird’s Eye View of Madison.” WSHS ID 3160
Figure 1: Artist recreation of Madison isthmus created in 1908.



Google Earth V 7.1.2.2041. Lake Mendota. 43° 8.046’ N, 89° 27.855’ W, Eye alt 11466 feet.
Landsat, NOAA 2014. http://www.earth.google.com [December 14, 2014].
Figure 2: Present day google earth image of the isthmus of Madison

Photo: 1898. Brown, Charles N. Photo of Picnic Point, Madison, WI. WSHS ID 58157
Figure 3: Photo of picnic point in 1898 showing natural vegetation as well as wooded forest prior to urbanization.

Taken by Eric Gunderson, 2014. Taken from the top floor of WARF building.
Figure 4: Photo showing picnic point as well as the increase in impervious pavements along Walnut street and Observatory Drive.

“Observatory Hill/Washburn Observatory,” created by Curtiss, 1900 ca. WSHS ID 23865
Figure 5: Historical photo showing Washburn Observatory in 1900 surrounded by forest and natural vegetation.

Google Earth V 7.1.2.2041. Washburn Observatory. 43° 4.598’ N, 89° 24.652’ W, Eye alt 1433 feet. Landsat 2014. http://www.earth.google.com [December 14, 2014].
Figure 6: Present day Google earth image looking at Washburn Observatory and the increased development along Observatory Drive.

“Conklin Ice House,” creator unknown, 1912. WSHS ID 11341
Figure 7: This photo displays Lake Mendota as a lake that is clean enough to support an ice business in 1912.

“Historical Map of Madison,” created by Laura Kremers, 1924. WSHS ID 112211
Figure 8: A re-creation of the isthmus of Madison in 1924. This photo shows little urbanization expanded from the isthmus with Shorewood Hills still remaining wooded.

“Aerial View of University of Wisconsin-Madison,” creator unknown, 1926 ca. WSHS ID 24043
Figure 9: An aerial view of the eastern portion of campus in 1926. The shoreline and bascom mall were primarily undeveloped.

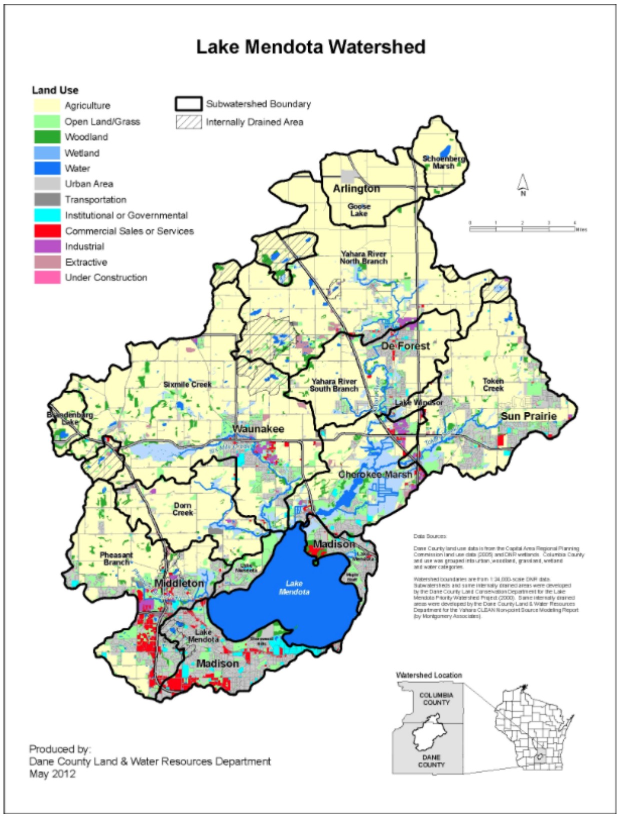
Google Earth V 7.1.2.2041. UW-Madison Science Hall. 43° 4.541’ N, 89° 24.044’ W, Eye alt 1433 feet. Landsat 2014. http://www.earth.google.com [December 14, 2014].
Figure 10: Present day image of the eastern portion of campus. The shoreline and bascom hall are much more developed now.

“Aerial View of Eagle Heights,” created by John Newhouse, 1958. WSHS ID 57583
Figure 11: Aerial view of Eagle Heights in 1958 without the massive neighborhood development.

Google Earth V 7.1.2.2041. Eagle Heights. 43° 4.999’ N, 89° 25.994’ W, Eye alt 3301 feet. Landsat 2014. http://www.earth.google.com [December 14, 2014].
Figure 12: Aerial view of present day Eagle Heights showing a major developmental growth near the lake.

Dane County. Photo by USDA. 1937. Wisconsin Historic Aerial Image Finder.
Figure 13: Aerial image of farmland in 1937. The agricultural fields are confined to small plots here.

Google Earth V 7.1.2.2041. Dane County Agriculture. 43° 8.851' N, 89° 27.956' W, Eye alt 4332 feet. Google, Europa Technologies 2014. http://www.earth.google.com [December 14, 2014].
Figure 14: Present day image of the farmland shown in figure 13. Agricultural land has increased and intensified while corporate farms have brought industrialization into the agricultural industry.



Data Sources:

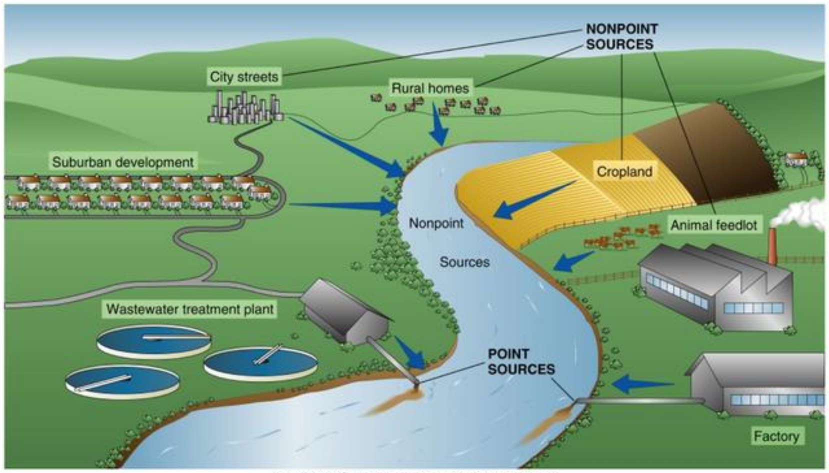
Dane County land use data is from the Capital Area Regional Planning Commission land use data (2005) and DNR wetlands. Columbia County land use was grouped into urban, woodland, grassland, wetland and water categories.

Watershed boundaries are from 1:24,000-scale DNR data. Subwatersheds and some internally drained areas were developed by the Dane County Land Conservation Department for the Lake Mendota Priority Watershed Project (2000). Some internally drained areas were developed by the Dane County Land & Water Resources Department for the Yahara CLEAN Non-point Source Modeling Report (by Montgomery Associates).

Produced by:
Dane County Land & Water Resources Department
May 2012

“Lake Mendota Watershed Land Use Map,” created by Dane County Land and Water Resources Department, 2012.

Figure 15: This map demonstrates the different land use types located around the Lake Mendota Watershed. Urban area is prominent along the shores of the lake, comprising of residential, commercial and institutional spaces. Agricultural area is prominent within the rest of the watershed, surrounding the tributaries of the lake.



Copyright © 2005 Pearson Prentice Hall, Inc.

Nebel, Bernard J., and Richard T. Wright. 2005. *Environmental Science: the way the world works*, 7th edition. Prentice Hall.

Figure 16: Examples of point and nonpoint source pollution and how they get into a body of water.

Photo Taken By: Weston Matthews, 2014.

Figure 17: This photo is of a bioswale that the university installed, located on the intersection of Observatory drive and Walnut Street, taken from the top floor of the WARF building. These are used to capture storm water runoff and filter out pollutants before they enter the lake.

Figure 18 Figure 19

Photo's taken by: Eric Gunderson, 2014

Best Management Practices implemented by a local resident to help filter out pollutants before they reach the lake. The rock wall (fig. 19) helps prevent erosion into the lake while buffer strips of plants help to absorb nutrients before they enter the lake (fig. 18).

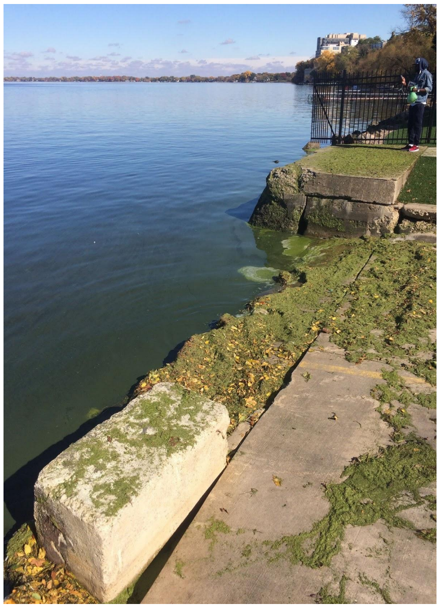
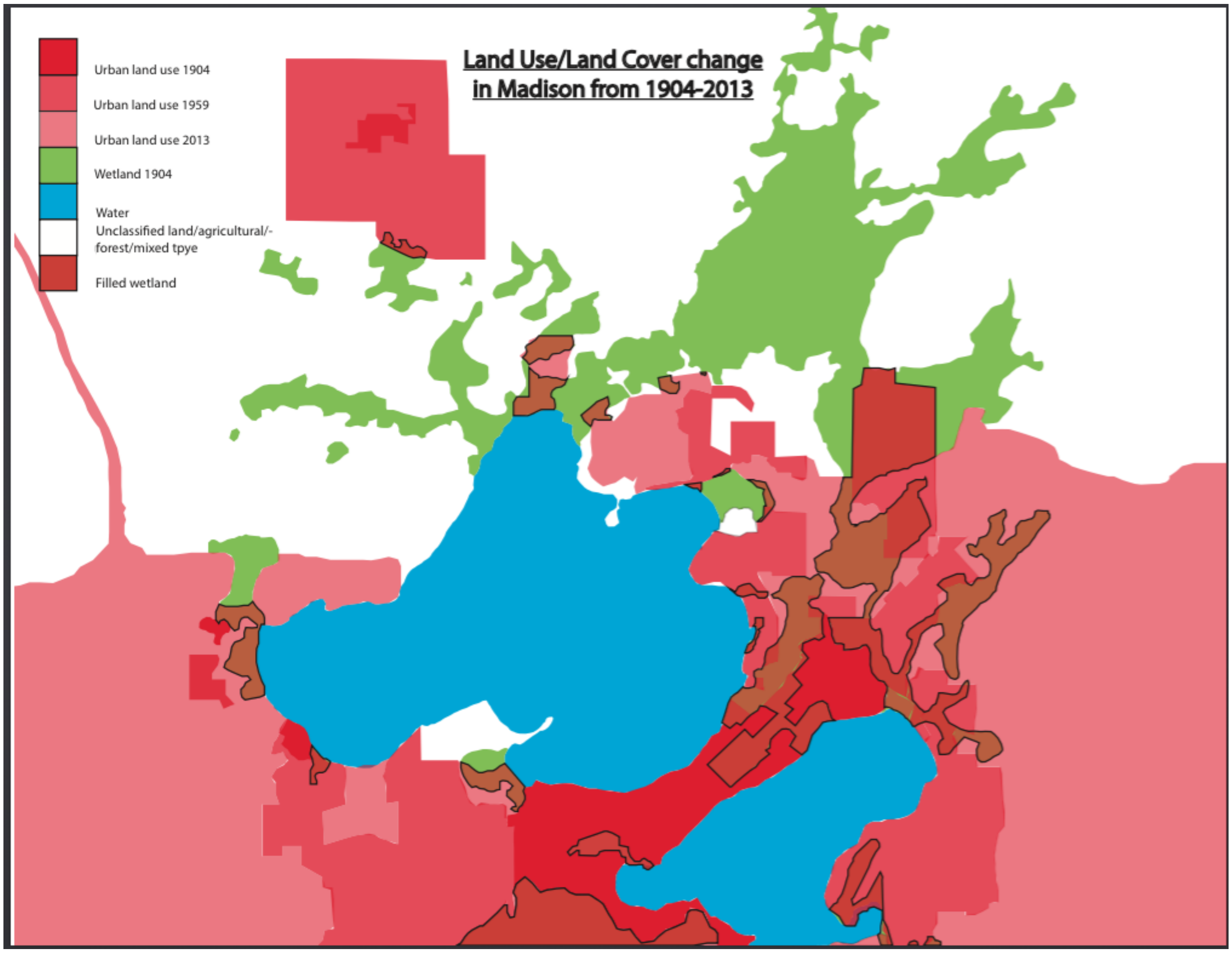


Photo taken by: Scott Caple, 2014.
Figure 20: This photo shows algae from Lake Mendota that reached shore near memorial union. Algal blooms have been a problem for many years due to accelerated eutrophication and increased nutrient loads.

Photo taken by: Quincy Gottwig, 2014
Figure 21: Education building green roof, which sits above a parking lot. Example of an intensive green roof that uses deep soil which supports a mix of trees, shrubs, and large grasses. These green roofs help eliminate the first flush phenomenon and runoff off building rooftops by soaking up and transpiring the water.

Photo taken by: Quincy Gottwig, 2014

Figure 22: Leaf collection trucks on the streets of Madison to ensure leaves do not flow into the lake and release phosphorus by breaking down.



Madison 1890, Madison 1904, Madison 1959, Madison West 2013, USGS Map Locator
LULC map created by: Scott Caple, Quincy Gottwig, Eric Gunderson, Weston Matthews 2014

Figure 23: LULC change map showing wetlands and urbanization through the years 1904, 1959, and 2013.

Appendix II - Interviews

Interview A:

Gary Brown and Rhonda James Interview

Director of Campus Planning and Landscape Architecture, Landscape Architecture Senior, UW-Madison

Q: How much of an impact do you think the University has on the water quality of Lake Mendota?

A: The university plays a role in the water quality of Lake Mendota, but there are more significant actors impacting the lake. One of biggest factors is urban runoff, the area around and just outside of campus feeds to willow creek watershed. Stormwater plan and management south of University is City of Madison's responsibility. City's problem. Agriculture runoff also just as big, farmers still using fertilizers along with animal waste runoff.

Q: Currently, what do you think about the water quality of Lake Mendota? Is there room for improvement?

A: The water quality of Lake Mendota has improved due to the DNR regulations enforced on new projects, but can continue to improve. Non-profit groups have helped immensely to protect the lakes and their water quality.

Q: Can you tell us about any campus management strategies to protect the lake's water quality?

A: The university takes the leaves from campus and composts them to be used on agricultural fields or for planting gardens. The university also uses detention and retention ponds, with the Nielson detention ponds as an example. The university uses bioswales which involve native plants transpiring water, cooling water down, which doesn't warm the lake which can add to the influence of algal blooms. Examples of bioswales on campus can be seen outside the WARF building and within Eagle Heights. Retention-keeps it in, detention-slows it down. The university uses green roofs which either use intensive deeper soil/12-18in, soil mix trees and shrubs/large grasses, or extensive-thin soil 4-6 in, small plants and native forbs.

First flush 1-2in in storms, green roofs hold all water by the plants sucking it up-no runoff, soil made up of crushed aggregate and organic material. Hold water on roof, transpire, no runoff, also insulation blanket keep building cool in summer and warm in winter. 40% goal of TSS in stormwater, campus around 33%. Pervious areas on campus 66% with the goal being 70%. The university will get close by 2015. 3 story parking ramps can then allow the campus to develop parking lot or turn to green space. Pervious pavement/porous concrete not much more maintenance than normal pavement. Gordon commons houses cisterns which are big holding tanks, that settle solid, and meter out water to city pipes. Institute for Discovery uses cisterns and graywater management.

Q: How does the university handle storm water runoff? Salting during winter? Fertilizer?

A: Road and water softener salt problem. Have to manage campus streets only. UW held to high expectations, lots of commuters and people needing to get from place to place safely. Most time spent on campus is in the winter. Brine and beet juice alternatives. Salt pile lot 60, have to manage it because trash winds up in it. Birds like it when begins to melt. Rebuilt area with breaker stone underground to help with infiltration. Class of 1918 Marsh has no outflow, doesn't help.

Q: Based on the University's current relationship with the lake, where do you think the future of Lake Mendota is headed?

A: Agricultural runoff has to be addressed and this can be done through nonprofits helping to educate people and to understand the effects runoff has on water quality.

Q: As far as improving stormwater management on campus, a 2008 study revealed that 66% of the campus consisted of pervious area. The goal was to reach 70% pervious area by 2015. Has the university come close to this goal at this time? What is the university doing to reach this goal?

A: The campus came close to the 70% goal. The building of pervious pavements helped to reduce the amount of asphalt used for parking. They have also added porous pavers by Dejope and porous concrete by the human ecology building.

END INTERVIEW

Interview B:

Don Lukes Interview

Lake Mendota Shoreline Property Owner and Long-term Resident

Q: Since 1982, what changes in land-use have you observed around Lake Mendota? What changes in water quality have you observed?

A: 1956 sewage into Kegonsa and Waubesa (septic system failures); 50s and 60s smell/stench of lake could be smelt couple blocks away, had to wheelbarrow loads of algae and weeds to curb, however city said they wouldn't take it. 1980's sewage straight into the lake; improved greatly since then; small cottages in the 1980's now new massive homes being built in place of cottages--tax revenue for state so not discouraged. Water quality in his eyes has improved greatly, not as stinky.

Q: How has the community's value of water quality changed over time? Can you give any specific examples?

A: Self regulation between owners, which needs to continue; rock shorelines built and two neighbors followed suit--prevent erosion and soil runoff. Boulder shore installed because soil was eroding something fierce. 1600 lb boulder deep in lakebed, tapers back to shore. DNR came to check permits when Don was building this, showed their presence. Lakeshore property owners take care of their own, see neighbors doing something wrong call proper authority, but this rarely happens. A community and joint effort approach has increased, everyone has done good, especially the CLA by bringing various actors together.

Q: What factors do you think are affecting the water quality of Lake Mendota?

A: Since 1940 the city has grown six times. Need to avoid urban runoff due to increase in development-every storm drain ends up in lake. Corporate farms, small farms evolving into large industrial farms. Big farms in Waunakee, Deforest, lot of manure, digesters failing, spilled over. Big mansions built on on hill, large heavy rain whole hill collapses into lake. Lot of public land still around the lake, mendota mental health, city and country parks, state parks, but have to watch people developing, houses getting bigger, people try to get away with anything they can, guy trying to claim more of mendota land. (Natural disasters/weather phenomena) Mississippi flood of 1993-inlet marsh, 10 acres brought up and floated across lake, destroyed piers, had to manually take it out in trucks. Tenny lock and one by Mcfarland doing good job in keeping lake water levels stable. Everybody working together, best that we can, good custodians of the land. (sewage into the lake,soil erosion, joint effort). When asked about how he acquired all of his knowledge about best management practices and lake water quality, he said **"you just kind of learn by osmosis."**

Q: As a lakeshore property owner, what management practices do you take part in? Do you know of any best management practices that your neighbors use?

A: Plants along side of his house to take nutrients; boulder wall to prevent erosion; plants annual ryegrass; rain garden; keeps his trees by the shore. Don not cutting down trees, holds soil, helps filtration, uses natural vegetation buffer strips, and rain gardens. 1-2 years neighbors followed suit with Don's bmp's (while others not).

Q: In your personal opinion, what do you feel is the biggest threat to the water quality of Lake Mendota?

A: Agriculture and biodigesters; sewage--every drain leads to the lakes; large houses being built take away the amount of natural barriers and increasing the amount of impervious surfaces.

Q: Are you a member of any local organizations that concentrate on the water quality of local lakes? What are your opinions on these organizations? Which are making the greatest impact?

A: Madison Lakes Association; Clean Lakes Alliance; Yahara Lakes Association

Q: What are your opinions regarding the city's role in promoting water quality? The university? Agriculturalists?

A: City promotes large houses being built because it is a source of tax revenue; promotes keeping water levels stable--dredging to allow water flow between lakes.

Q: What regulations are placed upon you as a lakefront property owner? Who imposes these regulations? How well are they enforced?

A: Self regulated; building laws to be 70 feet from the shore. DNR building regulations.

END INTERVIEW

Interview C

John Magnuson Interview

Professor Emeritus of Zoology and Director Emeritus of the Center for Limnology, UW-Madison

Q: How how long have you been observing Lake Mendota?

A: Observing 1966 to present day, off and on.

Q: Have you observed any changes in the water quality of Lake Mendota over the years?

A: Lake Mendota stubborn to change, total P is going down slowly, chloride up to 50 mg/L. Ice cover month shorter than 150 years ago, winter recreational activities suffering because of this, 25% reduction in opportunity time, thin ice more dangerous. But "it is hard to change people's way of behaving."

Q: If so, what factors would you say contributed to this change in water quality?

A: Road salt-deicer impact to chloride and water quality, 60s raw sewage until 9 springs, hard to make people change their ways.
Q: Are there any parts of the lake that have experienced a greater change in water quality than others?
A: Wetlands with chloride from salting. Wetland is filter to remove nutrients but does not remove chloride. Shallow water and inshore due to EWM (weeds and algae) washing up on shore, closing beaches and nuisance for lakeshore homeowners with lakefront property.
Q: Of the various local actors working to increase and protect the water quality of Lake Mendota, which do you think are the most effective? Why?
A: Needs to be a functional network, **“takes a village to raise a child, takes a community to clean a lake.”** Families-yard management, BPMs especially keeping storm drains clean and reducing winter salt and lawn fertilizer use, Magnuson story about him picking up dog poop frozen in yard with spoon. State regulator with water quality standards. Different parts have different responses. Center for Limnology (CFL)-research, provide data/figures and observations. City-stormwater management, quality of beaches, County-agriculture practices. County, City, DNR, new network, Clean lakes alliance. CLA- made list 77 steps to clean lake, narrowed to 10-20 need prioritized list, 10 urban 10 agr-improvement greater. Yahara pride-group of farmers reduce nutrient runoff, low till, winter crops, grass swales, buffer zones. In order to solve the water quality issue, everyone (local, state, federal government, as well as residents, and private organizations) needs to cooperate and work together.
Q: Of the many regulations on runoff entering Lake Mendota, which do you think are the most effective? Do you think that there are any that are superfluous?
A: Regulations-need more, necessary but not sufficient, store and liquid manure. Regulations on slope of manure spreading.
Q: In terms of quantity, what is the worst time of year for runoff/pollution entering the lake?
A: Runoff worse spring late winter, mostly agriculture. Storm events more common with global warming.
Q: Do you feel that the University/City/County/Residents are doing enough to protect and promote Lake Mendota?
A: Always more we can do, city (for example) is figuring out which leaf pick up practice works the best.
Q: What LULC’s (Land Use Land Cover) and pollutants are most detrimental to the water quality of Lake Mendota?
A: Wetlands/storm water runoff-off park street into willow stream. Salt runoff into lake and class of 1918 marsh and streams, people need more outreach. 9 springs above EPA standards into badfish creek for salt, no tech to remove salt, half stormwater half water softener.
END INTERVIEW

Interview D

Greg Fries Interview

Sanitary and Storm Sewer Principal Engineer, City of Madison

Q: How long have you worked for the city of Madison? Handling urban stormwater runoff?

A: Greg has worked for the city of Madison for 23 years, all handling urban stormwater runoff. He has worked as part of the Wisconsin pollution discharge elimination system (WPDES).

Q: What are the primary pollutants in urban stormwater runoff?

A: Primary pollutant in urban stormwater runoff is sediment (sand, dirt) measured by TSS but increasingly more important are SSC's (suspended solid concentration). The sediment also acts as a transport mechanism, as attached to the sediment are heavy metals including zinc and cadmium. Zinc is a common heavy metal as it's a bi-product from galvanized zinc plating on cars. Due to winter salting, the zinc plating can fall off and end up in storm drainage systems. Although zinc is getting into the lakes, most aquatic life has a very high tolerance for zinc and remain relatively unaffected.

Q: What is the City of Madison doing to reduce stormwater pollutants in runoff? Some more effective than others?

A: Vacuum (100 microns) and mechanical (200-250 microns) street sweepers, catch basins, bioretention ponds, buffers, and rain gardens. Ponds act as big settling tanks, to settle the sediments with an effective life of around 20 years, removing approx. 200 lbs phosphorus a year at the cost of $250/lb (Cherokee Marsh pond drains around 400 acres). Reasonably agreed upon numbers for phosphorus input is 70% agriculture and 30% from everything else. Focus on impacting the big stuff (pollutants) and gross pollutants for residents (trash, garbage, junk, sand at discharge sites). The city uses around 80% sand and 20% salt for winter deicers, with a strong focus on getting the sand and other gross pollutants out before the spring. Adaptive management, for the first time in the nation it is being implemented. Adaptive management entails the city using part of their budget for reducing their phosphorus goal of around 60% of their responsible 30%, in order to pay farmers to use best management practices to reduce their phosphorus load of the more important 70% contribution. City is required to meet certain phosphorus reduction goals, but farmers are not. Cannot make much progress when regulations only apply to those who produce the minority (30%) of phosphorus inputs. Stormwater utility taxes residents based on the amount of pervious and impervious land on their property. Government property exempt.

Q: What is the City of Madison doing to reduce flooding in the many flood prone areas in the City?

A: The city is putting in more storm drains to alleviate the current ones within the flood prone areas. Areas such as the one near the Hilldale mall and Old University, had stormwater systems added in 2003 and 2012 respectively. The cost was roughly $14 million for 1000ft of pipeline added. There is little that can be done about wetlands that weren't filled enough.

Q: What is the City required to do as part of our regulatory requirements and what are we doing to meet those requirements?

A: WPDES & TMDL. EPA, DNR. MAMSWaP- Madison area municipal stormwater partnership

Q: How does the City of Madison coordinate with other institutions/groups in regards to stormwater management? University? DNR? Local non-profits? Resident/Agriculturalist organizations? Businesses?

A: MAMSWaP. University and city combine as well as Shorewood Hills and Maple Bluff
DNR is talked to on the quarterly. Meet with the Friend's Groups.
END INTERVIEW

Interview E

Paul Dearlove and Rachel Fossum Interview

Watershed Program Manager and Rural Initiatives Coordinator, Clean Lakes Alliance

Q: Yahara Pride Farms has been successful in changing the attitudes and habits of agriculturalists towards water quality, but when working with other agriculturalists, are you generally met with opposition or cooperation? Do you foresee Yahara Pride Farms growing in the near future?

A: There are 60 Yahara Pride Farmers in Yahara Pride of the 330 farmers in the Yahara watershed. There is not a lot of resistance, but there is a hesitance due to a lack of trust. Their Adaptive Management Programs is in its final year and has pioneered new cost effective P reduction practices. CLA foresees Yahara Pride growing. Their biggest asset is that they are a non-profit/non-governmental agency and that they have a "farmer led motto," there is no fear of the farmers being fined or penalized for being out of code.

Q: How willing are local residents to donate to CLA? Who are your typical donors? Which residents are typically most interested in the work done by the CLA? Volunteers?

A: Most of the residents who donate or become interested in the work of the CLA do so through family/fun oriented events like "Loop the Lake" or "Frozen Assets", which are both events that engage families and residents in activities involving the lakes to highlight how important they are, which usually gets the participants to donate money. There are branches of the CLA, like the Friends of CLA, which is a neighborhood-oriented program that engages residents in water quality practices. A new initiative of the CLA is to move the donor basin from "high rollers" to include "all income levels."

Q: What kind of relationship does CLA have with its sponsors/community partners? What motivates these businesses to sponsor CLA? How big of a role do sponsors play in supporting CLA in comparison to residential donors? What has been your most effective strategy for recruiting new sponsors?

A: A corporation donated the office space the CLA uses. Businesses/corporations see the benefit in having cleaner lakes and want to donate to a cause that positively impacts the community. CLA organizes company wide volunteer days where a company/business is bussed out to a location (along a lake) and spends the day cleaning the shorelines and planting plants that will uphold the shoreline integrity.

Q: What do you think is the biggest obstacle stopping more people from getting actively involved in protecting and improving water quality?

A: It all comes down to a lack of education. All of the ignorance and misconceptions and apathy can be traced to people simply not knowing enough. 9/10 times when CLA is able to educate people about how to protect the lakes, they can get them to be supportive of it. CLA is looking at programs to make lake water quality a more inclusive effort, trying to train local water quality spotters, who know what to look for in the lake and create real time reports for other residents via a mobile app.

Q: How close was the Yahara CLEAN Strategic Action Plan that started in 2002 to reaching the 50% phosphorus reduction goal?

A: "Its an ambitious goal, but we see it being met." They have transitioned their work from planning to implementation. The entire idea is about getting everyone in the community together and focused on ONE GOAL.

Q: What do you think the biggest benefit being a non-profit organization has when working to promote water quality?

A: They can reach out to a broad audience of people in an approachable manner to create a community who cares about their lakes and wants them to be clean. They have the ability to work on a peer-to-peer level, instead of coming at it from a hierarchical position.

Q: The biggest hindrance?

A: Some people perceive the CLA as a "holier than thou" and finger pointing critics. They have to be careful about how they approach people and make sure they are being attentive and inclusive. They also have to be skeptical of who they partner with. CLA has no ulterior motives and they have to make that every donation they accept does not come with strings attached and make sure that no one else in the community will think that accepting a donation from a donor has some string attached. They have to constantly be aware of their reputation, which is clean at this point because they are so new, and make sure that they do not carry themselves as a group of non-profit zealots, they are here for the lakes and that is their only goal.

Q: The overall goal for CLA?

A: "Build a community of people who can go out into their influence spheres and spread the word." The mission of CLA is not to clean the lakes; the mission is to create a community centered on the lakes. There is a misconception that the lakes are far more known and studied than they actually are. Cleaning the lakes is not about singling out who is not doing their part; it takes everyone. If the lakes are going to be clean and improved, it has to be done throughout the community.

Q: Any future goals for CLA?

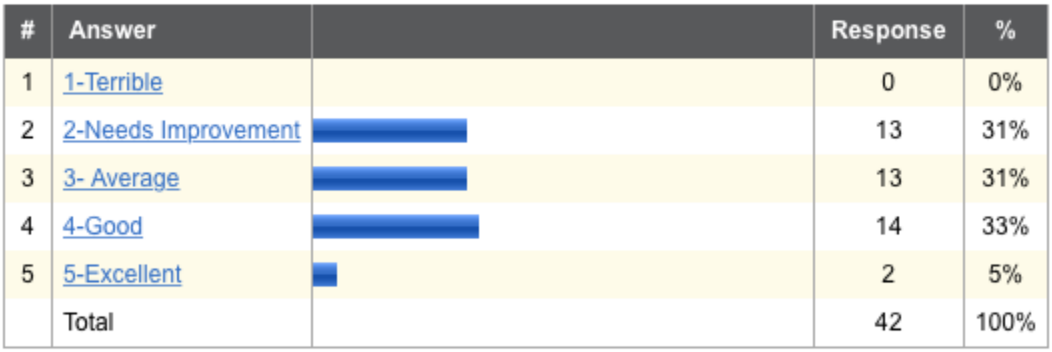
A: Establish educational outreach programs at the UW and Edgewood to engage professors and students in promoting the water quality and teaching them about Best Management Practices.

END INTERVIEW

Appendix III - Survey Data

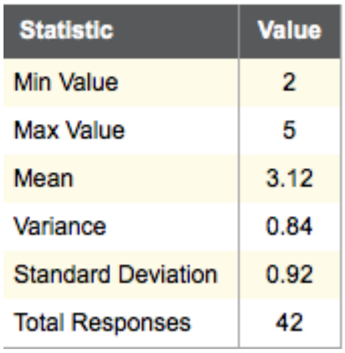
Figure 1

1. Please rate the water quality of Lake Mendota (*please circle*)
    - 1- terrible
    - 2- needs improvement
    - 3- average
    - 4- good
    - 5- excellent
2. Would you be willing to pay a small fee to ensure that Lake Mendota's water quality was upheld/improved? (*please circle*)
    - 1- not at all
    - 2- maybe
    - 3- yes
3. How familiar are you with best management practices to protect Lake Mendota's water quality? (*please circle*)
    - 1- Not familiar at all
    - 2- Slightly familiar
    - 3- Somewhat familiar
    - 4- Moderately familiar
    - 5- Extremely familiar
4. Do you engage in the following activities? (*please circle*)
    - a) Mulch your leaves/grass clippings
    - b) Make a compost pile
    - c) Build a rain garden
    - d) Keep storm drains clean
    - e) Pick up pet waste, if applicable
    - f) Have rain barrels
    - g) Reduce winter salting
    - h) Use lawn fertilizer



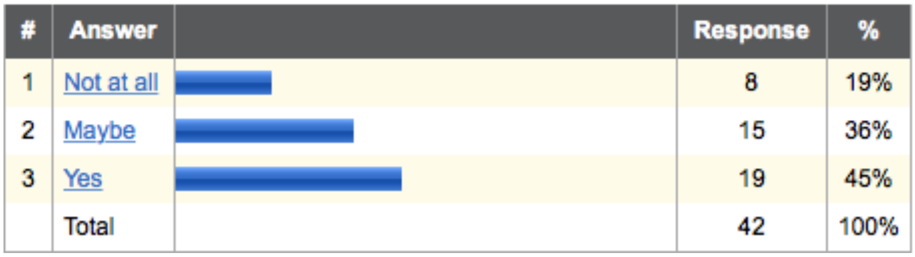
#	Answer		Response	%
1	1-Terrible		0	0%
2	2-Needs Improvement		13	31%
3	3- Average		13	31%
4	4-Good		14	33%
5	5-Excellent		2	5%
	Total		42	100%

Question 1 response rates, Figure 2



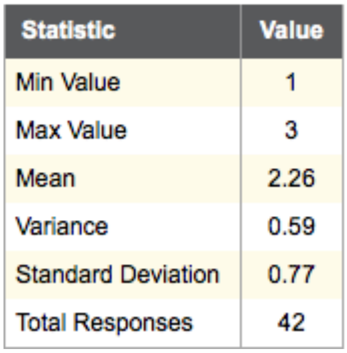
Statistic	Value
Min Value	2
Max Value	5
Mean	3.12
Variance	0.84
Standard Deviation	0.92
Total Responses	42

Question 1 descriptive statistics, Figure 3



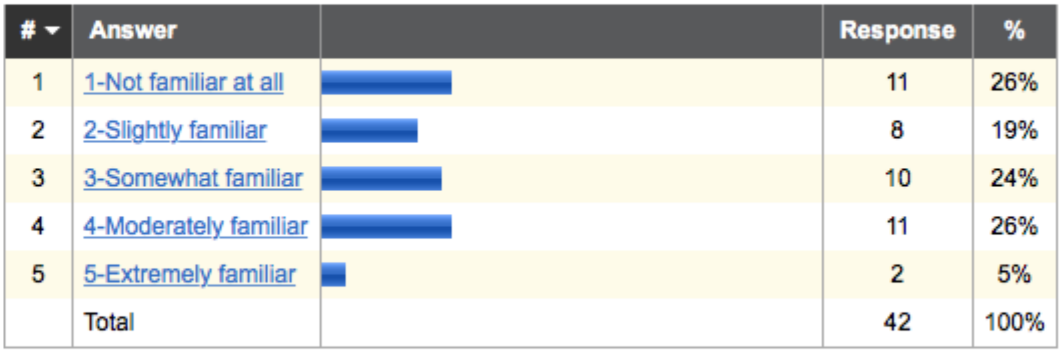
#	Answer		Response	%
1	Not at all		8	19%
2	Maybe		15	36%
3	Yes		19	45%
	Total		42	100%

Question 2 response rates, Figure 4



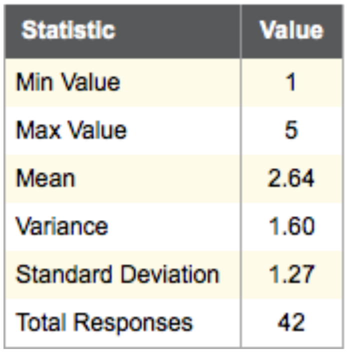
Statistic	Value
Min Value	1
Max Value	3
Mean	2.26
Variance	0.59
Standard Deviation	0.77
Total Responses	42

Question 2 descriptive statistics, Figure 5



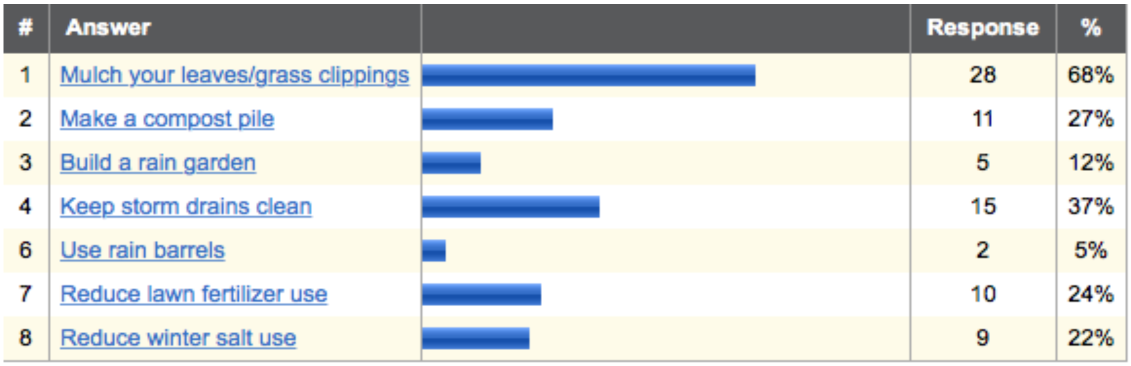
#	Answer		Response	%
1	1-Not familiar at all		11	26%
2	2-Slightly familiar		8	19%
3	3-Somewhat familiar		10	24%
4	4-Moderately familiar		11	26%
5	5-Extremely familiar		2	5%
	Total		42	100%

Question 3 response rates, Figure 6



Statistic	Value
Min Value	1
Max Value	5
Mean	2.64
Variance	1.60
Standard Deviation	1.27
Total Responses	42

Question 3 descriptive statistics, Figure 7



#	Answer		Response	%
1	Mulch your leaves/grass clippings		28	68%
2	Make a compost pile		11	27%
3	Build a rain garden		5	12%
4	Keep storm drains clean		15	37%
6	Use rain barrels		2	5%
7	Reduce lawn fertilizer use		10	24%
8	Reduce winter salt use		9	22%

Questions 4 response rate, Figure 8

	Unfamiliar or Slightly familiar	Somewhat familiar - Extremely familiar	Total
Engage in 2 or more BMP's	6	16	22
Engage in 1 or no BMP's	13	7	20
Total	19	23	P=.029

Figure 9: 2 x 2 contingency table for Fischer's exact test. Rows represent engagement in BMP's, columns represent residents' familiarity.

	Unfamiliar	Slightly familiar-extremely familiar	
Yes/Maybe	13	21	34
Not at all	6	2	8
Total	19	23	P=.112

Figure 10: 2 x 2 contingency table for Fischer’s exact test. Rows represent willingness to pay, columns represent residents’ familiarity.