2016 WATER RESOURCES MANAGEMENT PRACTICUM REPORT

MAKING **STRICKER'S POND** A BETTER RESOURCE FOR MIDDLETON AND MADISON RESIDENTS

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The Water Resources Management Practicum is a regular part of the curriculum of the Water Resources Management Graduate Program in the Nelson Institute at the University of Wisconsin-Madison. The practicum involves an interdisciplinary team of faculty members and graduate students in the analysis of a contemporary water resource problem.

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PREFACE

The Water Resources Management (WRM) master's degree program is a collaborative and interdisciplinary graduate program in the Nelson Institute for Environmental Studies at the University of Wisconsin-Madison. The program prepares students for lifelong careers as water resources management professionals.

The capstone of the WRM program is the summer practicum. Since the 1970s, this practicum, or workshop, has served as an interactive and immersive experience for the program's students. It focuses on current issues in Wisconsin water resources management. The practicum is one of the finest and most impactful examples of the Wisconsin Idea – that is, the notion that the boundaries of the institution extend to those of the state. The Wisconsin Idea represents the university's commitment to public service. This report serves as documentation of the 2015 WRM cohort's practicum that took place during the summer of 2016 at Stricker's Pond, located between the cities of Middleton and Madison, Wisconsin.

Ten students participated in the practicum (Figure 1.1).

They are:
Abigail Cook
Mari Dallapiazza
Bridget Faust
Sarah Fuller
Katherine Hanson
Eric Scott Mortensen
Josh Olson
Amanda Smith
Sean Spencer
Josh Wolf

Professor Anita Thompson (Figure 1.2) serves as the WRM program chair and is the Nelson Institute Professor of Water Resources and a professor in the Department of Biological Systems Engineering. Accordingly, she served as the project advisor for the Stricker's Pond practicum.

Figure 1.1: The 2015 WRM cohort. From left to right: Bridget Faust, Abigail Cook, Eric Scott Mortensen, Katherine Hanson, Josh Wolf, Sarah Fuller, Sean Spencer, Mari Dallapiazza, Josh Olson, Amanda Smith.

Figure 1.2: Professor Anita Thompson

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ACKNOWLEDGMENTS

The 2015 WRM cohort acknowledges that this project would not have been possible with the support, guidance and feedback from numerous groups and individuals from the academic, professional and local communities.

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Dave Beck, Middleton Public Lands
Samer Alatout, UW-Madison

Lastly, the 2015 WRM cohort would like to thank the residents of the Stricker's Pond watershed, who value and are committed to improving this special community resource.

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EXECUTIVE SUMMARY

Stricker's Pond is a small yet invaluable natural resource located on the border of Middleton and Madison in southern Wisconsin. The pond and its surrounding environs form an important component of the ecological and societal fabric of the area, testifying to the changes that have occurred over the past 200 years. As a result of land use/land cover changes, discrepancies in management policies between Middleton and Madison, and varied public opinions of the pond, Stricker's Pond faces several challenges. These include degraded wildlife habitat (terrestrial and aquatic), limited biodiversity, water quality and flood concerns, and an under-informed public. To assist in improving the current state of the pond and the watershed, the 2015 WRM cohort conducted a multidisciplinary, comprehensive assessment. Guided by previous studies of Stricker's Pond and surrounding sites, input from formal and informal stakeholder groups, and standards and protocols of the involved fields of study, a project plan was developed to address the physical, biological, and social aspects of Stricker's Pond.

Frequent sampling and watershed modeling determined that the water of Stricker's Pond contains excessive levels of phosphorus and nitrogen. The source of these contaminants is the surrounding neighborhoods within the watershed. Due to the highly urbanized nature of the watershed, storm events serve as a system-wide flushes that transport large quantities of contaminant-laden water to the pond in relatively short periods of time. The result of these runoff events is degraded water quality and elevated pond stages. This degraded water quality is an issue of great concern for the City of Middleton as the Wisconsin Pollutant Discharge Elimination System (WPDES) guidelines affecting downstream Tiedeman's Pond limit the amount of pollutants allowed to be discharged further downstream into Lake Mendota.

Most flood concerns related to storm events have been abated by the implementation of a hydraulic connection, a culvert controlled by an outlet valve, which allows Stricker's Pond to drain (as opposed to natural kettle pond conditions in which the primary natural outlet would be evaporation). Under certain conditions, though, such as under an amplified precipitation regime or an instance of improper valve management, high water levels could inundate surrounding public and private properties.

To mitigate existing water quality and flood concerns, a suite of best management practices was evaluated in this assessment, with varying levels of success. Implementation of certain best management practices can attenuate storm event peaks by at least one foot and reduce the amount of pollutants entering Stricker's Pond by up to 50 percent. The practices evaluated (permeable pavements, rain gardens, and infiltration basins) provide the cities of Middleton and Madison several avenues to consider to improve water quality and reduce inputs to the pond. Other alternatives, such as an additional sedimentation forebay (an artificial pool in front of a larger body of water), should be avoided due to encroachment of valuable public lands and minimal impact on water quality.

The poor water quality of Stricker's Pond limits the biodiversity of pond wildlife. Specifically, fish and macroinvertebrate populations, assessed during this project, are indicative of poor environmental integrity for the system as a whole. While the bird community is quite vibrant, in sharp contrast to fish and macroinvertebrates, improved water quality would lead to strengthened communities in and around the pond for all wildlife. It is crucial that a resident population of goldfish is eradicated from Stricker's Pond. A member of the carp family, these bottom feeders only reduce water quality. Any improvements in water quality as a result of upstream efforts would likely be negated by the goldfish if they are allowed to remain in the pond.

A further indicator of the pond's degraded state is the presence of only one species of aquatic vegetation, the American lotus. This hardy plant naturally occurs in southern Wisconsin and has a long, interesting history in this and surrounding ponds. The lotus colony assessed in this project was introduced roughly 15 years ago as an effort by the City of Middleton to improve the habitat of the pond. But the plants have come to be considered an eyesore by several community members and a threat to open water. Due to its protected status, however, the expanding colony of American lotus in Stricker's Pond cannot be removed. This disconnect between public opinion and management objectives must

be bridged through a concerted effort to communicate with the community about the several benefits this aquatic plant provides.

In addition to the aquatic vegetation survey, a terrestrial vegetation survey was also conducted. The results of this comprehensive effort to quantify the environs of Middleton and Madison woodlands and prairie areas serve as evidence of the difference in management priorities of the two cities. Vegetated areas in Middleton consistently achieved higher floristic quality index scores than those of Madison. This is likely due to Middleton's proactive approach in managing its public lands. In general, vegetation surveys of the pond's surroundings tell a story of a landscape dominated by invasive species, especially reed canary grass, buckthorn, and garlic mustard. For the sake of vegetation management, it is strongly recommended that the two cities put forth a concerted effort to create a synchronized and economically efficient plan to proactively manage these public areas that are so highly valued by the community.

Generally, the high level of ownership and community engagement observed for Stricker's Pond is encouraging. As quantified through written records, personal accounts, and community events, the individuals who recreate around Stricker's Pond highly value this community asset. Areas for improvement in community involvement include improved leaf management protocols (the absence of which has both water quality and flood repercussions) and effective communication of vegetation, wildlife, and recreational management goals. It would also be beneficial for the cities to update existing signage around the pond to better inform the public of Stricker's Pond historical, ecological, and cultural significance.

Stricker's Pond (and its watershed) form a complex system. The purpose of this assessment was to identify existing and future concerns for the pond and provide recommendations on how to overcome these issues. Based on the results of this assessment, the 2015 Water Resources Management Cohort recommends that the cities of Middleton and Madison:

1. Design a proper protocol for drainage valve management.
2. Improve existing educational signage around the pond.
3. Clearly establish and communicate American lotus management objectives.
4. Formulate a coherent vegetation management plan.
5. Eradicate goldfish and establish native fish community.
6. Implement watershed scale initiatives to enhance water quality.
7. Create a holistic management plan to harmonize management of Stricker's Pond, and
8. Consider creating an intergovernmental agreement to ensure management objectives are uniformly implemented.

While the issues identified range in scale, intricacy, and amount of necessary investment, we believe that Stricker's Pond will be a more resilient resource for the community if the recommendations in this report are adopted by stakeholders and policy makers. Stricker's Pond is a unique and valuable resource. The information and recommendations in this report can help Middleton and Madison together transform the pond into an even greater community asset.

Acronyms

The following acronyms appear in this report:

AMS – Above Mean Sea Level
BMP – Best Management Practice
CLC – Conservancy Lands Committee
DBH – Diameter at Breast Height
DRP – Dissolved Reactive Phosphorus
FPOM – Fine-particulate Organic Matter
FQA – Floristic Quality Assessment
FQI – Floristic Quality Index
GIS – Geographic Information Systems
IRB – Institutional Review Board
NOAA – National Oceanic and Atmospheric Administration
NOx – Nitrate and Nitrite
MAMSWAP – Madison Area Municipal Storm Water Partnership
PRFC – Parks, Recreation, and Forestry Commission
PRMS – Precipitation Runoff Modeling System
TDS – Total Dissolved Solids
TKN – Total Kjeldahl Nitrogen
TN – Total Nitrogen
TP – Total Phosphorus
TS – Total Solids
TSS – Total Suspended Solids
TDS – Total Dissolved Solid
WDNR – Wisconsin Department of Natural Resources
WPDES – Wisconsin Pollutant Discharge Elimination System
WRM – Water Resources Management
WRMC – Water Resources Management Commission
WWMI – Wisconsin Wetland Macroinvertebrate Index

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INTRODUCTION

Stricker's Pond and its surrounding environs are unique environmental assets that have been part of the social fabric of Middleton and Madison for hundreds of years. The pond has served as habitat for migrating birds; a harbor for a wide variety of insects, frogs, and fish; a source of livelihood for Native Americans; and a place of inspiration and relaxation for people who call the area home today.

While serving as an invaluable resource for the community, Stricker's Pond also testifies to the changes that have occurred in the region as its watershed was developed from oak savanna and prairielands into farmlands and subsequently into the neighborhoods which today make up portions of Middleton and Madison. Changes in land use and land cover, however, have brought certain consequences. More stormwater reaches the pond now than in years past, causing flooding concerns in surrounding neighborhoods. Ecosystems– both on land and in water – have been encroached upon and degraded. While some of the issues elicited by the watershed's urbanization have been directly addressed (e.g., the creation of a stormwater outlet which allows drainage from Stricker's Pond), several other issues remain unresolved. The disconnect between how the current condition of the pond and its potential if properly managed has been noted by both citizens and government officials in Middleton. The 2015 Water Resources Management (WRM) cohort approached the City of Middleton's Water Resources Management Commission and proposed to conduct an assessment of the pond and watershed with the objective of developing a plan to improve the pond.

The cohort set the following goals to guide the Stricker's Pond practicum:

- Assess the current status of vegetation, wildlife, water, and recreational resources of the pond and surrounding areas.
- Engage stakeholders in determining the history, purposes, benefits, and desired future visions of the pond.
- Craft recommendations for the City of Middleton and the City of Madison for ways in which these two entities might bolster existing efforts to manage the pond and realize other potential actions to improve the watershed as a whole.

This report describes in detail the work undertaken by the 2015 WRM cohort. It begins with contextual information regarding Stricker's Pond and its watershed. Efforts to assess water quality and quantity in the pond are subsequently presented. The report then elaborates on the surveys conducted to assess terrestrial and aquatic vegetation, fish populations, macroinvertebrate populations, and bird populations. Complementing the physical and biological assessments of Stricker's Pond is a discussion of the societal benefits afforded by the pond, presented in the form of results from a distributed questionnaire, ideas drawn from town hall meetings hosted in Middleton, oral histories collected from longtime residents of the area, and resource user assessments. Finally, recommendations are proposed regarding the aforementioned topics to provide the City of Middleton and City of Madison with a firm foundation to guide future planning efforts for Stricker's Pond.

Stricker's Pond is an interesting and beautiful area that has been enjoyed by generations of Wisconsinites. As a result of this inclusive assessment, it is the hope of the 2015 WRM cohort that Stricker's Pond will be enhanced and fortified as an environmental resource for the region's future generations.

5 BACKGROUND

Stricker's Pond is an approximately 30-acre kettle pond located at the boundary between southern Middleton and western Madison, Wisconsin, in the Yahara watershed. The watershed that drains to the pond encompasses slightly less than one square mile within these two municipalities (Figure 5.1).

While the pond is the primary focus of this assessment, the entire watershed must be considered in any planning effort. The following sections provide information on characteristics of both the pond and surrounding watershed.

Pond formation

Stricker's Pond is one of several kettle ponds within the Yahara River watershed, which also includes Tiedeman, Esser, and Graber ponds. It is likely that this region was formed about 10,000 years ago by the Green Bay lobe of the Wisconsin glaciation. It is thought that large blocks of ice left behind from the receding glacier created depressions in the land, which were then covered by till, forming the clay layer underlying Stricker's Pond (House, 1984). The deposition of these highly impermeable sediments created a perched water table, preventing water in this area from naturally draining into the rest of the Yahara watershed.

Climate

In 2015, the total annual precipitation at the Middleton NOAA station (575471) was 37.9 inches (National Environmental Satellite, Data and Information Service, 2015a). The average total annual precipitation from 2005-2015 for the Madison area was 37.5 inches, and the average annual temperature was 47.4 °F, as recorded at Madison Regional Airport .

Meteorological data show warming trends in Wisconsin throughout the 20th century. From 1950 to 2006, both the annual average low temperatures at night and high temperatures during the day increased, and the growing season became longer (Kucharik et al., 2010). In this same period, Middleton's annual average temperature increased 1°F and annual average precipitation increased five inches (Wisconsin Initiative on Climate Change Impacts, 2011). The mean winter temperature, which increased by 2.7 °F, showed the greatest observed change. The length of the growing season also lengthened by about four days (Kucharik et al., 2010)

Overall, Wisconsin temperatures are projected to increase the most during the winter. Some warming will occur in the fall and spring, and the smallest temperature increase will be in the summer (Wisconsin Initiative on Climate Change Impacts, 2011). Precipitation is also likely to increase the most during winter, spring, and fall, with more frequent large-storm events in spring and fall.

Additionally, climate models project that in the next half century, Wisconsin will continue to have a faster rate of warming than in the past, with an annual average temperature increase of around 5 °F. A larger change, approximately 7.5 °F, is projected for winter (Kucharik et al., 2010). This would extend the growing season by approximately one month within the state.

These climatic changes will impact Stricker's Pond by influencing overall temperature conditions, the timing of stormwater runoff reaching the pond, and the extent of winter ice cover. Changes will encompass increasing water temperature and evapotranspiration rates (Wisconsin Initiative on Climate Change Impacts, 2011). Large storm events will test the capacity of Stricker's Pond and could result in flooding if runoff volumes are large. The pond will also have fewer days of ice cover during the winter, which will influence plant and animal survival through the winter. Warmer winters will reduce the frequency with which the pond completely freezes. Events such as the 2014 winter fish kill will become more uncommon in the future as the growing season extends and the winters of Wisconsin continue to warm.

Historical land use

The first inhabitants of the area were the indigenous peoples who populated the greater Yahara Lakes region. Collared pots from as early as the Kekoskee Phase, occurring roughly 1,000 years ago, have been discovered at Stricker's Pond (Christiansen III, 2005). As evidenced by the Christiansen survey, this area and others like it served as important encampments for the Late Woodlands societies due to their

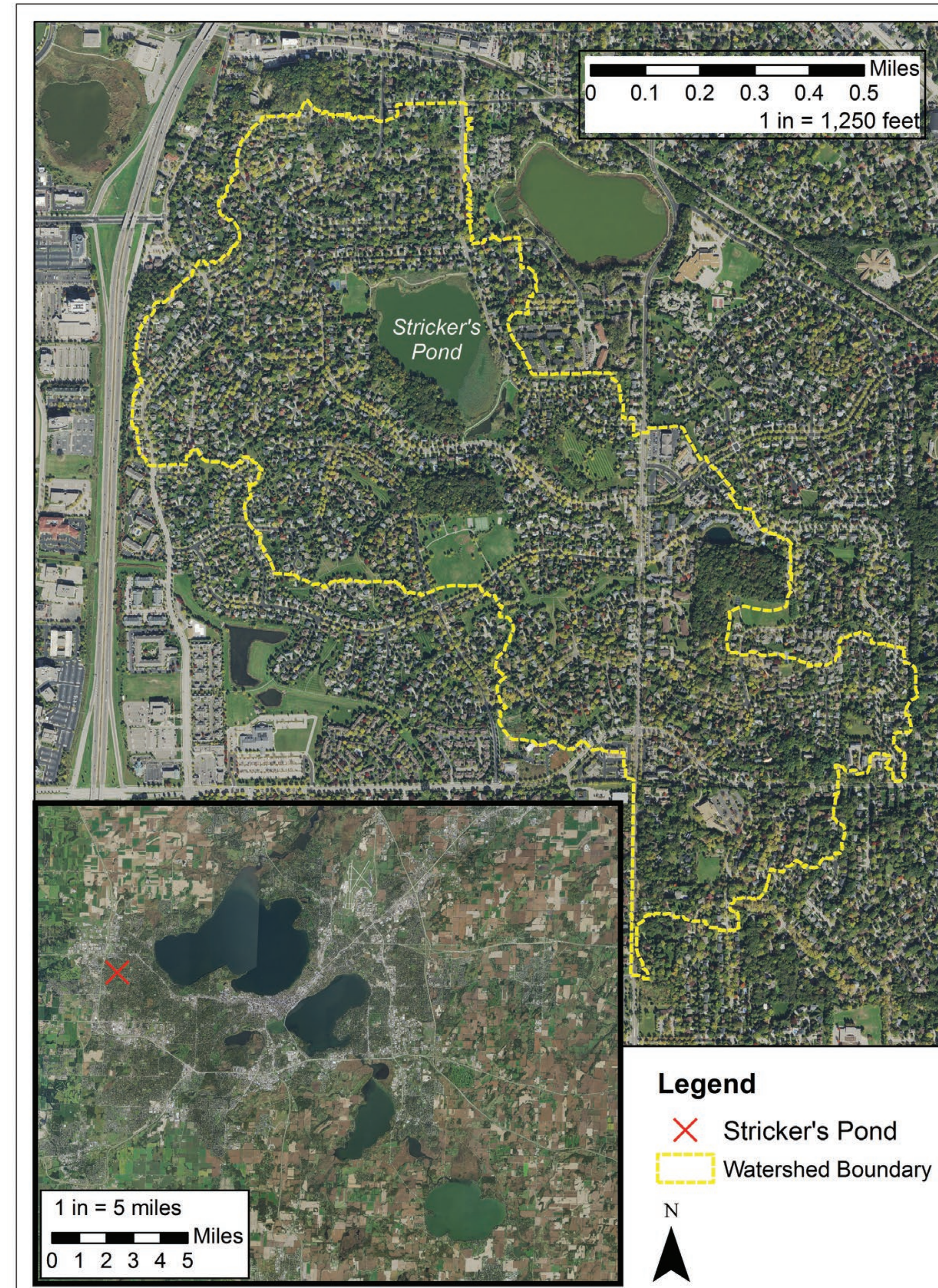


Figure 5.1: Stricker's Pond is one of several kettle ponds in the area and empties into Lake Mendota in the Yahara River system.

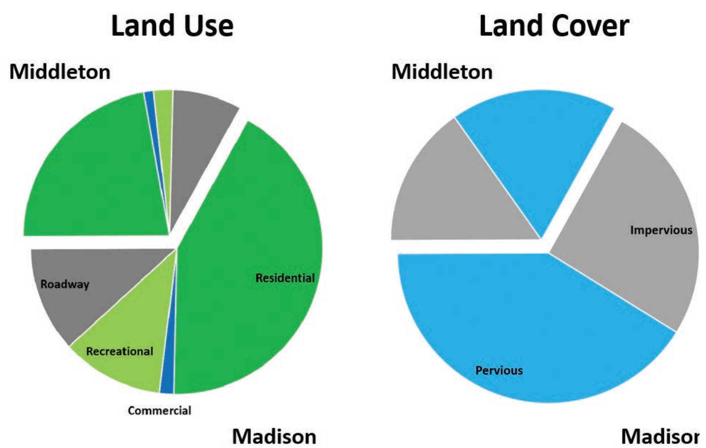


Figure 5.2: Current land use and land cover for the watershed.

abundance of aquatic resources and protection from major waterways.

European immigrants first settled in the Stricker's Pond area in the mid-1800s. The watershed remained mostly undeveloped until the 1870s, with pond stage varying naturally, influenced by annual rainfall and snowmelt. After that time, runoff into and sedimentation within the pond began to increase as portions of the watershed were put into agricultural production (Marshall & Healy, 2014).

By the 1930s, the area immediately adjacent to Stricker's Pond, as well as that of the greater watershed, were used mainly for agricultural purposes. The prairie and wetlands were converted to cropland or used for livestock grazing (Marshall & Healy, 2014; BioLogic Environmental Consulting, LLC, 2005). Aerial photos from this period do not show vegetation buffers around the pond that would have limited sediment and nutrient influx (Marshall & Healy, 2014). It is possible that the pond was actually an emergent wetland prior to the 1870s as historical maps of the Middleton area do not depict the pond before this time (Marshall & Healy, 2014).

In the 1960s, the City of Middleton acquired land immediately surrounding Stricker's Pond. Prior to that time, the pond area was owned by a private developer, although all parts of the pond below 921.11 feet mean sea level were already in the public trust (Stockham & Vandewalle, 1982). The original 1982 Stricker's Pond Master Plan recommended that the City of Middleton acquire three acres of the sediment basin (present-day Stricker's Park), two lots on Voss Parkway, and the shoreline around Stricker's Pond to be placed into conservation zoning (Stockham & Vandewalle, 1982).

The watershed area remained primarily farmland until recent decades (City of Madison Parks Division, 2016). Houses first appeared on the pond's eastern shore in the early 1960s (BioLogic Environmental Consulting, LLC, 2005). In the 1980s, the predominant area land use shifted from row crop agriculture to urban residential housing (Marshall & Healy, 2014).

Current land use

By 1984, the watershed was 27 percent urbanized (Mueller, 1984), with rapid urbanization occurring over the next twenty years. Presently, the watershed is almost completely urban (Figure 5.2), causing more serious runoff issues and concerns about flooding of residential properties (City of Middleton, 2000). The Stricker's Pond watershed is approximately 557 acres, with a ratio of watershed area to pond area of about 31:1 (Zimmerman, 1991). Based on storm sewer information from 1991, the pond receives stormwater from 370 acres of Madison and from almost 190 acres of Middleton.

Land use and current management

The City of Middleton has zoned Stricker's Pond and the surrounding wetland habitat as lowland conservancy (CO-L), following direction from the Wisconsin Legislature (Stockham & Vandewalle, 1982; City of Middleton, 2016). All conservancy lands in the city are managed for "passive recreation and conservation purposes," as required by Wisconsin Statute § 28.20. While the Middleton Common Council and the Public Lands Department have ultimate authority over the pond, three city government committees mainly govern pond management: the Conservancy Lands Committee (CLC), the Water Resources Management Commission (WRMC), and the Park, Recreation, and Forestry Commission (PRFC) (Schreiber Anderson Associates, 2010).

The City of Middleton Conservancy Lands Plan states that "periodic water level maintenance" of the pond may be required (Schreiber Anderson Associates, 2010). To manage flooding issues, an underground infiltration field was installed near the north edge of the pond in 1986 (Vorhees, 1989). The infiltration field performed poorly, however, and it was shut down the next year (Vorhees, 1989). The Wisconsin Department of Natural Resources (WDNR) has given the city guidance on how to control floodwater and restore habitat (Schreiber Anderson Associates, 2010).

The Dane County Water Body Classification Study lists Stricker's Pond under its restoration/protection category, and Adaptive Restoration, LLC has suggested that pond restoration should be emphasized (Marshall & Healy, 2014). As detailed in the Conservancy Lands Plan, the city created the first management plan for Stricker's Pond in 1982 (Schreiber Anderson Associates, 2010). This plan was supplemented in 2005 with an oak savanna management initiative, facilitated by a WDNR grant (Schreiber Anderson Associates, 2010). To implement this initiative, BioLogic Environmental Consulting, LLC (since acquired by Adaptive Restoration, LLC) completed a Woodland Assessment and Restoration Plan for the woodlands on the west side of the pond. However, the city has not completed a new master plan for the entirety of the Stricker's Pond Conservation Area.

After receiving several grants, Middleton has "improved stormwater runoff points on the ponds and has made an effort to control flooding" (Schreiber Anderson Associates, 2010). According to the Conservancy Lands Plan, "[t]hese recent efforts to control and reduce the water levels in the pond have produced opportunities to manage the pond edge vegetation, aquatic vegetation and wildlife habitat, and improve the nature trails around the pond" (Schreiber Anderson Associates, 2010). The plan also notes that the area would benefit from further projects, recommending a master plan focused on uniting the recreational features on the Middleton and Madison ends of the pond (Schreiber Anderson Associates, 2010).

In contrast to Middleton's various management plans and grant-funded initiatives, the City of Madison's efforts to manage its portion of Stricker's Pond have mainly been limited to water level regulation. According to the Madison Parks website: "Now [the cities] have some measure of control over the water levels. Both municipalities are working to restore native plant and animal communities in and around the ponds. We may not be able to restore these natural systems to pristine conditions, but through active stewardship we can improve them immensely, to the benefit of both people and wildlife." (City of Madison Parks Division, 2016).

6 WATER QUALITY

Because Stricker's Pond is hydraulically connected to Lake Mendota, its water quality is important for environmental and human health of the Yahara watershed. Stricker's Pond and Lake Mendota ultimately drain to the Yahara River, which is listed as impaired for sediment and phosphorus (Cadmus Group, 2011). This chapter details the framework of federal, state, and local policies relating to water quality within Stricker's Pond followed by a description of the procedures used for water sample collection and analysis, the resulting nutrient data, an analysis of nutrient conditions on overall pond health, and conclusions relating to water quality. Based on historical data and samples collected throughout the one-year study, further understanding of storm event and seasonal water quality in Stricker's Pond was attained.

Policies and legal requirements

The water quality in Stricker's Pond does not simply affect the cities of Middleton and Madison. The water, along with the pollutants it carries, flows into Tiedeman Pond, then through the Yahara Lakes, into the Yahara River, and then into the Rock River. This means that changes in Stricker's Pond water quality can have positive and negative downstream impacts. Any pollutant reductions achieved in the Stricker's Pond watershed will also reduce pollutant discharges to downstream waters.

Water from Stricker's Pond drains to Tiedeman Pond via a valve and underground pipe. Complaints of flooding from local residents led the WDNR to implement regulations (under Wisconsin Statute § 31.02) that dictate minimum and maximum pond levels. To mitigate stormwater influx, the City of Middleton installed a culvert in 2000 to drain water from Stricker's to Tiedeman Pond (City of Middleton, 2000). Overflow water is then pumped from Tiedeman Pond into Lake Mendota.

The WDNR set an initial minimum water level of 921.0 feet mean sea level (MSL) (Levels Permit 3-SC-2001-13-61-6153LR, 2002). The City of Middleton filed a proposal to change the minimum pond height from 921.0 MSL to a range from 920.5-923 MSL. The city made the proposal to "better manage the ponds to maximize growth and maintenance of beneficial aquatic plants, minimize adverse impacts to reptile and amphibian populations in the ponds, and better enable the City to control flooding in the ponds." The WDNR approved the city's request in February 2002 (Levels Permit 3-SC-2001-13-61-6153LR, 2002).

Both Tiedeman and Stricker's Ponds are classified as navigable waters of the State, and Tiedeman Pond is regulated as part of the City of Middleton Wisconsin Pollutant Discharge Elimination System (WPDES) permit (Eagan, 2012). Tiedeman Pond is therefore subject to a number of environmental discharge restrictions. As sampled at the outfall, Tiedeman Pond discharge is limited to 1.0 ppm total phosphorus (TP) monthly average as sampled twice per month over a 12-month rolling average. Total suspended solids (TSS) are limited to 30 ppm monthly average as sampled twice per month. This requirement was initiated with a rolling schedule on December 31, 2002, and final TSS limitations were required to be achieved by March 1, 2004 (Wisconsin Department of Natural Resources, 2002).

Stricker's and Tiedeman Ponds are not directly subject to federal requirements, but they are indirectly involved in federal water quality standards due to the classification of Lake Mendota, Lake Monona, and the Yahara River. Pursuant to Section 303(d) of the Clean Water Act, the WDNR has classified both the lakes and river as impaired waterways. Lake Mendota is impaired for water quality due to total phosphorus,and contaminated fish tissue due to PCBs. Lake Monona is impaired for eutrophication and TP pollution. The Yahara River is impaired for dissolved oxygen and degraded habitat; the pollutants causing these impairments are TP and TSS.

The Yahara Lakes and Yahara River are incorporated into the Rock River's Total Maximum Daily Load (TMDL). Section 303(d) of the Clean Water Act also requires states to develop TMDLs for all pollutants that do not meet water quality standards in impaired water bodies. The TMDL establishes the maximum amount of a pollutant that a water body can contain and still meet water quality standards. The Rock River TMDL sets allocations for the pollutants of TP and TSS.

The Rock River TMDL sets pollutant load reductions for nonpoint sources, wastewater treatment facilities, and municipal separate storm sewer systems (MS4s). Because Stricker's Pond receives stormwater inputs, it is most relevant to discuss MS4 requirements. The TMDL set an average TP reduction of 47% and TSS reduction of 55% for MS4s in the Lake Mendota and Monona basins. The TMDL also sets allocations for specific municipalities, and the MS4 area in the City of Middleton has an annual wasteload allocation of 476.66 lbs. of TP and 51.27 tons of TSS. Stricker's and Tiedeman are within Reach 64 of the Rock River TMDL. MS4 reductions for that reach, under no-control conditions, have been set as a 73% reduction for TSS and 61% for TP. A WinSLAMM model of the Tiedeman Pond watershed showed that existing controls reduce TSS by 80% and TP by 47% (City of Middleton, 2016a), indicating a need for continued controls for TP reduction.

Figure 6.1: Locations of monthly water sampling sites.

Water Quality Sampling

PURPOSE

With a TMDL in place for the Rock River, the cities of Madison and Middleton have incentives for reducing TP and TSS loads. Water quality was monitored within Stricker's Pond to assess current nutrient concentrations and describe habitat conditions within the pond, as high levels of bioavailable nutrients influence ecosystem processes.

METHODS

Stricker's Pond receives water through Madison and Middleton's storm sewer networks. Madison's stormwater flows through a constructed forebay on the southern side before entering the pond. Middleton has four storm sewers that drain directly into the pond. Seven sampling sites were monitored (Figure 6.1): two at inputs to the pond (Forebay Input and Stormwater Input), one inside the forebay (Madison Forebay) to evaluate water quality before entering the pond; one at a previous WDNR sampling point (SWIMS 133461; Deep Hole); one in open water in the northwestern portion of the pond (Open Water); one at the edge of the American lotus patch (Edge of Lotus); and one at the entrance of the pipe that drains to Tiedeman (Pond Outlet). Coordinates of each location are provided in Appendix 1.

Buoys were installed to mark the locations of the three sampling sites in the middle of the pond. Locations were accessed by kayak, and grab samples were collected at approximately one foot below the water's surface on each sampling date (Figure 6.2). Sites around the edge of the pond had identifying markers that facilitated returning to the same locations. Water samples near the edge of the pond were collected from shore using a ten-foot sampling pole (Figure 6.3).

Samples were collected on November 20, 2015, and March 15, April 13, April 28, May 27, June 14, June 15, July 12, August 22, and September 22, 2016. Samples taken on April 28, June 15, and September 22 followed storm events (at least 0.25 inches of rain within the previous 24 hours). The November 20 sampling date had rain eight days prior; March 15 had rain two days prior; April 13 had rain seven days prior; May 27 had rain 33 hours prior; and July 12 had rain three days prior to the sampling event.

Samples were analyzed in the Environmental Quality Laboratory in the Biological Systems Engineering Department at University of Wisconsin-Madison for electric conductivity (EC), pH, total solids (TS), and total suspended solids (TSS) using standardized protocols (Eaton et al., 1995); and total phosphorus (method EPA-135-A Rev. 5), dissolved reactive phosphorus (DRP; method EPA-118- A Rev. 5), total Kjeldahl nitrogen (TKN; method EPA-111-A Rev. 8), nitrate and nitrite (NOx; method EPA-126-A Rev. 9 or EPA-114-A Rev. 9), and total nitrogen (TN = TKN + NOx).

A consultant at the UW-Madison College of Agriculture and Life Sciences Statistical Consulting Lab developed a mixed effects model using SAS 9.4 for statistical com-

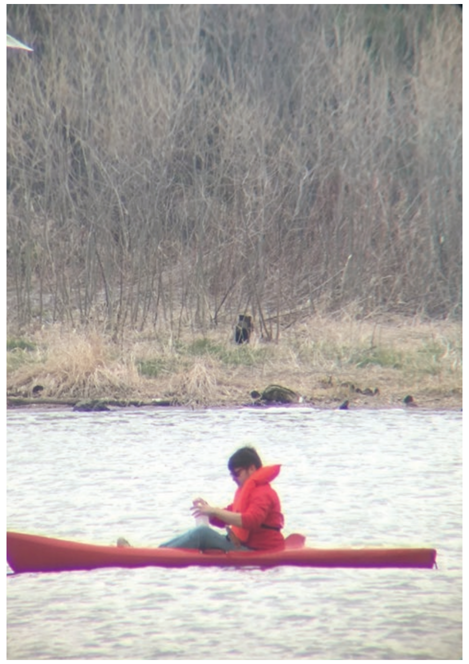


Figure 6.2: Collecting water quality samples by kayak.

Figure 6.3: Collecting water quality samples at the Stormwater Input site (November 2015).

parison of water quality parameters (a =0.05). Sites were clustered to determine differences among water entering the pond, the open water in the middle of the pond, and water at the outlet. Cluster 1 (Inputs) included the Madison Forebay, Forebay Input to Pond, and Stormwater Input sites. Cluster 2 (Middle of Pond) included the Open Water, Deep Hole, and Edge of Lotus sites. Cluster 3 (Outlet) was only the Pond Outlet site. For comparison of statistical differences among clusters, all samples (November 2015 through October 2016) for all sites within each cluster were grouped. Differences among seasons were also examined. Spring samples included those taken on March 15, April 13, April 28, and May 27, 2016. Summer samples were collected on June 14, June 15, July 12, and August 22, 2016. Fall samples were taken on November 20, 2015 and September 22, 2016. Differences among storm (April 28, June 15, and September 22) and non-storm events (March 15, April 13, May 27, June 14, July 12, and August 22) were also evaluated.

RESULTS

The following discussion includes results for TSS, TP, DRP, TN, and pH. Additional results for EC, TS, TKN, and NOx are presented in Appendix 1

TOTAL SUSPENDED SOLIDS

High TSS (solids that can be trapped by a filter; excludes dissolved solids) concentrations reduce the amount of light that can pass through the water column, reducing the survival of submerged aquatic macrophytes. A body of water with high TSS concentrations is indicative of nutrient pollution and potential erosion issues within the watershed. A combination of high TSS and excess nutrients, such as nitrogen and phosphorus, can create an environment favorable to algae growth.

A general increase in TSS throughout the spring and early summer was attributed to increased loading from storm events. TSS levels at the Inputs were similar to Outlet concentration in the early spring (Figure 6.4) while Outlet levels were higher than Inputs in summer and fall. Outlet TSS concentrations were consistently greater than the Tiedeman Pond discharge limit of 30 ppm from late April through September. TSS was generally sediment-dominated at the Inputs and algae-dominated in the Middle of the Pond (Figure 6.5). When sites were clustered into Inputs, Middle of Pond, and Outlet groups over the whole sampling period, no statistically significant differences in TSS were observed among sampling clusters. Similarly, no significant differences were found when comparing seasons or storm and non-storm events.

TSS inputs from Madison (Madison Forebay and Forebay Input) and Middleton (Stormwater Input) were similar (Figure 6.6). More stormwater enters at the Forebay Input on the Madison side than at the two other Middleton Inputs. The increased stormwater flow could have re-suspended deposited sediment in the Madison Forebay, and contributed to the slightly higher TSS concentrations. Additionally, the channel at the Forebay Input site is constricted, resulting in faster flow of stormwater that can keep larger particles in suspension. The two other Inputs open to a wide area where flow is slowed.

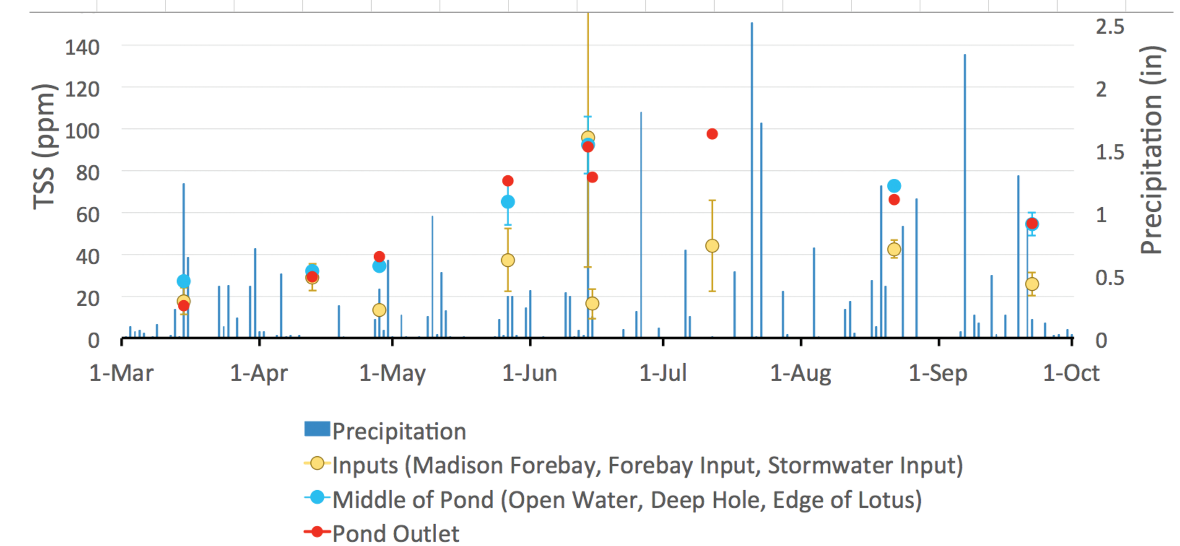


Figure 6.4: Average Total Suspended Solids at Inputs, Middle of Pond, and Outlet of Stricker's Pond from March-September 2016. Bars represent standard error. Daily precipitation is also shown.

PHOSPHORUS

Phosphorus, an important nutrient for plant and algae growth, is a prevalent pollutant in Wisconsin. Wisconsin Administrative Code Chapter NR 102.06 defines tolerable TP levels for rivers, streams, reservoirs and lakes (Wisconsin Department of Natural Resources, 2013).

Total phosphorus concentrations increased from March through June, with the highest average values measured at the Inputs in May (Figure 6.7). The lowest concentrations were observed in March. At the Inputs, evidence of dilution in TP concentrations was seen after the large storm in June. The TP concentrations discharging to Tiedeman Pond (Outlet site) were below the permitted TP values for Tiedeman Pond discharge (1.0 ppm). However, Stricker's TP levels were above the regulated lake levels of 40 ppb (which is to be expected for an urbanized watershed). When sites were clustered into Inputs, Middle of Pond, and Outlet groups over the whole sampling period, no statistically significant differences between clusters were found. Similarly, there were no significant differences in TP when comparing seasons or storm and non-storm events.

The forebay was originally installed to retain P and reduce amounts entering the pond. However, TP concentrations were similar inside the forebay (Madison Forebay) and at the input to the pond (Forebay Input) (Figure 6.8). The two sites were in close proximity, which could have contributed to similar results. Middleton's runoff at the Stormwater Input had a lower median TP concentration.

Dissolved reactive phosphorus (DRP) is the highly "bioavailable" fraction of P, meaning that it can quickly be used by algae (Lake Erie Algae, n.d.). DRP concentrations were generally below the detection limit of 0.01 ppm at the Middle of Pond and Outlet sites (Figure 6.9); the Outlet only had detectable DRP concentrations on March 15 (0.01 ppm) and April 28 (0.012 ppm). The Inputs, however, often had detectable concentrations significantly greater than concentrations in the Middle of Pond and Outlet sites. Especially high DRP concentrations were observed at the Inputs after the September storm event, showing evidence of P loading from fall storms. Differences between storm and non-storm event DRP concentrations were not statistically significant. Appendix 1 shows differences in DRP among the three inputs; median DRP concentration was lower at the Forebay Input compared to both the Madison Forebay and Stormwater Input locations.

NITROGEN

Like phosphorus, nitrogen is a critical nutrient for plant and algae growth. However, unlike phosphorus, the state of Wisconsin has not developed water quality standards for defining excessive N levels within water bodies. Only groundwater and drinking water N standards exist, which are specified in Wisconsin Administrative Code Chapter NR 140 and 809. Allowable groundwater and drinking water

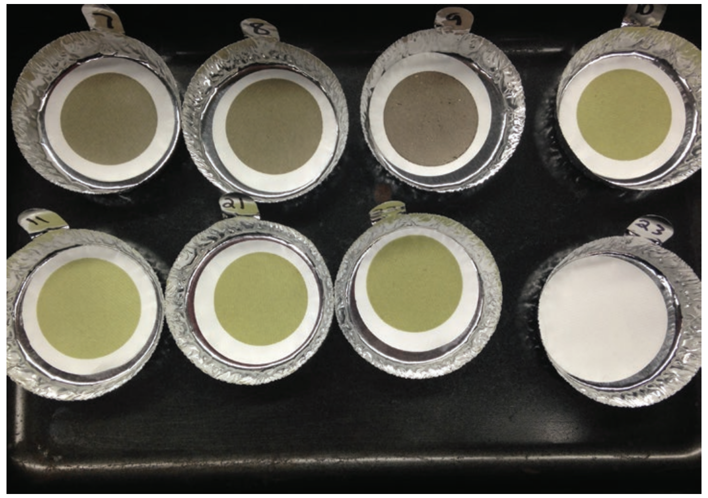


Figure 6.5 TSS filters from April 28, 2016. The three brown filters show suspended solids predominantly composed of sediments in samples taken at inputs to the pond. The green filters, showing prevalent suspended algae, are from the Middle of the Pond and Outlet sites. The white filter in the bottom right was a blank for comparison.

concentrations of nitrate (NO_3^-) are ≤10 ppm and ≤1 ppm for nitrite (NO_2^-). Concentrations of NOx (nitrate + nitrite) in Stricker's Pond, were below these standard levels (average of 0.07 ppm).

Total nitrogen (TN) concentrations increased from spring to early summer. The highest average concentrations were recorded at the Inputs in May (Figure 6.10). The lowest average concentrations, besides after a storm event, were observed in March when Inputs, Middle of Pond and Output sites all had average concentrations below 2 ppm. An outlier (15.49 ppm TN) occurred during the May sampling event at the Stormwater Input site. No statistically significant differences in TN were observed among clusters, seasons, or among storm and non-storm events. NOx concentrations were generally below detection limits with the exception of the Inputs, the Outlet in early spring, and the outlier (See Appendix 1).

Typically, P is considered a limiting nutrient in inland systems because N can be produced biologically (Downing & McCauley, 1992). Eutrophic systems, however, typically have low N:P ratios because of P abundance. In general, an N:P molar mass ratio above 20 is P limiting and a ratio below 10 is N limiting. Figure 6.11 shows the average N:P ratios at the Middle of Pond sites.

ACIDITY

A pH of 7 is neutral, and natural waters generally range from 6 to 8.5 (Tucker & D'Abramo, 2008). A range of 6 to 9 is tolerable for most aquatic species. Within the pond, average pH values ranged from about 7.5 to 9.5 and peaked during May and June. The Open Water location reached a pH of almost 10.5 in June (Figure 6.12). The Edge of Lotus site consistently had lower pH values from May through September compared to the Open Water, Deep Hole, and Outlet sites, suggesting less algae photosynthesis at the Edge of Lotus site. The pH at the Input sites averaged between 6 and 7.5, significantly lower than the Middle of Pond and Outlet sites, which could be a result of less algae photosynthesis at the Input sites. Fall pH levels were significantly lower compared to the other seasons (the fall 2015 sampling event is not shown in Figure 6.10). There were no significant differences in pH among storm and non-storm events.

CONCLUSIONS

Nutrient availability within an aquatic ecosystem greatly influences its biological composition. Both N and P concentrations were high within Stricker's Pond, and the pond showed hypereutrophic conditions during the growing season consistent with results from August 2014 (Marshall & Healy, 2014). Throughout the season, N:P ratios were closer

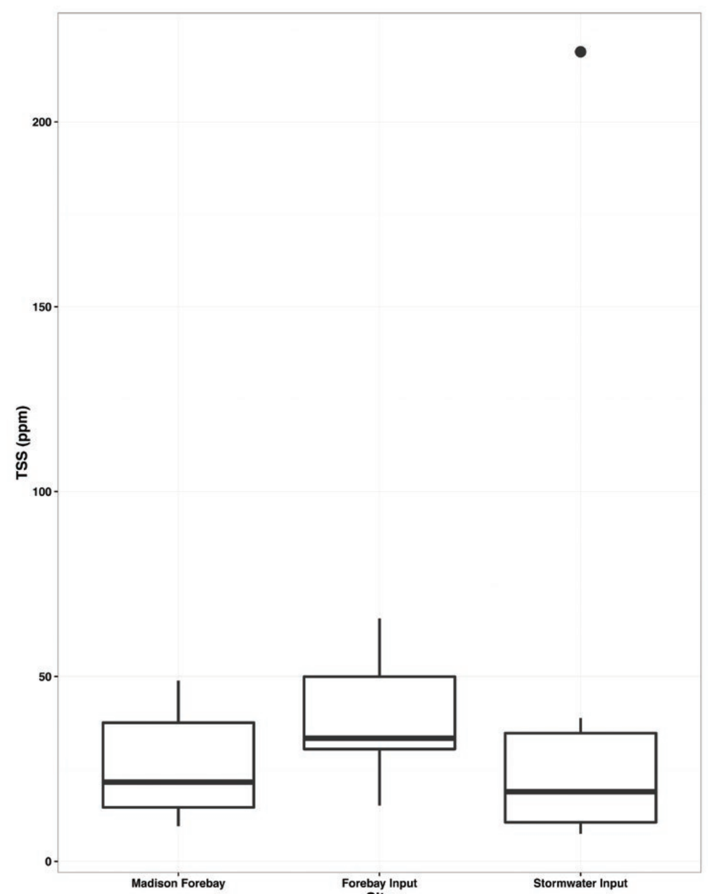


Figure 6.6: Box-and-whisker plots for TSS (ppm) at Stricker's Pond Inputs. Data from November 2015-September 2016. Center lines represent medians; boxes show first and third quartiles; and dots show outliers.

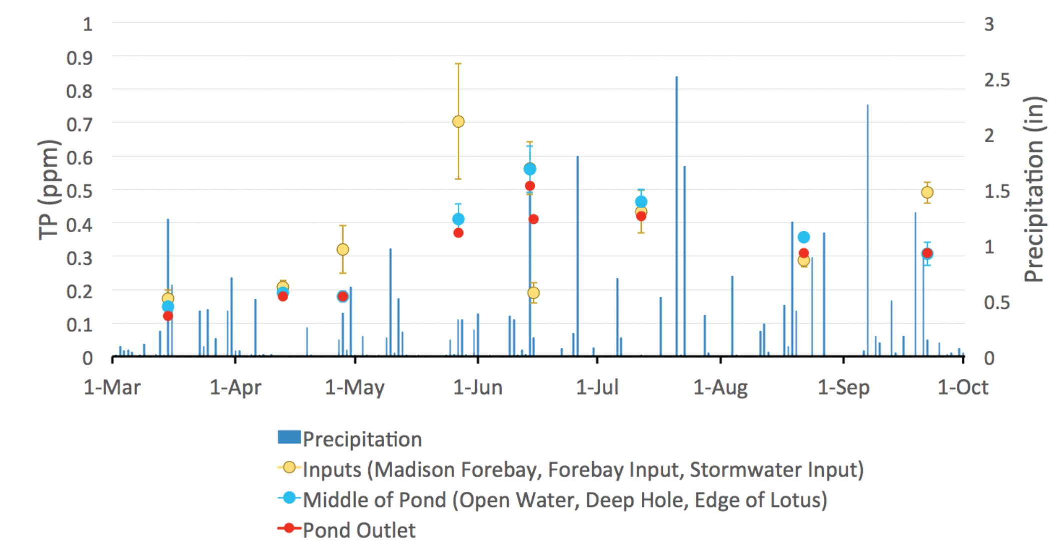


Figure 6.7: Average TP at Inputs, Middle of Pond, and Outlet of Sticker's Pond from March-September 2016. Bars represent standard error. Daily precipitation is also shown.

to the P limiting conditions. However, in June and July, P was prevalent and likely not a limiting nutrient. These enriched nutrient conditions promote algae growth. The differences in DRP between the Inputs and the other locations indicate that much of the DRP entering Stricker's Pond is consumed and that the high levels of TP observed at Middle of Pond and Outlet sites were predominantly particulate P.

The high pH levels in the Middle of Pond and Outlet are associated with underwater photosynthesis. Samples were always collected before noon, but if they had been collected later in the day, pH levels in the open water could have been higher as algae photosynthesis occurred. The American lotus (Nelumbo lutea) population appeared to reduce pH. Lotus leaves, which shade the water, could reduce algae photosynthesis, leading to higher carbon dioxide concentrations and thus lower pH. The overall high pH values could make Stricker's Pond inhospitable for some organisms, especially juvenile fish. Reduced algae growth could lead to more tolerable pH conditions for aquatic organisms.

Although not statistically significant when grouped by cluster over the whole sampling period, higher concentrations of TP were observed at Input locations compared to the Output from April through June. This suggests that during the spring and early summer, the pond could be acting as a P sink, retaining some of the excess nutrients within the system. The high Input P concentrations following the September storm suggest that fall storms could lead to large P inputs – perhaps leached from leaves. In general, DRP was mostly consumed by algae within the system; Outlet concentrations were typically below detection limits, and values at Inputs were greater than both Middle of Pond and Outlet sites.

Although not statistically significant when grouped by cluster over the whole sampling period, higher concentrations of TN were observed at the Outlet than at the Inputs in March and April. From May through July, this trend reversed and TN at the Inputs were higher than at the Outputs. These differences reflect the growth stages of the algae and aquatic macrophytes in the pond. Vegetation tends to grow slowly in April and May when water temperatures are still warming up after spring turnover. In June and July, vegetation experiences rapid growth (Barko & Smart, 1981). In August and September, the Output concentrations were again greater than the Inputs, which correlates with the end of the growing season.

The TN outlier measured at the Stormwater Input site in May was surprising. This sample site is in close proximity to several residential lawns, and the spike in TN may have been the result of lawn fertilizer application. However, studies suggest that nitrogen from lawn runoff is not a significant contributor to nutrient loading (Garn, 2002). Another contributing factor may have been warming water temperatures in late spring that can increase TN concentrations, particularly nitrate and ammonia, resulting from increased decomposition rates (Godshalk et al., 1978).

Total Kjeldahl nitrogen (TKN) concentrations were similar to TN concentrations indicating that a majority of the nitrogen in the pond is organic N (i.e., biomass) or ammonia (i.e., the byproduct of decomposition). The Open Water and Edge of Lotus sites were typically highest while the Madison

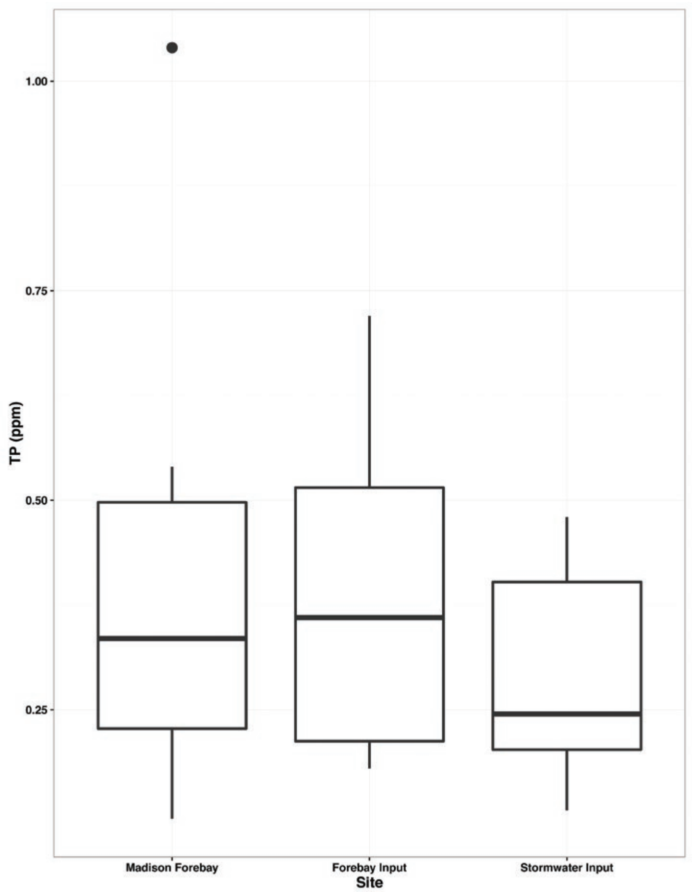


Figure 6.8: Box-and-whisker plots for TP results at Sticker's Pond Inputs. Data from November 2015-September 2016. Center lines represents medians; boxes show first and third quartiles; and dots show outliers.

Forebay and Stormwater Input sites were lowest (with the exception of the outlier). The Open Water sites were likely to have more algal biomass, whereas the near-shore water was somewhat light limited due to trees blocking sunlight. NOx levels were generally below detection limits with the exception of the Outlet in early spring, the Inputs, and the outlier. Again, this signifies that N was available primarily from biomass and its decomposition.

Electrical conductivity (EC) decreased throughout the 2016 growing season (Appendix 1). The highest conductivity in the spring could be the result of road salt application throughout the winter and early spring. This may also explain why TDS levels were high in the spring and early summer. The high TSS levels during the summer months at the Middle of Pond and Outlet locations were due to more algae.

In general, water quality parameters were similar between the Madison Forebay and Forebay Input sites (Appendix 1). Likewise, Middleton and Madison inputs were similar for many water quality parameters.

These water quality data provide several benefits. They present a year-long record of nutrients and other chemical inputs to Stricker's Pond which can establish baseline conditions for evaluating the pond's ecology. The methods used to conduct this study can also be followed for future water quality analysis. Lastly, these data can inform future modeling efforts and guide and ultimately evaluate the effectiveness of a holistic management plan.

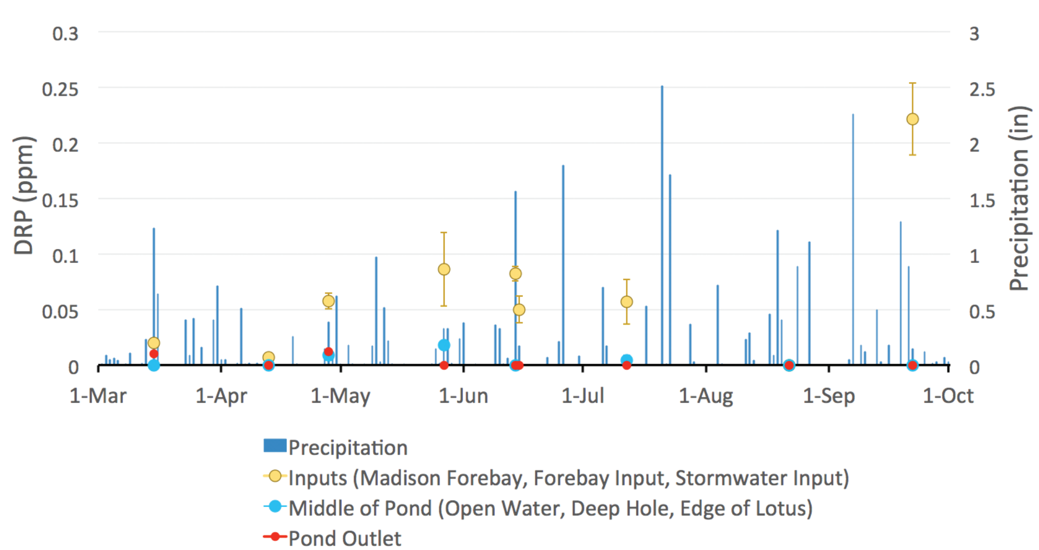


Figure 6.9: Average DRP at Inputs, Middle of Pond, and Outlet of Sticker's Pond from March-September 2016. Bars represent standard error. Points at zero were below the detection limit of 0.01 ppm. Daily precipitation is also shown.

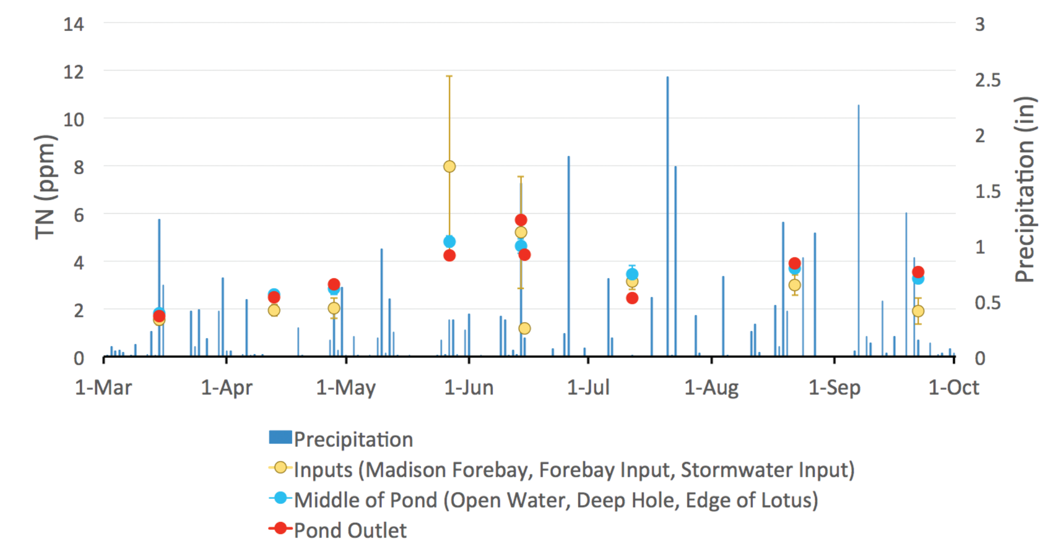


Figure 6.10: TN results from Inputs, Middle of Pond, and Outlet of Sticker's Pond from March-September 2016. Bars represent standard error. Daily precipitation is also shown.

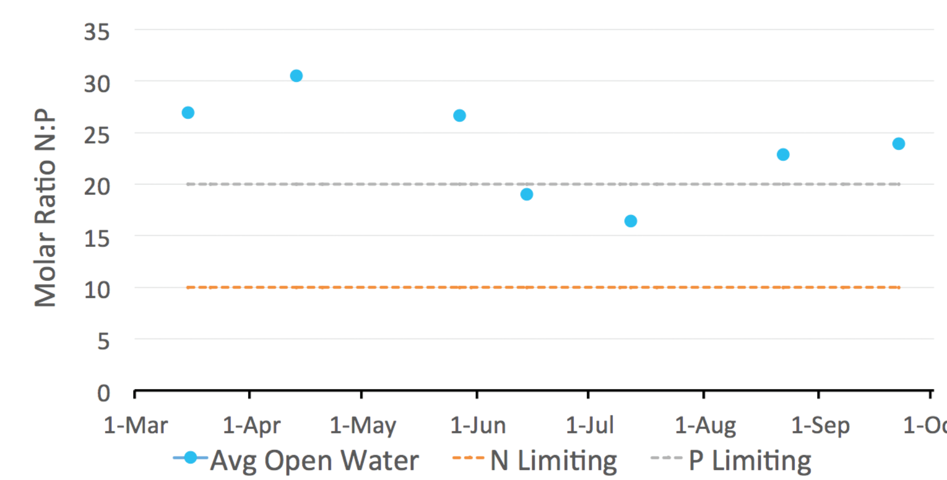


Figure 6.11: Molar N:P ratios fluctuated around the P limiting line throughout the season. In June and July, P was not a limiting nutrient.

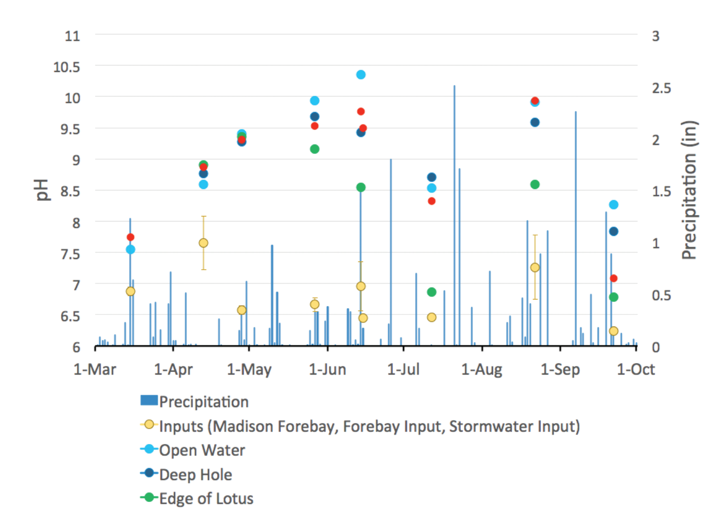


Figure 6.12: Results for pH from sampling sites within Stricker's Pond from March-September 2016. Bars represent standard error. Daily precipitation is also shown. Inputs consistently had lower pH values than the other sites. Among the sites in the Middle of the Pond, the Edge of Lotus site showed lower pH values.

7 MODELING

Modeling is a useful tool for connecting scientific theory to observations. In water resources management, computational modeling plays a crucial role in facilitating understanding of the physical processes that drive and control water quality and water quantity. Modeling also provides managers and stakeholders with information to make water quality- and quantity-related policy decisions. To guide the modeling process, a bathymetric survey was conducted to produce a stage-area-storage relationship for the pond. For this assessment, three different models were developed to better understand Stricker's Pond and its watershed: 1) a water budget to describe the relationship between inputs and outputs of water to the pond and corresponding pond levels; 2) HydroCAD to represent stormwater hydrology for the watershed; and 3) WinSLAMM to quantify the watershed's impact on pond water quality. The results of the HydroCAD and WinSLAMM models are presented together in a scenario-by-scenario format to facilitate better interpretation of results.

Bathymetric Survey

A bathymetric map details the elevations within a water body. This type of map was not only critical in the hydrological modeling efforts, but also for ecological considerations (e.g., water depth is a limiting factor for American Lotus; see Section 8.1). Pond bottom elevation data were collected every 32.8 ft (10 meters) along transects also spaced 32.8 ft (10 meters) apart. Trimble Juno ST units were used to record GPS locations, and a weighted rope was used to measure water depth (± 3 in). Data were collected on June 14 and 17, 2016, and depths were corrected for the change in pond stage between dates.

A Triangular irregular network (TIN) was created from the data in ESRI ArcMap. A TIN represents land surface by connecting irregularly distributed elevations -- in this case depths -- with a network of non-overlapping triangles. Based on the TIN, contour lines were generated using the "Surface Contour" tool (Figure 7.1). The TIN was then used to create a stage-surface area relationship for the pond. When this relationship is compared to that presented in Mueller (1984), a discrepancy between the two surveys is illustrated (Figure 7.2).

According to the results of the 2016 bathymetric survey, Stricker's Pond has lost an average of approximately eight inches of depth across the entire pond since 1984. This loss in depth could be a result of soil erosion from the watershed during development; accumulation of biological materials; and/or debris transported to the pond during large storm events. The majority of the changes to the watershed's land cover and land use regimes occurred during this 30-year period, and therefore soil erosion from the watershed is likely the primary contributor.

The 2016 stage-area-storage relationship was used in the modeling analysis for all elevations below 922 feet. Above this level, recent topographic data were used to determine surface areas (relevant for modeling high-water events caused by large storm events).

Water budget

PURPOSE

Water budgets, also known as water balances, are a watershed management tool used for estimating the net flux of water into or out of a drainage basin. Net flux calculations are made by characterizing the components of the hydrologic budget (e.g., precipitation, runoff, groundwater seepage, and evapotranspiration) as inputs and outputs to the system and determining their impact on total water storage. For Stricker's Pond, precipitation, seepage, evaporation, and pond stage (storage) were assessed (Equation 1).

Equation 1:

Δ Pond Storage = Precipitation ± Surface Water ± Seepage - Evaporation

Flux estimates provide information about the quantities of water being handled by Stricker's Pond across a range of stormwater storage demand. Periods of high storage demand, when more stormwater runoff flowed into the pond than was discharged into Tiedeman Pond, were determined and evaluated for their impact on pond stage and flood potential. Additionally, periods absent of stormwater inflow were used to estimate pond losses and discharge volumes into Tiedeman Pond under dry weather conditions.

METHODS

Pond stage was used to determine changes in pond storage and was monitored at 15-minute intervals onsite using two Solinst Levelogger pressure transducers (Figure 7.3). One transducer was installed in a pond-monitoring well near the outlet of Stricker's Pond to measure changes in pond depth. A second transducer was installed nearby onshore to measure barometric pressure. Pond depth measurements were corrected for variations in barometric pressure and calibrated to manual water depth measurements taken during data downloads. Water depth values were converted to pond stage elevations, which were used with the bathymetric stage-storage equation (Appendix 2.1) to estimate hourly changes in pond storage.

In addition to storage, precipitation, seepage and evaporation were also estimated. Hourly precipitation data were obtained from the Pheasant Branch monitoring station (USGS 05427948) located approximately one mile north of Stricker's Pond. Precipitation volume was estimated by multiplying precipitation depth by the surface area of the pond. Evaporation was estimated over the pond surface area using the Lamoreux method, which estimates lake evaporation based on temperature, vapor pressure, wind, and solar radiation. Temperature, vapor pressure, and wind data were obtained from the National Weather Service (NWS, 2016), and solar radiation values were obtained from University of Wisconsin Extension agricultural weather data (University of WisconsinW Extension , 2016).

Seepage rates were measured at four shore locations around the pond and one located in the forebay using seepage meters (Appendix 2.1). These rates were compared to seepage estimates made using pond stage data. During periods of no precipitation, decreases in pond storage are due primarily to evaporation and seepage. Evaporation estimates were subtracted from measured declines in pond storage to estimate seepage. Seepage values were calculated in this manner at different pond stages to account for variations in head between the pond and groundwater system. Using this method, no correlation was found between pond stage and seepage rate. Finally, net surface flows (stormwater runoff into Stricker's Pond minus discharge to Tiedeman Pond; Equation 2) were calculated by taking the change in pond storage, adding losses based on seepage and evaporation estimates, and subtracting inputs from precipitation. Net surface flow calculated during precipitation events was used to evaluate stormwater storage demand on Stricker's Pond.

Equation 2: Net Surface Flow = Δ Pond Storage + Seepage + Evaporation – Precipitation

RESULTS

The calculated average daily evaporation rate from April through mid-November 2016 was approximately 0.13 in/day. Values ranged from below 0.05 in/day in October and November to as high as 0.29 in/day in late June (Fig. 7.4). Seepage rates for Stricker's Pond (not the forebay) averaged 0.45 in/day (Table 7.1). Seepage rates measured on the north portion of the pond (locations 2 and 3 in Appendix 2.1) were lower than those measured farther south (locations 1 and 4 in Appendix 2.1), and seepage was lowest in the forebay. Combined evaporation and seepage losses from April through October averaged approximately 0.6 in/day.

Several large precipitation events occurred during the monitoring period. In late July, 4.23 inches of rain fell over a 72-hour period (two events separated by one day), causing the pond level to rise three feet (Fig. 7.5). Additionally, pond storage increased nearly 50 acre-ft the first day and more than 66 acre-ft total (Fig. 7.6). As few precipitation events caused increases in pond elevation of more than half a foot, the late July event provided valuable information about stormwater storage demand on the pond under more extreme conditions.

The calculated net surface flow values from Equation 2 helped assess the role that surface water plays in storage demand. Of the 66 acre-ft pond storage increase observed during the late July events, 60.5 acre-ft (90%) was attributed to net surface flow (Figure 7.7). Net surface flow contributions were also high (82-95%) for other 24-hour precipitation events (Table 7.2). Small events (0.5-1 inch in a 24-hour period) had proportionally the greatest net surface flow contributions (95% on average) to change in pond storage. These results indicate that surface flow (stormwater runoff) is the greatest source of demand on pond storage. Controlling these runoff volumes is a critical component of managing pond storage and reducing the risk of flooding.

Large precipitation event (>2" in 24 hr)	Medium precipitation event (1-2" in 24 hr)	Small precipitation event (0.5-1" in 24 hr)
0.82	0.85	0.95

HydroCAD

PURPOSE

HydroCAD is computer-aided design software primarily used to model the quantity and timing of stormwater produced from specific storm events. HydroCAD is unique in that it has the capacity to represent watershed-scale hydrologic processes with a user-friendly interface. The software

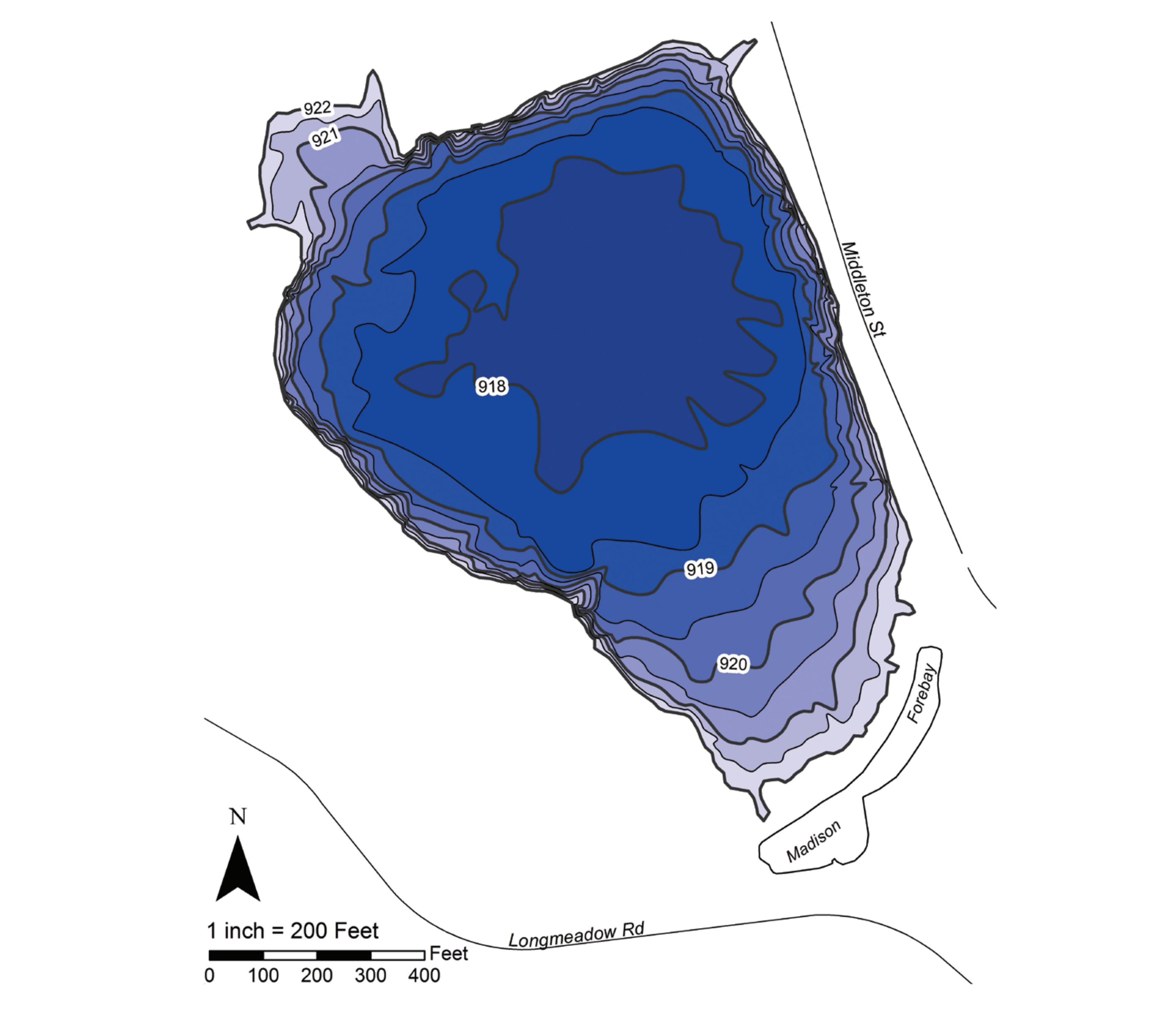


Figure 7.1: Bathymetric map. The pond bottom is shown at 918.0'.

combines several runoff estimation techniques to estimate the time distribution of hydrologic fluxes in a given system. Furthermore, HydroCAD's ability to represent small-scale urban watershed hydrology makes the software a useful tool for this assessment of Stricker's Pond.

To better understand the Stricker's Pond watershed and its hydrologic response to storm events, HydroCAD-10 was employed to evaluate a series of storm scenarios. The scenarios included both design (modeled) storms as well as storms derived from historic time series data. To establish a baseline, the current Stricker's Pond watershed characteristics (fully urbanized state) were first assessed to determine the incurred effect on stormwater hydrology. In addition, several modifications to land cover and land use were made and evaluated to represent the implementation of best management practice (BMP) scenarios. The evaluated BMPs included pervious pavement, small-scale rain gardens, and regional infiltration practices. The results of the various scenarios allowed the group to evaluate the current hydrologic status of the watershed and guide future directions which municipal and regional stakeholders may consider to mitigate stormwater concerns.

METHODS

Land use and land cover in the watershed were characterized using ArcGIS. Land use categories include residential, commercial, open spaces, and roadways (Appendix 2), while land cover was simply classified as either pervious or impervious surfaces. Land use and land areas were similar to those provided by Eric Thompson, PE, CFM of MSA Professional Services, Inc., of Madison, Wisconsin.

Using a previous HydroCAD model of Stricker's Pond, also provided by Eric Thompson, as guidance, the group created a new watershed model. The watershed was divided into several subwatersheds to more accurately represent the hydrology/hydraulics within the basin. These delineations were determined using a combination of a digital elevation model and a current map of Middleton and Madison municipal storm sewer systems. Based on these delineations, times of concentration were determined for each subwatershed.

Because the HydroCAD software used in this assessment was restricted to only 20 nodes, two separate models were created; one to represent the Middleton portion of the watershed and one to represent the Madison portion of the watershed. Using link nodes, model results for the entire watershed were created by aggregating the two models.

The outlet of Stricker's Pond, which drains to the adjacent Tiedeman Pond, was modeled based on as-built construction plans from the early 2000s. It should be noted, however, that the outlet is sporadically opened and closed throughout the year by staff from the City of Middleton. These alterations, intended to manage the amount of water entering Tiedeman Pond, are not necessarily consistent or regularly recorded. To account for uncertainty associated with these changing hydraulic conditions, select HydroCAD runs were conducted with: 1) a fully functioning (completely open) outlet and 2) no outlet (completely closed). This envelope represents not only scenarios with a fully opened or closed valve, but also conditions which may occur in the event of a clogged outlet.

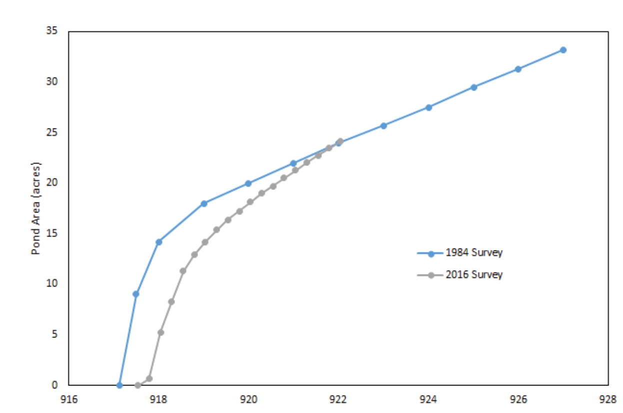


Figure 7.2: Stage-area curves for the 2016 and 1984 bathymetric surveys.

The hydrologic responses of the Madison and Middleton portions of the watershed, under existing conditions, were evaluated using several rainfall time series and a design storm in HydroCAD. The 100-year, 24-hour design storm was determined using NOAA Atlas 14 (the selected site in the Atlas, Charmany Farm, is located less than one mile from the pond). Historical rainfall time series from 1981 and 2016 were selected to represent "average" and "abnormally wet" conditions, respectively. The year 1981 is often considered by stormwater modelers as a typical year in the Madison area for total rainfall, spatial distribution of events, etc. In contrast, 2016 was an abnormally wet year for the region (approximately 15% greater annual total precipitation than average), with 11 days logging more than 1 inch of rainfall, compared to only one >1 inch event in 1981. The time series for each of these years were converted into HydroCAD storm format and used as model inputs.

To evaluate potential impacts of climate change on the region's hydrology, each rainfall depth in the 2016 historical time series was amplified by a factor of two. This modification accounts for the potential for increased rainfall event intensity, but not the potential for increased rainfall event frequency.

In addition to current land use and land cover conditions, implementation of the following BMPs were evaluated: pervious pavement, small-scale rain gardens, and regional infiltration practices. HydroCAD provides guidance in incorporating these features into an existing modeled system. The three BMP scenarios considered include a watershed in which: 1) every roadway is converted from traditional pavement to porous pavement; 2) 5% of each residential lot is dedicated as rain garden; and 3) two large (18 and 10 acres) common open spaces are modified to augment infiltration (Figure 7.8). Pervious pavements were modeled for the entire watershed, a total length of over six miles of roadway including portions of North Gammon Road and Old Sauk Road (main thoroughfares in Middleton and Madison). While some of these scenarios may not be deemed realistic, they provide a starting point to guide water quantity management solutions.

Finally, implementation of a sedimentation forebay on the northwest corner of the pond, similar to the existing forebay on the south end of the pond, was evaluated. While the WDNR's conservation practice standard for sediment basins (Wisconsin Department of Natural Resources, 2006) was used as guidance, the new forebay berm thickness and maximum depth were assumed to be similar to those of the existing forebay (as suggested by Gary Huth, Assistant

Figure 7.3: Pressure transducers were installed to monitor pond stage and barometric pressure.

Public Works Director and Assistant City Engineer for Middleton). This forebay was first proposed by the City of Middleton Parks Department, and its implementation has been the subject of debate.

WinSLAMM

PURPOSE

The Source Loading & Management Model for Windows (WinSLAMM) is an urban stormwater quality model that estimates runoff volume and pollutant loading for individual source areas in a watershed. The model can be run for a continuous rainfall record or a single rain event. The model can also be used to evaluate the effectiveness of stormwater control practices to decrease runoff and pollutant loadings to receiving waters. For our assessment, WinSLAMM was used to estimate phosphorous and total suspended solids loads from the Stricker's Pond watershed. Based on source allocations of pollutant loads, targeted control practices can be evaluated for their effectiveness to lower pollutant concentrations and improve water quality.

METHODS

The final version of the WinSLAMM model used in our assessment of Stricker's Pond and the surrounding watershed is shown in Figure 7.9. Land use and land areas in the model were similar to those provided by Eric Thompson, PE, CFM of MSA Professional Services, Inc., of Madison, WI. Each land use was assigned characteristics (e.g., amount of pervious or impervious area) by applying a "Standard Land Use" file. The Madison and Middleton portions of the watershed were modeled separately. Stricker's Pond and the Madison forebay were modeled as "wet pond" control practices that remove pollutants based on their stage-area relationship and outlet characteristics. The outlet structure dimensions were taken from as-built construction plans from the early 2000s.

Similar to the HydroCAD analysis, three best management practice scenarios were modeled: permeable pavement, small-scale infiltration (e.g., rain gardens) and regional infiltration. The permeable pavement was distributed to every land use in the whole watershed as a replacement for all concrete and road surfaces and was assigned an infiltration rate of 100 in/hr using guidelines from the Wisconsin Department of Natural Resources (WDNR, 2016). For the small-scale infiltration, every land use tile in the watershed had an infiltration basin placed where it drained. The regional infiltration practice was located in the southernmost site depicted in Figure 7.3.1. Both regional and small-scale infiltration basins were sized to be 5% of their contributing drainage area and 6 inches deep using the Homeowners How-To Manual produced by the Wisconsin Department of Natural Resources (WDNR, 2003). The existing watershed conditions and the three best management practice scenarios were evaluated using the same rainfall time series and design storm described in section 7.3.2.

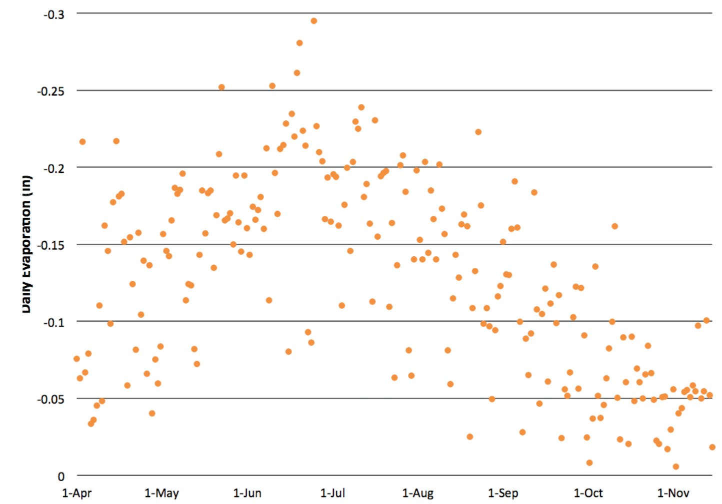


Figure 7.4: 2016 daily evaporation values calculated using the Lamoreux method and weather data from the National Weather Service and UW Extension.

Location	Measured Volumetric Seepage Rate (in3/min)	Seepage Rate (in/day)	
1	Southeast Pond	-0.31	-0.62
2	Pond Outlet	-0.10	-0.19
3	North Pond	-0.14	-0.28
4	West Pond	-0.35	-0.70
5	Forebay	-0.05	-0.10

Table 7.1: Seepage rates measured in mid-July at four near-shore locations in the pond and one in the forebay (locations shown in Appendix 2.1).

RESULTS

100-YEAR, 24-HOUR DESIGN STORM

The 100-year, 24-hour rainfall depth for the immediate vicinity of Stricker's Pond is approximately 6.68 inches (National Environmental Satellite, Data and Information Service, 2015a). Using a MS4 rainfall distribution, the resulting hydrographs (for the entire watershed as well as the Middleton and Madison portions of the watershed, separately), and pond elevation are displayed in Figure 7.10. The runoff response for the heavily urbanized watershed to the pond is rapid. The time between peak rainfall and peak discharge for this rainfall scenario is only 45 minutes. The pond's surface elevation changes more slowly; peak stage occurs roughly 12 hours after peak rainfall.

The Middleton portion of the watershed is approximately 30% compared to Madison's 70%; however, Middleton contributes disproportionately more runoff (36%) to the pond than Madison (64%). This trend was consistent for all rainfall scenarios using current land cover/land use conditions. A reason for this disproportionality may stem from the composition of each municipality's subwatershed (see Fig. 5.2). The

Figure 7.5: 2016 daily average measured pond elevations and daily precipitation from the USGS Pheasant Branch monitoring station.

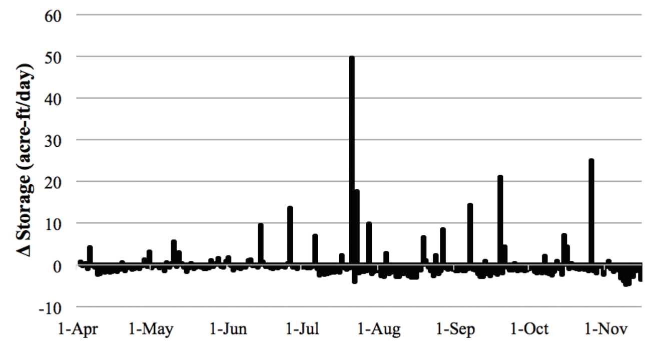


Figure 7.6: 2016 daily change in pond storage estimated using pond stage measurements and the bathymetric stage-storage equation (Section 7.2).

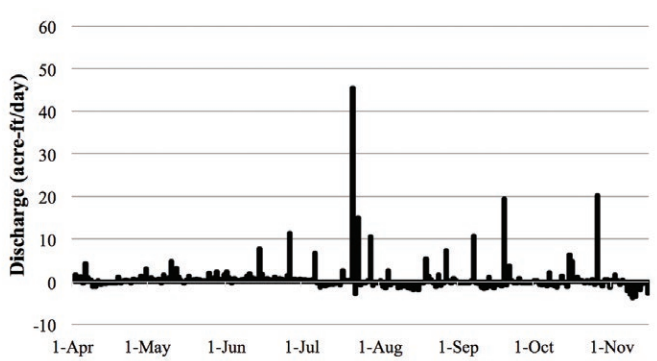


Figure 7.7: 2016 daily net surface flow calculated from the water budget.

Large precipitation event (>2" in 24 hr)	Medium precipitation event (1-2" in 24 hr)	Small precipitation event (0.5-1" in 24 hr)
0.82	0.85	0.95

Table 7.2: Average ratio of daily net surface flow to daily change in pond storage grouped by precipitation amounts.

Middleton subwatershed is predominantly residential with little to no open space, while the Madison subwatershed contains several parks, woodlands, and other open areas that allow for more infiltration and less runoff.

The estimated total pollutant loads entering Stricker's Pond from the surrounding watershed for the 100-year, 24-hour storm under existing conditions are shown in Figure 7.11. Madison contributes more TP and TSS than Middleton, which is not surprising as Madison constitutes a larger portion of the watershed. Similar to runoff, Middleton contributes 36% of the total TP and TSS loads, while Madison contributes 64%. This trend was consistent for all rainfall scenarios using current land cover/land use conditions.

1981 AND 2016 PRECIPITATION TIME SERIES

In addition to the design storm, historical time series from 1981 and 2016 were simulated over the watershed in its current state. Precipitation and pond stage for these two simulations are represented in Figure 7.12 and 7.13, respectively.

The annual average water level for the 2016 run is more than 1.5 feet higher than in 1981; however, the 1981 run produced the highest overall peak stage of 925.25 feet, despite lower overall rainfall depths. Although HydroCAD is a sophisticated stormwater modeling software, the simplifications it makes with regard to antecedent conditions in the watershed likely affect the results. Additionally, the coarseness of the 2016 daily precipitation data compared to the 1981 hourly data may dampen the response of the pond. The observed stage of Stricker's Pond in 2016 agreed fairly well with the modeled stage (Pearson's correlation = 0.71; Figure 7.14).

Consistent with the 100-year storm event, Madison contributes more annual pollutant loads to the pond than Middleton for both the 1981 and 2016 rainfall series (Figures 7.15 and 7.16). The annual loads for both total phosphorous and total suspended solids are greater than the loads for the 100-year single storm event. Pollutant loads for both Madison and Middleton were slightly greater in 2016 than 1981; 2016 was moderately more wet than 1981.

CLOSED/OPENED VALVE

The 2016 modeled results reflect a fully open outlet of Stricker's Pond. In reality, the valve controlling drainage was adjusted several times during the year, resulting in several periods of limited to no drainage from Stricker's Pond and transitively high waters. For example, at the beginning of August the outlet valve was completely closed for several days as a result of high water levels in Tiedeman Pond. These valve adjustments likely explain certain disparities between the modeled and observed water level time series for 2016, such as the one observed at the beginning of August (Figure 7.14). The envelope of potential pond levels with an open or closed valve is displayed in Figure 7.17.

If there were ever a condition in which the outlet from Stricker's Pond was inoperable for the entire season with precipitation such as occurred in 2016, the surface elevation of the pond is estimated to reach approximately 929 feet. As verified with existing topographic maps, the water would

Figure 7.8: Two sites in Madison were selected as candidates for infiltration basins, shown in blue. The location of the proposed forebay is indicated in yellow in the pond's northwest corner.

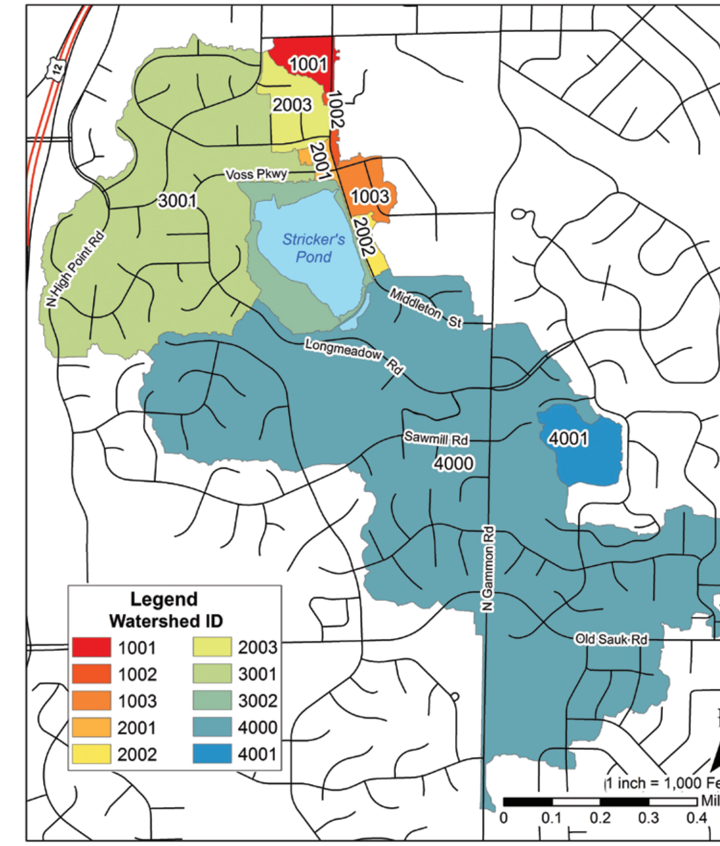


Figure 7.9: Schematic of subwatersheds for the WinSLAMM model. Subwatershed 4001 is hydraulically disconnected to Stricker's Pond and therefore discharges to an "other device" that reduces 99.99% of pollutants and flow volume. It was included in the model to account for all land uses.

begin to inundate the streets at the northern end of the pond in addition to numerous yards of adjacent households. While it is highly unlikely that an entire year would pass with no outlet, the stage range indicates that much of the surrounding community would experience heavy flooding, and certain streets around the pond would be inundated.

AMPLIFIED PRECIPITATION

As described at the beginning of this report, it is expected that the local hydrologic cycle will intensify by both total amount and frequency of precipitation. The 2016 precipitation depths were each amplified by a factor of two to demonstrate future conditions if subjected to an intensified hydrologic cycle. The pond elevation time series in response to amplified precipitation is shown in Figure 7.18 and compared to the actual 2016 time series. With amplified precipitation, the pond stage reaches a maximum level of 929 feet on three occasions, and the average pond level is 2.5 feet in excess of what it was in 2016. While this amplification is somewhat arbitrary, future changes in precipitation should be considered; an excessively wet year today may, by the end of the century, be considered "normal".

Total pollutant loads for the amplified precipitation under existing conditions are shown in Figure 7.19. The increasing trend for TP and TSS from 1981 to 2016 continues with this scenario. The amplified precipitation results in a considerable increase in both TP and TSS from Middleton and Madison. For example, annual TP load from Middleton increases from 169 lbs. in 1981 to 180 lbs. in 2016 to 457 lbs. for the amplified precipitation. This large increase in TP is attributed to elevated runoff from the increase in precipitation.

BEST MANAGEMENT PRACTICES IMPLEMENTATION

Because the 1981 rainfall time series is commonly used by stormwater modelers in Madison, this time series was used to evaluate the implementation of the previously identified best management practices (BMPs). The implementation of pervious pavements, rain gardens, and infiltration basins in

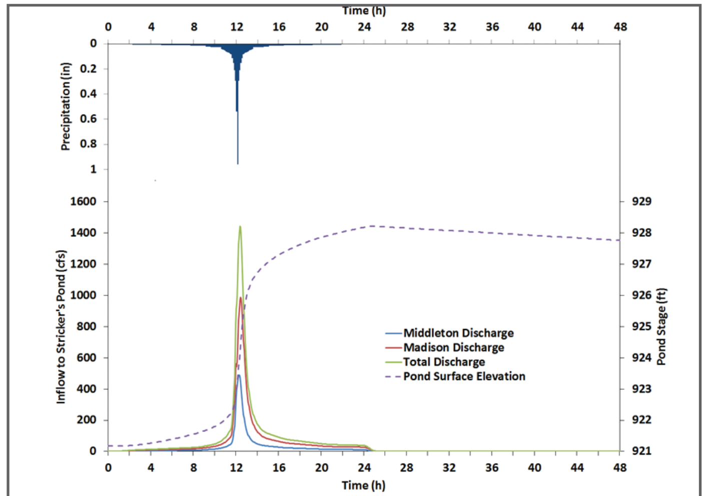


Figure 7.10: The 100-year, 24-hour storm, with subwatershed inflows and pond elevation portrayed. Stricker's Pond responds relatively quickly to intense pulses of rainfall.

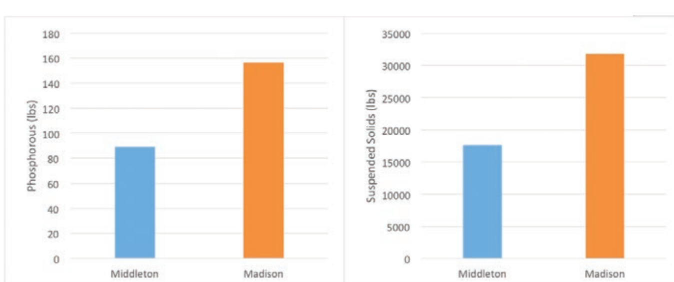


Figure 7.11: Total phosphorous (left) and total suspended solids (right) loads for the 100-year, 24-hour storm event and existing watershed conditions.

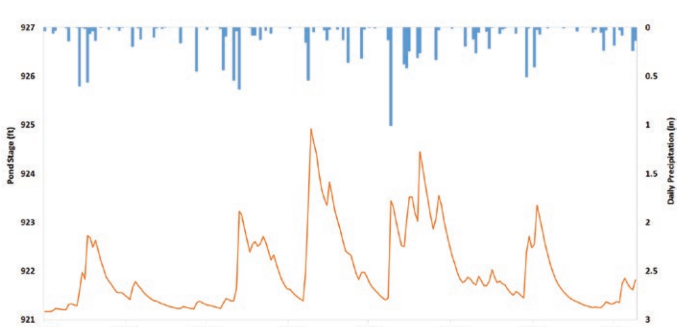


Figure 7.12: Precipitation time series and subsequent modeled pond stage for 1981. This is considered an 'average' year for rainfall in the Madison area.

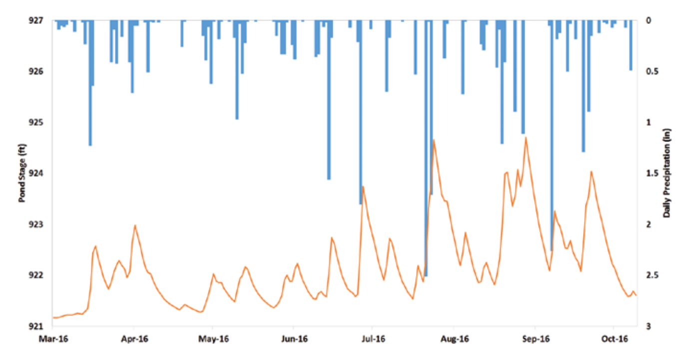


Figure 7.13: Precipitation time series and subsequent modeled pond stage for 2016, whichhad 11 days with more than one inch of precipitation, compared to one such day in 1981.

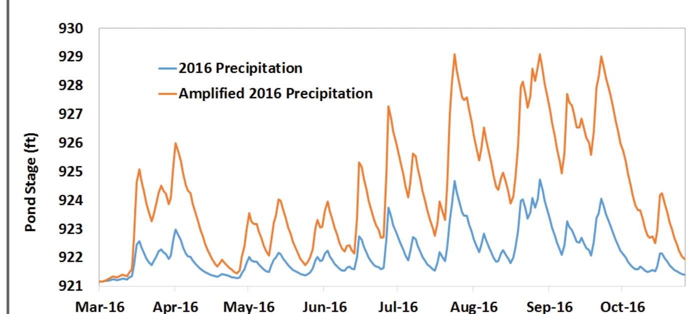


Figure 7.14: Comparison of modeled and observed pond stage for 2016. While some discrepancies exist, overall the model correlates well with the observed conditions.

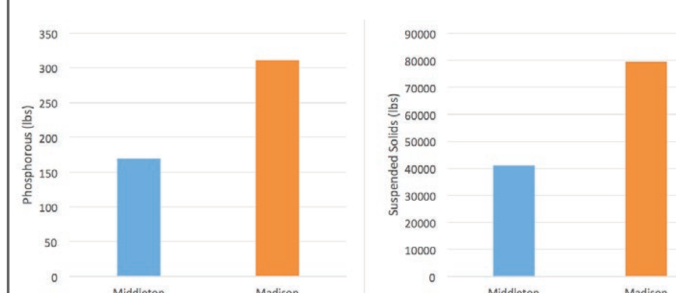


Figure 7.15: Total phosphorous (top) and total suspended solids (bottom) loads for the 1981 rainfall time series and existing watershed conditions.

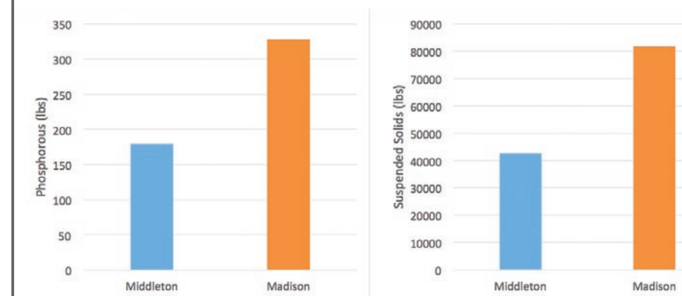


Figure 7.16: Total phosphorous (left) and total suspended solids (right) loads for the 2016 rainfall time series and existing watershed conditions.

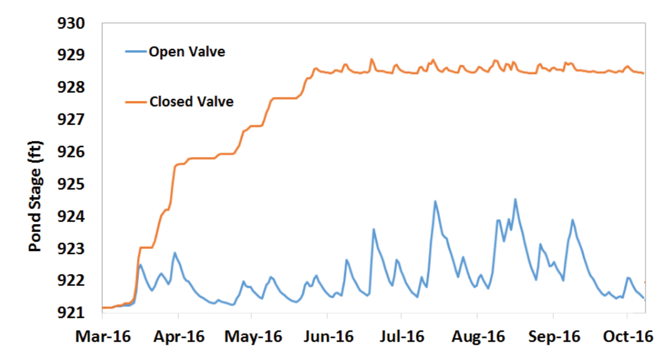


Figure 7.17: Modeled 2016 time series with fully open and fully closed valve. With a completely inoperable/closed outlet, the pond's surface elevation reaches a staggering 929 feet.

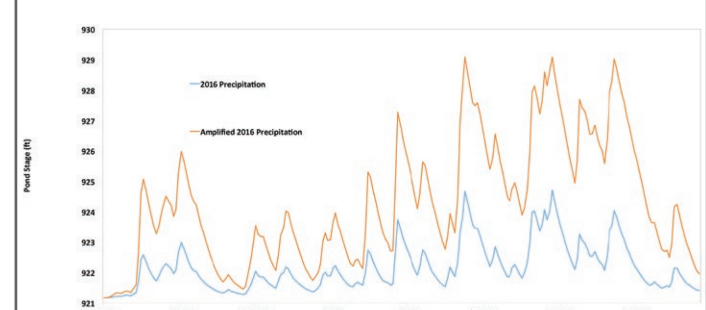


Figure 7.18: Modeled results for actual and amplified 2016 precipitation time series. A changing climate could have a profound impact on Stricker's Pond.

the watershed had varying results.

Implementing pervious pavements at this scale reduces peak pond elevations by up to one foot during storm events. This reduction in stormwater quantity is a result of pervious pavements acting as transport media for stormwater from otherwise impervious surfaces to soils. The water permeates through the pavement and infiltrates into surrounding soil. While pervious pavements also have the potential to reduce pollutants, this BMP is not likely to be feasible at this scale, especially on the watershed thoroughfares with heavy traffic demand. In certain areas of the watershed, however, such as the northeast portion of the Middleton subwatershed (in Figure 7.9, subwatersheds 1001, 1002, 2001, and 2003) and in neighborhood culs-de-sac, roadways could be converted in an effort to reduce stormwater runoff if a cost-benefit analysis suggested feasibility, and public interest existed to match.

Watershed-wide rain gardens and two regional infiltration basins both resulted in peak pond level reductions of up to half a foot. These solutions are characterized by their own sets of challenges. Implementation with every homeowner in the watershed dedicating 5% of their lot to a rain garden or a similar practice would be difficult. The selected locations of the two infiltration basins are both park areas in Madison (Figure 7.8). While they would reduce the amount of stormwater entering Stricker's Pond, these areas are important components of the neighborhoods surrounding the pond.

The annual pollutant loads for the three BMP scenarios and the 1981 time series are shown in Figure 7.20. Each BMP scenario reduces pollutant loads to the pond from both cities. For the whole watershed, permeable pavement, regional infiltration and distributed rain gardens reduce TP loads by 36%, 32% and 34%, respectively, and TSS loads by 53%, 37%, and 17%, respectively. Of the three practices, permeable pavement provides the most benefit (greatest TP and TSS reduction) to Middleton while the regional infiltration basin provides the greatest benefit to Madison. The infiltration basin is within Madison, so it is not expected to benefit Middleton. The pollutant loads for existing watershed conditions and the BMP scenarios are presented in Table A2.1 (Appendix 2) for the 100-year storm, and the 1981, 2016, and 2016 amplified rainfall series.

The pollutant loads for each subwatershed under existing conditions in Middleton and Madison are shown in Table A2.2 (Appendix 2). Total pollutant loads increase with watershed area. With the exception of subwatersheds 3002 and 4001, a slight decrease in pollutant loads per acre is observed as subwatershed area increases.

SEDIMENTATION FOREBAY

Finally, a sedimentation forebay was modeled on the north-

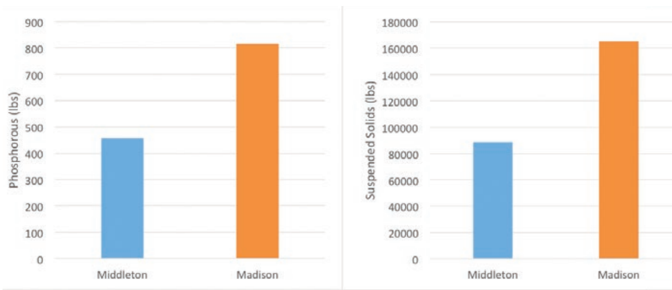


Figure 7.19. : Total phosphorous (left) and total suspended solids (right) loads for the amplified 2016 rainfall and existing watershed conditions.

western edge of the pond in Middleton. This forebay (Figure 7.8) takes advantage of an existing lobe of the pond. Based on guidelines provided by WDNR conservation practice standards for sediment basins (WDNR, 2006), more storage volume is needed for the forebay to meet required total vs. active volume ratio. As proposed, the forebay also would not meet space specifications (specifically, length-to-width ratio of 3:1). If the City of Middleton converted adjacent land from the north shore prairie restoration area or Stricker Park for this forebay, limited water quality benefits would result. During storm events, the pond's stage is only temporarily reduced, while the adjacent Stricker Park would be flooded for several days at a time following events.

CONCLUSIONS

Uncertainty in the modeling efforts was addressed by sets of relevant assumptions. While uncertainty is inherent and to be expected with some terms of the pond water balance (e.g., evapotranspiration), in other instances uncertainty is created by the pond's stewards. Most notably, the current management of the pond outlet valve is somewhat crude and should be modified immediately. The pond's outlet is currently managed by the Parks Department of the City of Middleton. From the time of its implementation, the state of the outlet valve has been qualitatively described (with descriptors such as "3 clicks" of a valve or 2 turns of a wrench) as opposed to quantitatively (opened at 75% capacity or allowing a flowrate of 3 cfs). While the uncertainty and ambiguity associated with this valve made modeling difficult, more importantly the current practices of controlling and monitoring the valve could lead to potential flooding in adjacent neighborhoods if proper conditions arose. A descriptive protocol should be created for the valve and include the water levels at which the outlet valve should be closed, partially opened, etc. to ensure the proactive and proper management of Stricker's Pond.

As confirmed through the water budget, the main inflows to the pond are stormwater runoff from Middleton and Madison. Because the only outflows from the pond are the engineered outlet and other relatively minor fluxes, such as evapotranspiration and groundwater interactions, the pond moreover serves as a retention basin for the stormwater runoff from the surrounding neighborhoods. Stricker's Pond has a large capacity for stormwater retention, with threats to private property and public infrastructure only occurring at exceptional water levels, as simulated using the amplified 2016 rainfall. As observed from the late July storm event, large precipitation events that overwhelm the watershed's infiltration capacity have a disproportionately large impact on pond storage and resultant pond stage increases.

Under many cases circumstances, adjacent areas of the pond, such as Stricker Park in Middleton, may become inundated during large storm events. If Middleton and Madison wish to protect these areas from inundation by controlling the quantity of water entering the pond, it is best to look upstream in the watershed. As shown in the BMP HydroCAD runs, several practices can be implemented to reduce the amount of water entering the pond during storm events. To determine which tools to implement and at what extent, a cost-benefit analysis of each prescribed BMP -- rain gardens, permeable pavement, and infiltration basins - should be conducted. At a preliminary level, while the most reduction in stormwater runoff occurs with permeable pavements, infiltration basins may prove to be the most feasible and least intrusive practice for the watershed. Ideally, these and several more BMPs should be used in unison to have the greatest impact on stormwater runoff.

Furthermore, as confirmed through SLAMM modeling, the adoption of control practices in the watershed can help improve water quality. The runs using permeable pavement across the watershed show the greatest reductions in both total phosphorus and total suspended solids loads for the 1981 rain scenario and the greatest reductions in TSS for the remaining rain scenarios; the caveat being that converting all existing pavement to permeable pavement is not a realistic option. The most likely of control devices used would be rain gardens or an infiltration basin. A large-scale basin is feasible within the watershed, but it would take a concerted effort to find an appropriate location for its implementation. While the results of the SLAMM model also indicate small-scale, distributed infiltration practices could have a positive impact, ensuring widespread citizen participation may be difficult.

In considering the characteristics of the watershed, it may be best for the cities to pursue infiltration basins and other large-scale features in the larger subwatersheds (e.g., 3001 and 4000) in an effort to reduce the absolute amount of pollutants and stormwater runoff coming from these catchments. Meanwhile, rain gardens and other small-scale features in smaller subwatersheds (e.g., 1001, 1002, 2001, 2002, and 2003) could be adopted by citizen-fueled initiatives to reduce the relative amount of contaminants contributed from those areas.

While the results presented in this section represent dozens of model runs performed using SLAMM, HydroCAD, and Matlab, they should only serve as a general guidance and a starting point for potential policy changes. To refine the accuracy of these models, a professionally licensed engineering firm should be hired to conduct further modeling and run additional simulations of the pond.

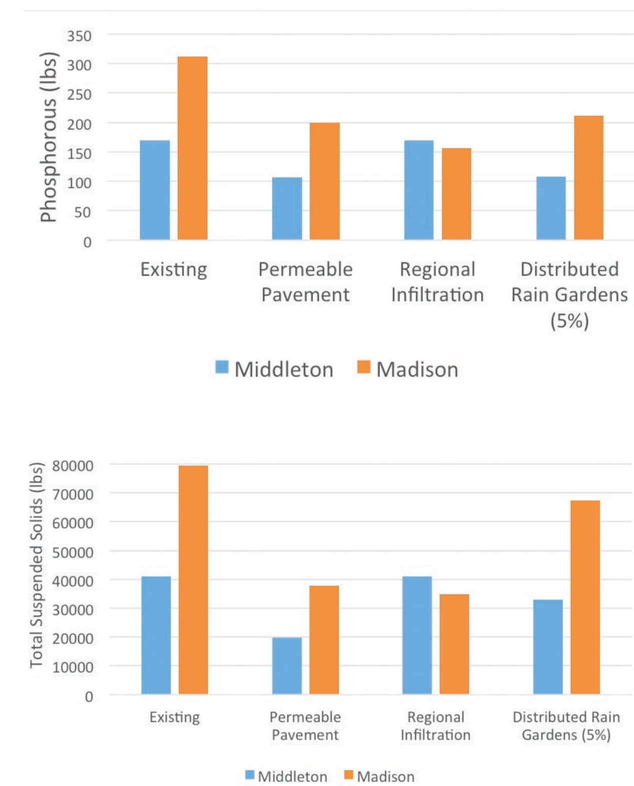


Figure 7.20. : Total phosphorous (left) and total suspended solids (right) loads for the 1981 rainfall for existing conditions and the three BMP scenarios.

8 ECOLOGICAL EVALUATION

Stricker's Pond provides recreational opportunities and natural beauty to the surrounding neighborhood in Middleton and Madison. Recognizing the importance of the pond to the local community, an ecological study of Stricker's Pond and surrounding park was conducted during the summer of 2016 to identify how habitat improvements could benefit Stricker's Pond. Terrestrial field studies included examination of vegetation and birds, while aquatic field studies included macroinvertebrate and fish monitoring and an aquatic plant assessment.

The ecological characteristics of Stricker's Pond, combined with the previously discussed water quality data, provide a more comprehensive understanding of how Stricker's Pond functions and allowed us to suggest management opportunities and strategies for habitat improvement.

Figure 8.1: Canoeing through five-foot-tall American lotus was a challenge.

Figure 8.2: Aquatic plants were sampled with a double-headed rake.

Aquatic plants

PURPOSE

Aquatic plants, or macrophytes, are organisms that have adapted to living in aquatic environments and are an integral part of a healthy aquatic ecosystem. Benefits of aquatic plants include: minimizing nuisance algal blooms by consuming nutrients that may otherwise be used by plankton, being a source of oxygen for other aquatic organisms, providing habitat for wildlife, and limiting sediment and nutrient resuspension by holding sediment in their root masses. Healthy and stable communities of aquatic plants help prevent the establishment of non-native invasive species within the aquatic ecosystem.

A concern for Stricker's Pond is the presence of American lotus (*Nelumbo lutea*), which was introduced to the pond in the early 2000s as part of a restoration effort to establish native aquatic plants by the City of Madison Parks Division. The American lotus has continued to expand within the pond, and many residents are concerned about the rapid expansion over the past decade. Due to its unique physiology, emergent character, and density, American lotus has thrived within Stricker's Pond. The City of Madison also introduced six other native plants, including pickerel weed (*Pontederia cordata*), white water lily (*Nymphaea odorata*), hardstem bulrush (*Scirpus acutus*), giant burreed (*Sparganium eurycarpum*), duck potato (*Sagittaria latifolia*), and river bulrush (*Scirpus fluviatilus*) when it introduced the American lotus.

METHODS

On July 16, 2016, a point-intercept survey was conducted to assess the aquatic plants of Stricker's Pond. The sampling process followed WDNR protocols (Hauxwell et al., 2010). A sampling grid of 35 points with 175-foot spacing was overlaid onto Stricker's Pond in ArcMap and then uploaded to an eTrex 10 handheld GPS unit to navigate to each point. Sampling points were adjusted within the lotus area because of difficulty maneuvering the canoe (Figure 8.1). Plant samples were collected at each point using a double-headed rake attached to a pole (Figure 8.2). Sediment type, individual plant species, and species density on the rake were recorded. Any visible aquatic plant species at the survey point were also recorded. Aquatic plants were sampled in the Madison forebay by repeatedly tossing a double-headed rake attached to a rope from several points along the shoreline.

Expansion of the American lotus population was documented using historic aerial images and onsite mapping. Google Earth Pro® was used to delineate the area occupied by American lotus over the past decade. Images were available for 2014, 2012, 2010, 2008, and 2006. Prior to 2006, the American lotus patch was not large enough to be mapped without higher resolution images. The border of the American lotus population was mapped by canoe on July 16, 2016, using an eTrex 10 GPS unit.

Monthly photos of the American lotus patches were captured throughout the growing season of 2016. These photos were taken with an unmanned aerial vehicle at 400, 200, and 100 feet above the pond and were used to document the growth and extent of the lotus in 2016. Aerial photos were taken above the northeastern lotus patch on June 18, July 14, August 21, and September 26, and above the southern patch on April 22, June 11, July 14, August 21, and September 26.

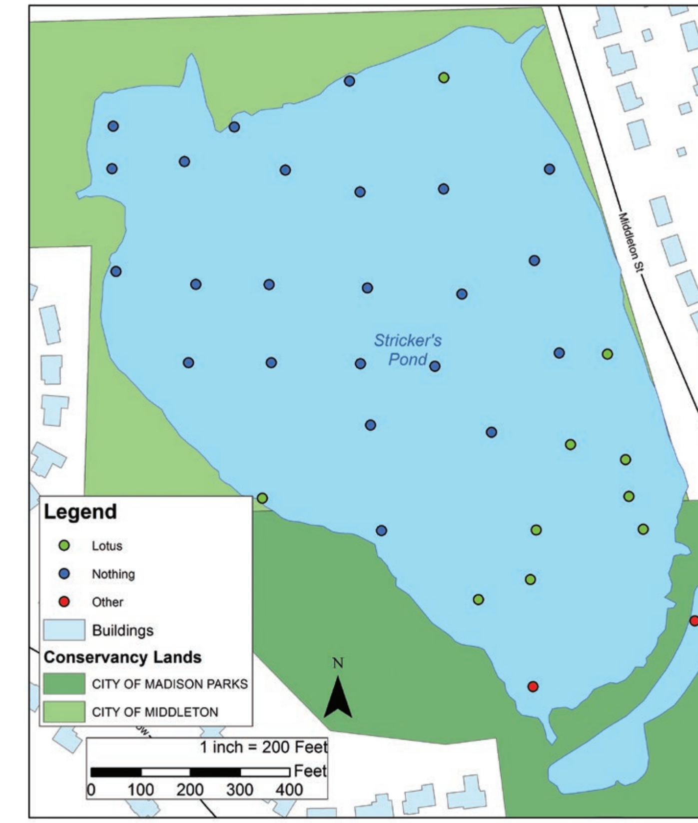


Figure 8.3: The aquatic plant point-intercept survey results. American lotus was found at 11 of the 35 sampling points. Broadleaf cattail and common duckweed were present at one point alongside American lotus. There were no plants found at the remaining 24 sampling points.

RESULTS

American lotus was present at 11 of the 35 sampling points in Stricker's Pond. Common duckweed (*Lemna minor*) and broadleaf cattail (*Typha latifolia*) were present at one site alongside American lotus. No aquatic plants were found at the remaining 24 sampling sites (Figure 8.3). Six aquatic plant species were observed in the forebay (Table 8.1). Five of the plant species are considered native to southern Wisconsin. Curly-leaf pondweed (*Potamogeton crispus*) is listed as a restricted invasive species on the WDNR NR 40 list (Chapter NR40: Invasive Species Identification, Classification, and Control, 2015).

Figure 8.4: Extent of southern American lotus patch on a) April 22; b) June 11; c) July 14; d) August 21; and e) September 26, 2016.

Scientific Name	Common Name
Potamogeton amplifolius	Largeleaf pondweed
Elodea nuttalii	Slender waterweed
Lemna minor	Common duckweed
Potoamogeton pusillus	Slender pondweed
Potamogeton crispus	Curly-leaf pondweed
Typha latifolia	Broadleaf cattail

Table 8.1: Aquatic plant species present on the rake or seen along the north-eastern edge of the Madison forebay.

Aerial images taken 400 feet above the pond show American lotus emerging in June and senescing in September (Figures 8.4 and 8.5). The extent of the American lotus increased from 0.38 acres in 2006 to 6.4 acres in 2016 (Figure 8.6 and 8.7), a 1,500 percent increase over a decade.

AQUATIC PLANT CONCLUSIONS

The rapid expansion of the pond's American lotus population over the past decade indicates a successful emergent wetland restoration. However, the impact of the plant on the pond ecosystem is not clear (Table 8.1.2).

The presence of American lotus in Stricker's Pond may not improve water quality. The leaf area may prevent atmospheric gas exchange with the water and has been found to add little dissolved oxygen (DO) to the water column during photosynthesis because the leaves rise above the surface of the water (Pokorny & Rejmankova, 1983; Turner, 2010). On a shallow, turbid, and highly eutrophic lake in Pennsylvania, much like Stricker's Pond only larger (surface area of 6645 hectares), DO concentrations were consistently lower within the American lotus bed than in open water, and within the bed, concentrations declined over the course of the summer (Turner, 2010). Furthermore, large dense beds of American lotus block wind from mixing the water column and creating wave turbulence — both of which increase DO concentrations (Turner, 2010).

On the other hand, the American lotus can potentially improve water quality by slowing the movement of water within and adjacent to plant beds, which allows sediment and nutrients to settle to the bottom (Mikulyk, 2016). In addition, the lotus rhizomes hold sediment in place, preventing wind and fish from re-suspending sediment and nutrients back into the water column (Madsen et al., 2001). If management of the lotus were to include physical rhizome removal, sediments and nutrients would more readily re-suspended into the water column.

Figure 8.5: Aerial photos of northeast American lotus patch on a) June 18; b) July 14; c) August 21; and d) September 26, 2016.

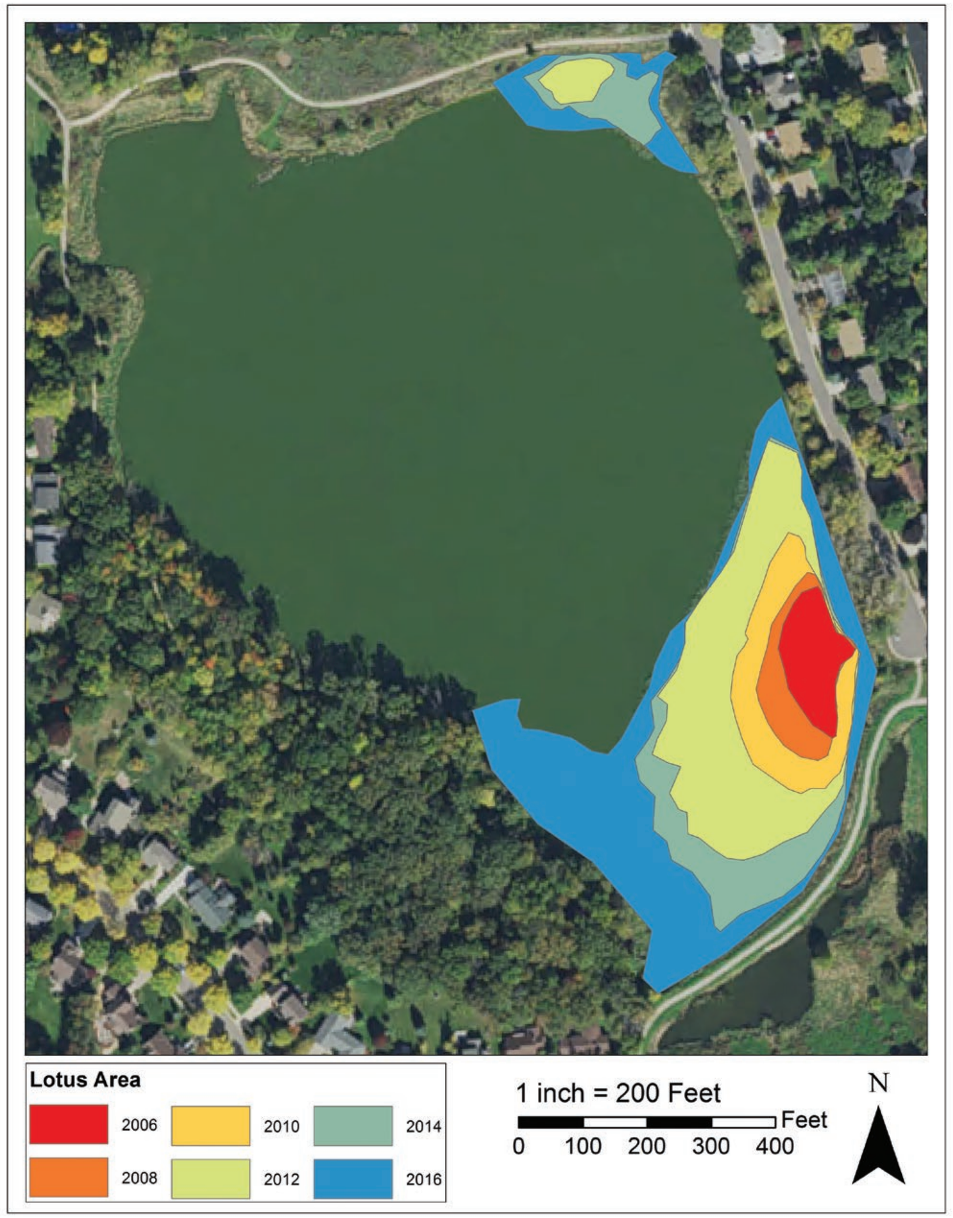


Figure 8.6: The expansion of the American lotus over the past decade in Stricker's Pond. 2016 data was collected in the field using a GPS. The remaining acreages were calculated using Google Earth Pro's Historic Image Reviewer to outline and calculate the extent of the American lotus.

The rapid decomposition of American lotus tissue by microbes and the physical breakdown into fine-particulate organic matter (FPOM) has the potential to contribute excess nutrients, such as phosphorus, to the pond water. One riverine system study suggests that FPOM could serve as food for filter-feeding invertebrates. However, if these organisms do not exist in substantial numbers, FPOM is likely to release nutrients (Grubaugh et al., 1986).

The aggressive nature of American lotus may have detrimental effects on biological diversity. The presence of aquatic organisms, especially fish, macroinvertebrates, and amphibians, is highly dependent on DO, and only highly tolerant species (e.g., fathead minnows and goldfish) will survive in low DO habitats. Additionally, the emergent leaves of American lotus block light from entering the water column, thereby limiting or preventing submerged macrophytes, periphyton, or phytoplankton from conducting photosynthesis or surviving (Frodge, 1990). However, removal of the lotus may allow for invasive species, such as common reed (*Phragmites australis*) or cattails, to establish and spread in Stricker's Pond. Removal may also increase toxic blue-green algae in the pond because of reduced shaded areas (Mikulyk, 2016; Graham, 2016). Lower pH values were observed at the Edge of Lotus site (Section 6.2.3.4), suggesting lower rates of underwater photosynthesis and lower concentrations of algae. One species of algae, Anabaena spiroides ,was identified in the pond. A. spiroides is a filamentous cyanobacteria known to produce neurotoxins, which can harm wildlife, pets and humans (World Health Organization, 1999).

	Pros	Cons
Water Quality	Slows water movement (Mikulyk 2016)	Decreases dissolved oxygen (Turner, 2010)
	Stabilizes sediment (Madsen et al., 2001)	Contributes nutrients (Lubinksi & Sparks, 1984)
	Cools water via shade & limits blue-green algae (Graham, 2016)	
Ecological	Local seed source for other restorations	Grows rapidly in ideal conditions
	Attracts wildlife	
	Outcompetes non-native species	
	Can withstand goldfish	
Social	Cultural heritage	Blocks view of the pond
	Beautiful flower in late summer	Aesthetic seed pods post-season
		Dead vegetation limits winter recreation
		Reduces open water

Table 8.2. The pros and cons of the American lotus.

American lotus can be a nuisance in water bodies for which the aesthetics of open water is highly valued. While each plant produces a large, often fragrant flower, the flower is short lived and the leaves reach heights that hinder views of the rest of the pond. However, if the lotus is reducing suspended sediment in Stricker's Pond, the clarity of the water is higher than if there were no aquatic plants. The lotus also provides wildlife habitat and is a source of food for waterfowl and mammals (Mikulyk, 2016). A cyclical pattern of lotus population expansion and decrease has been observed in nearby Morse Pond, the seed source of Stricker's lotus population (Graham, 2016).

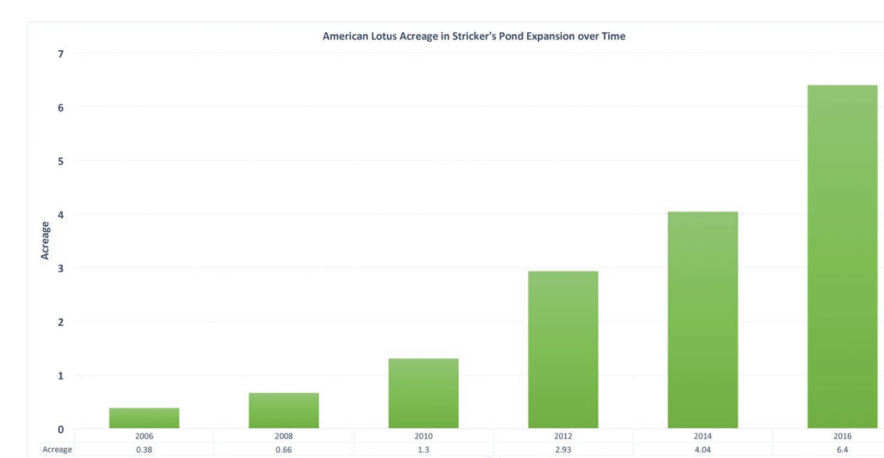
Overall, Stricker's Pond lacks aquatic macrophyte life. With respect to poor water quality, the surrounding land use is an issue, as is biological activity within the pond. This study indicates that an important opportunity to sequester excess nutrients through the establishment of diverse macrophyte species is not occurring within the pond. The results of this study indicate that the ecological benefits of the lotus likely outweigh any of the negative impacts.

Terrestrial plants

PURPOSE

Stricker's Pond is surrounded by natural areas on both the Middleton and Madison sides (Figure 8.8). Middleton owns

Figure 8.7: The expansion of the American Lotus in acres over the past decade. 2016 data was collected in the field using a GPS. The remaining acreages were calculated using Google Earth Pro's Historic Image Reviewer to outline and calculate the extent of the American lotus



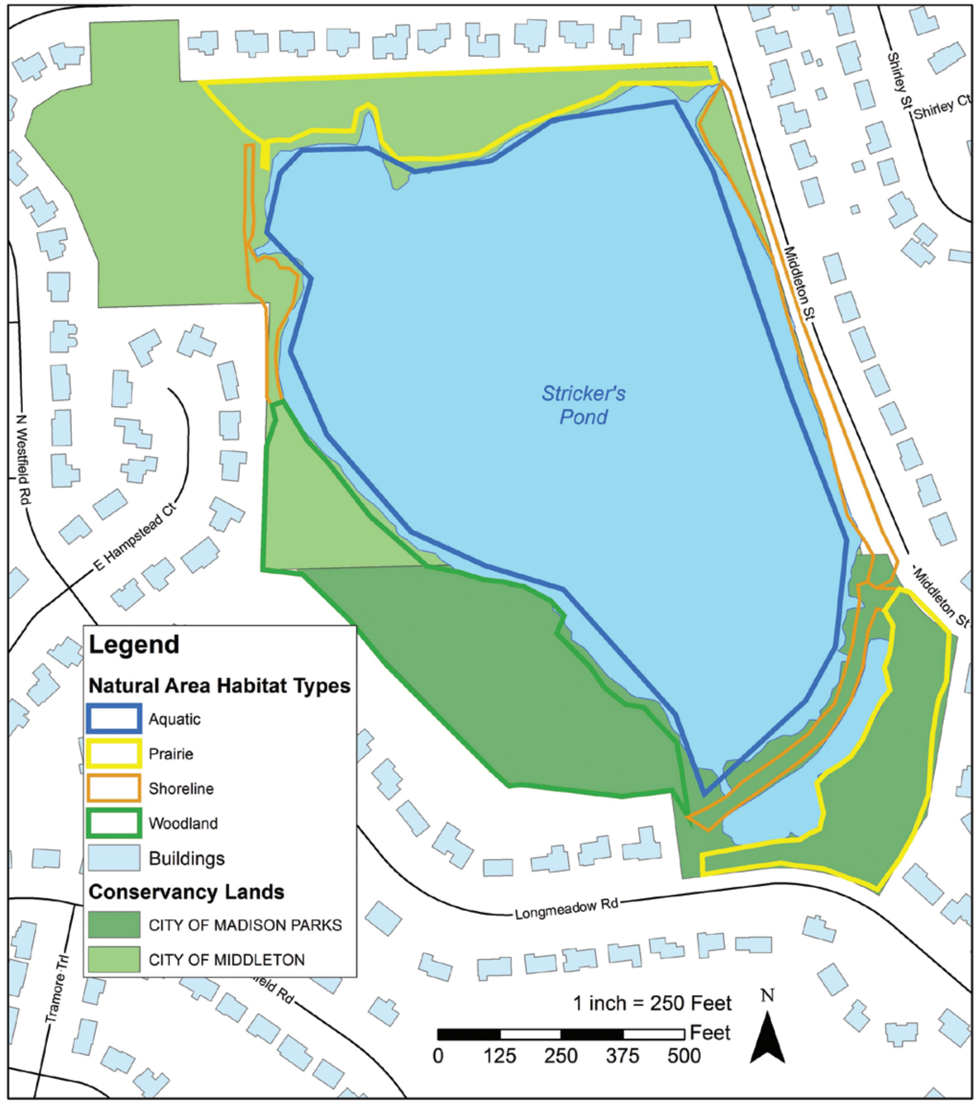


Figure 8.8: Natural area habitats at Stricker's Pond.

the Stricker Pond Conservancy Area, which is comprised of 24.9 acres of aquatic, wetland, mesic prairie, and oak woodland habitats. For conservancy areas, the city develops five-year plans addressing management techniques for recreation and conservation purposes (Schrieber Anderson Asssociates, 2010). In Madison, 13.5 acres constitute the conservation park of Stricker's Pond. Madison manages conservation parks "to preserve and restore native plant and animal populations" (City of Madison Parks Division, 2012). Since both cities have defined conservation and native habitats as management goals for Stricker's Pond, a terrestrial vegetation survey was conducted to quantify the conservation value of plant communities and to characterize the prevalence of invasive species.

A previous ecological assessment of the woodland area led to the development of an oak savanna management plan (Biologic Environmental Consulting, 2005). The report stated that the woodland area had likely been oak savanna and oak woodland before European settlement and subsequently transitioned to mesic forest. Oak savanna is characterized by a more open canopy and different species composition than a mesic forest. This change to mesic forest likely occurred because of grazing, lack of fire, excessive shade, and establishment of exotic species. The management plan outlined a vision for restoring the woodland to oak woodland (relatively dense oak and shagbark hickory canopy) in the southern portion, and oak savanna (scattered, open grown oaks) in the northern portion, by removing unwanted trees and shrubs, removing invasive species, and supplementing groundcover with additional native species. A goal of the 2016 vegetation assessment was to quantify the effect of these management efforts.

The 2005 woodland assessment listed garlic mustard (*Alliaria petiolata*), Canada thistle (*Cirsium arvense*), dame's rocket (*Hesperis matronalis*), Asian bittersweet (*Celastrus orbiculatus*), honeysuckle (*Lonicera spp.*), common buckthorn (*Rhamnus cathartica*), multiflora rose (*Rosa multiflora*), European highbush cranberry (*Viburnum opulus*), and reed canary grass (*Phalaris arundinacea*) as invasive species of significant concern (Biologic Environmental Consulting, 2005). Some of these species were of concern because populations were likely to increase as trees were thinned and the understory received more sunlight. In 2014, other invasive species were identified in shoreline areas – crown vetch (*Securigera varia*), bird's-foot trefoil (*Lotus corniculata*), *Miscanthus spp.*, and leafy spurge (*Euphorbia esula*) (Marshall & Healy, 2014).

Natural lands management depends on available financial resources. Since the 2005 study, Middleton has invested resources in restoration initiatives for mesic prairie and oak savanna habitats, but these efforts have waned in recent years (personal communication, Mike Healy, Adaptive Restoration LLC). Within the past decade, Madison has not followed a specified vegetation management plan for Stricker's Pond (personal communication, Paul Quinlan, City of Madison Parks Division). A second goal of the 2016 terrestrial plant evaluation was to quantify differences in plant communities resulting from different management strategies employed by the two cities.

METHODS

A terrestrial plant survey assessed herbaceous, shrub, and tree cover of the natural areas surrounding Stricker's Pond.

HERBACEOUS SURVEY

Herbaceous plants, or nonwoody species, were surveyed by visually examining vegetative ground cover. The survey focused on the prairie and woodland habitats that have been actively managed or have the potential for increased vegetation management. Herbaceous plant cover was quantified in 10.7 ft^2 (1 m^2) quadrats throughout the site (Figure 8.9a). Transects spaced 100 feet apart were established in the woodland and prairie habitats. Herbaceous plants were assessed every 40 feet along the length of each transect, resulting in 108 quadrats in the prairie and woodland habitats.

Each location was surveyed twice during the summer of 2016: June 1-24 and August 2-5. At each survey point, a PVC quadrat was placed around the vegetation (Figure 8.9b). Percent foliar cover for each species and percent bare ground

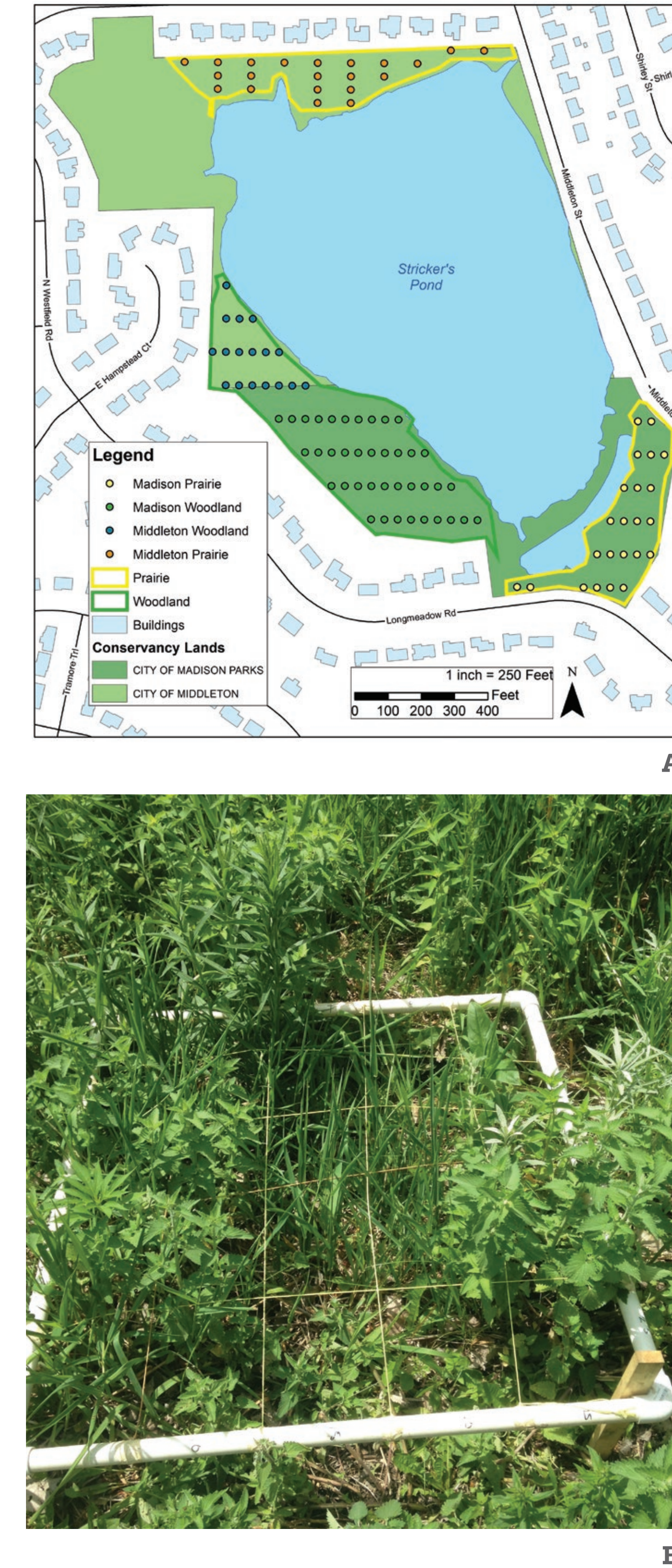


Figure 8.9: (a) Quadrat locations for assessment of herbaceous plants. (b) 10.7 ft2 (1 m2) PVC quadrat with labeled wooden stake marking quadrat location.

within each quadrat were recorded. During the August survey, more species were flowering, which allowed identification of previously unidentifiable species. The second assessment also served to document how species prevalence shifted through the summer. Identification was made to the species level if a plant occupied more than one percent of the quadrat. Books were used to identify vegetation, and local experts were consulted if further species identification was needed.

Data from the herbaceous survey were entered into the Universal Floristic Quality Assessment (FQA) calculator at UniversalFQA.org (Freyman et al., 2016b) to evaluate the quality of the natural areas around Stricker's Pond. Each species was assigned a coefficient of conservatism (C value) ranging from 0 to 10 from the Wisconsin-Northcentral-Northeast Region, 2014 FQA database. A C value of 0 indicates that the species is nonnative to the region. Plants tolerant of anthropogenic disturbance and degradation have

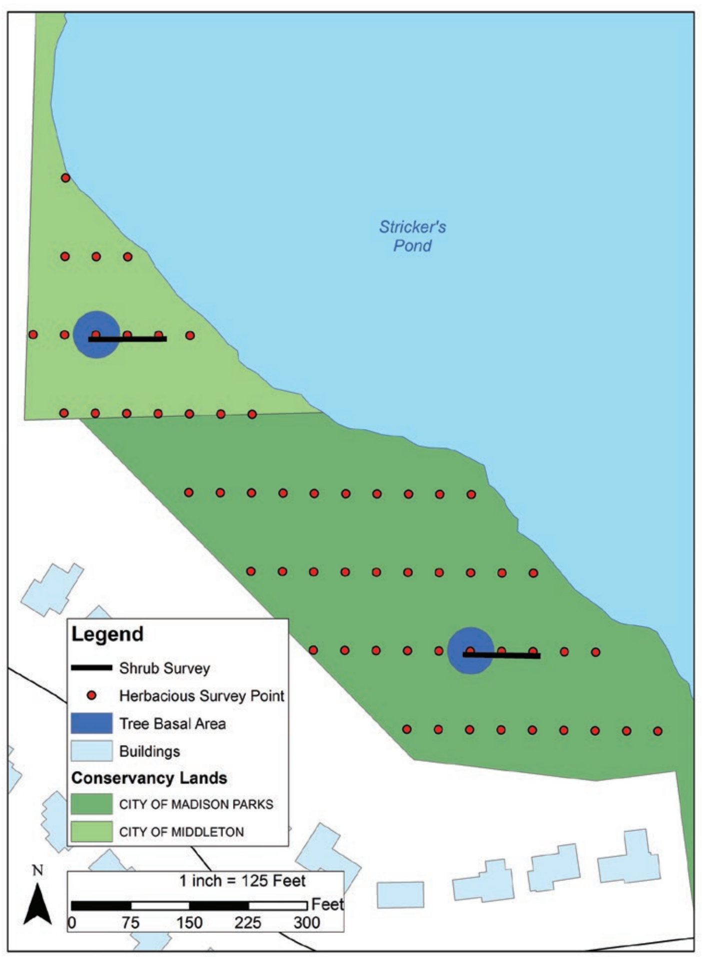


Figure 8.10: Basal area was calculated at two locations, one within each city's woodland. 100- foot shrub survey transects were also established in Middleton (to the north) and Madison (to the south).

C values below 3. Highly conservative plants — those with a C value above 7 — generally require undisturbed habitat conditions. A cover-weighted floristic quality index (FQI) was calculated by combining the C values of existing plants, species richness and species cover within each habitat. A large FQI indicates a high-quality natural area. These values facilitate comparisons between sites and over time within the same site.

The Universal FQA calculator generated additional metrics, including the number of native and nonnative species; the proportion of plants that were annuals, perennials, or biennials; and a cover-weighted mean C. Percent cover of individual species within each quadrat and the relative frequency of each species were used to determine a metric of relative importance for the vegetation plots (Freyman et al., 2016).

SHRUB SURVEY

A survey of the shrub layer was conducted along two 100-foot transects in the woodland area, one on the Middleton side and one on the Madison side, using the line-intercept method (Figure 8.10). Species of shrub cover – defined as any woody vegetation up to 20 feet tall – was noted if it intercepted the transect. This method results in a percent cover by species along the transect (Caratti, 2006)

TREE SURVEY

To assess the differences in tree density between the Madison and Middleton portions of the woodland, a basal area survey was conducted. Two plots (radius 30 feet) were established in interior woodland areas, one on the Middleton side and one on the Madison side (Figure 8.2.4). Within each plot, trees with a diameter at breast height (DBH, defined as 4.6 ft (1.4 m) from the ground) larger than 1.97 in (5 cm) were recorded, and basal area per acre was clculated for each plot.

RESULTS

HERBACEOUS SURVEY

Species lists were compiled for each vegetated area, which included all plants observed in June and/or August (see Appendix 4). Overall, 176 species were observed, 108 of which were native. There were 15 species with C values above 7 (Table 8.3).

During the August survey, some quadrats around the edge of the pond were submerged due to high water levels. Cover for those quadrats was assumed to be the same as June observations (June results are presented in Appendix 4). About 40% of the species identified in all habitats were nonnative (Figure 8.11). In all areas except the Madison prairie,

Scientific Name	Common Name	C Value
Cephalanthus occidentalis	Buttonbush	9
Astragalus canadensis	Canadian milk-vetch	8
Baptisia alba	White wild indigo	8
Eryngium yuccifolium	Rattlesnake-master	8
Silphium laciniatum	Compass-plant	8
Allium cernuum	Nodding wild onion	7
Drymocallis arguta	Prairie cinquefoil	7
Dryopteris carthusiana	Spinulose wood fern	7
Galium asprellum	Rough bedstraw	7
Helianthus pauciflorus	Few-leaved sunflower	7
Liatris pycnostachya	Prairie blazing-star	7
Physostegia virginiana	False dragonhead	7
Rudbeckia subtomentosa	Sweet black-eyed Susan	7
Silene stellata	Starry campion	7
Silphium terebinthinaceum	Prairie-dock	7

Table 8.3: From June -August 2016, 15 species were identified with a C value > 7.

30% of the species had C values greater than 4. At each location, only 3-6% of species had C values between 7-10; on the Madison side, only two high-conservation-value species were observed (*Baptisia alba* and *Dryopteris carthusiana*).

Within all four surveyed areas, invasive species were some of the most prevalent (Figure 8.12). Bare ground was a common and dominant cover in both woodland areas and the Middleton prairie. Invasive reed canary grass, buckthorn, garlic mustard, and Canada thistle were all within the top three relative importance values for at least one habitat type. Both native plants that were also common, Canada goldenrod (*Solidago canadensis*) and broad-leafed enchanter's nightshade (*Circaea canadensis*), are of little conservation value.

Middleton's prairie had the highest cover-weighted FQI at the pond, and the Madison woodland had the lowest (Figure 8.13). Both of Madison's habitats were lower than the Middleton counterpart.

SHRUB SURVEY

The Madison transect had shrub cover consisting of com-

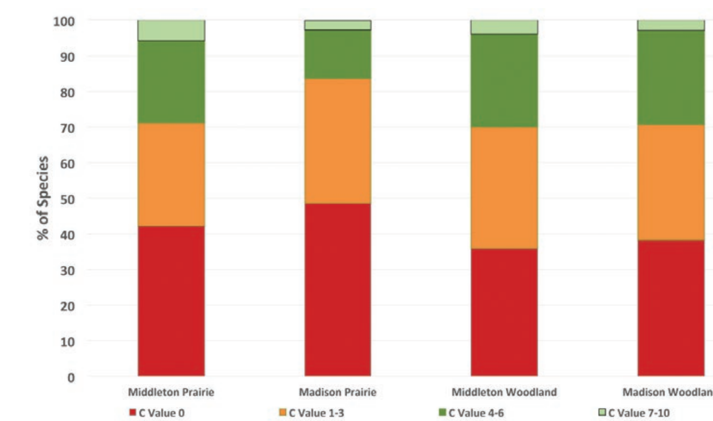


Figure 8.11: The percent of species in each C value category for prairie and woodland habitats at Stricker's Pond (August survey).

mon buckthorn, American elm (*Ulmus americana*), and European highbush cranberry. Shrubs covered almost 80% of the transect (Table 8.4). Other shrubs identified in close proximity to the transect were chokecherry (*Prunus virginiana*) and green ash (*Fraxinus pennsylvanica*). The Middleton transect had shrubs of common buckthorn and American elderberry (*Sambucus nigra*), and shrub cover was almost 20%. In Middleton, shrubs were observed to have been top-killed from the spring 2016 prescribed burn; common buckthorn, American elderberry, European highbush cranberry, and chokecherry shrubs all showed signs of impact in the vicinity of the transect. There was no pre-

Transect	% Shrub Cover of Transect	% Nonnative Shrub Cover of Transect
Middleton	18	3
Madison	79	60

Table 8.4: Shrub cover along 100-foot transect.

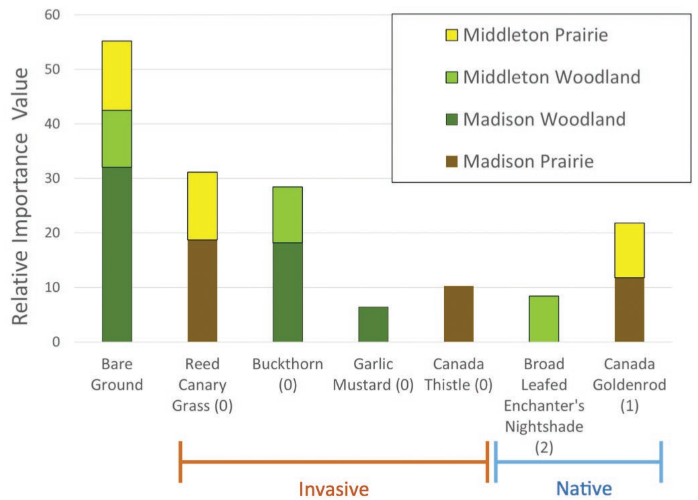


Figure 8.12: Within each habitat type, this figure shows which three covers had the highest relative importance values (the average of relative frequency and relative coverage). C values for those species are shown in parentheses (August survey).

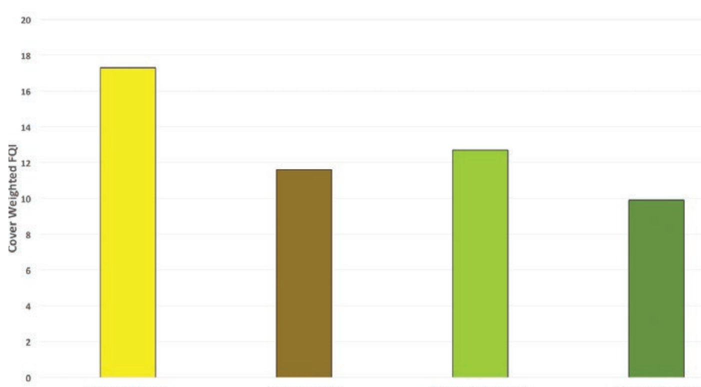


Figure 8.13: Cover-weighted FQI for each habitat type (August survey).

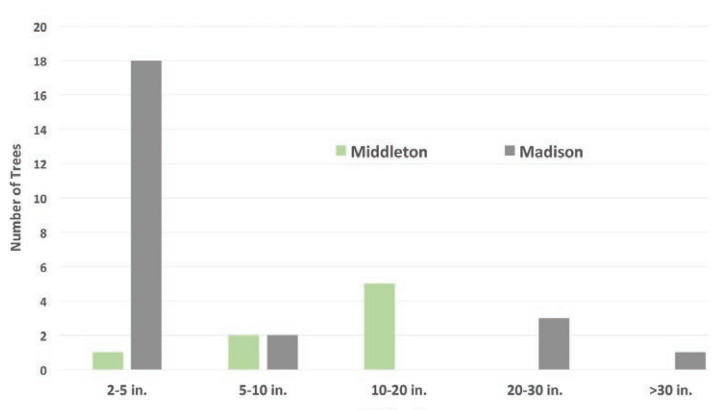


Figure 8.14: The number of trees in each DBH size class for 30-foot radius plots in Middleton and Madison.

scribed burn in the Madison portion of the woodland in spring 2016.

TREE SURVEY

Basal area was greater in the Madison plot than the Middleton plot (Table 8.5). Middleton's plot contained black cherry (*Prunus serotina*), white oak, red oak (*Quercus rubra*) and silver maple (*Acer saccharinum*). There was only one tree, a white oak, in the 2-5 inch DBH size class.

Plot	Basal Area (ft2/acre)
Middleton	78.9
Madison	312.5

Table 8.5: Basal area within each sampled plot.

The largest tree was a silver maple with a DBH of 17.4 inches. In Madison, there were white oaks (*Quercus alba*), American elm, and buckthorn. The white oaks were large, ranging from 23 inches to 37 inches DBH, and there were many small buckthorn stems in the 2-5 inch DBH range (Figure 8.11).

TERRESTRIAL PLANT CONCLUSIONS

The few herbaceous species with high conservation value in both the Middleton and Madison prairies are the result of past restoration efforts and are threatened by the continued encroachment of invasives, such as reed canary grass, crown vetch, and Canada thistle. While management strategies have included mowing, prescribed burning, herbicide application, and brush and tree removal (Schrieber Anderson Asssociates, 2010), vegetation management requires continued investment.

A challenge for establishing quality vegetation continues to be fluctuating water levels in the pond (Figure 8.15). Research has shown the synergetic relationships between increased nutrients (from sources such as stormwater runoff), fluctuating water levels, and the establishment of reed canary grass (Kercher & Zedler, 2004). Reed canary grass is prevalent close to the water's edge, and future management should actively suppress these populations. Stabilizing water levels could enable establishment of other species. If water levels continue to fluctuate by up to two feet, as observed in 2016, shoreline restoration efforts may be impeded.

Neither woodland area has high-quality oak savanna or oak woodland plant communities; bare ground and buckthorn dominate on both sides. Evidence of Middleton's savanna management and tree removal (visible stumps and a lower basal area compared to Madison) was observed. The shrub layer in Middleton was also less dense than in

Figure 8.15: Fluctuating water levels at the Stormwater Input water quality sampling site in May (left) and September (right) 2016. Invasive reed canary grass is prevalent along the shoreline.

Madison, with top kill evident from a prescribed burn in the spring (Figure 8.16). There was noticeable buckthorn removal on the Middleton side. Management recommendations from the 2005 woodland assessment (Biologic Environmental Consulting, 2005) are still applicable, especially on the Madison side. The Middleton Conservancy Lands Plan states that Stricker's Pond "would benefit from a master plan focusing on reuniting the recreational features" of Middleton and Madison (Schreiber Anderson Associates, 2010). This is especially important given the stark differences observed between the Madison and Middleton woodlands.

The woodland assessment from 2005 indicated that 66% of the vines, grasses, sedges, and forbs were native (Biologic Environmental Consulting, 2005). The 2016 survey showed a similar proportion. No ferns were observed in 2005; however, ferns were identified at multiple locations during the summer of 2016. The population of European highbush cranberry has increased since 2005. Some invasive species that were predicted to increase, such as multiflora rose, have not done so yet. These species could pose a threat, however, as new areas are cleared of invasive shrubs.

Following the 2005 woodland assessment, it was recommended that initial efforts should focus on invasive shrub removal (Biologic Environmental Consulting, 2005). This was partially implemented within the Middleton woodland, and it is recommended that these efforts continue. Once shrubs have been removed, parts of the canopy can be thinned to create savanna conditions. Intermittent burns should continue in order to suppress brush and invasive species. Since the City of Madison has not recently defined a vegetation management strategy for the natural areas surrounding Stricker's Pond, it is suggested that Madison should follow recommendations from the 2005 woodland management plan. Buckthorn continues to have high abundance in the Madison woodland and should be a removal priority. Once invasive species have been removed, restoration efforts can focus on establishing native herbaceous plants and oak seedlings. Restoring the woodland will require ongoing management, since invasive plants can reestablish from surrounding populations.

Macroinvertebrates

PURPOSE

Aquatic macroinvertebrates are small organisms, often the larval form of adult terrestrial insects, which live in the substrate, water column, or surface of a water body. They play a significant role in food-web dynamics. For example, the spiny waterflea is an invasive species of particular concern, discovered in Lake Mendota (close proximity and hydraulically connected to Stricker's Pond) in 2009. The morphology of the spiny waterflea, distinguishable by a long sharp spine on its rear, often prevents it from being preyed upon by predators such as larval fish. Furthermore, the spiny water flea preys upon filter-feeding species, thereby reducing the ecological service of removing excess algae.

Macroinvertebrates can also serve as water quality indicators, because certain taxa groups are more sensitive to environmental conditions than others. Taxa groups like damselflies, soldier flies, phantom midges, and worms serve as the main food source for many adult fish species, and some have certain environmental preferences (e.g., cold water temperatures and high oxygen levels). The objective of our macroinvertebrate study for Stricker's Pond was to assess macroinvertebrate diversity to understand food-web dynamics and the impact of water quality on biological diversity within the pond.

Figure 8.16: A prescribed burn in Middleton's woodland shows top-killed shrubs and exposed tree stumps (May 2016).

METHODS

Samples were collected at three locations on April 14, June 6, June 27, and July 17, 2016, resulting in twelve samples. The three locations were representative of the shoreline substrates (sandy and leaf detritus), and within the American lotus where the water was less than 3.3 feet (1 m) deep. Each sample was collected using a D-frame net, which was swept over a 3.3-foot (1 m) length of the substrate (Figure 8.17). The contents of the D-net were deposited onto a filtering screen, where large particles such as twigs and leaves were rinsed with water before being discarded from the sample. The remaining sample was transferred to a one-gallon sealable plastic bag and preserved with 95% ethanol. Subsamples were processed (identified and quantified) using microscopes at a later date. The macroinvertebrate biological integrity of the pond was assessed using the Wisconsin Wetland Macroinvertebrate Biological Index (Lillie, 2000). The index takes into account the type of wetland, the number of taxa groups, and the quantity of individuals within each taxa group to ultimately classify the water body on a scale from 0 (worst) to 5 (best).

RESULTS

The Wisconsin Wetland Macroinvertebrate Biological Index for Stricker's Pond averaged 1.9 out of 5 (Table 86). Of the 375 individual macroinvertebrates found in the subsamples, Annelids (worms), Zygoptera (damselflies), and Corixidae (water boatmen) were the most abundant (maximum index of 5). Molluska (mollusks) and Trichoptera (caddisflies) were the least abundant (index of 1). Three of the eight taxa groups were absent altogether (index of 0). Beyond the taxa groups included in the index, there were no Cladocera (waterfleas); however, a small population of Copepods (zooplankton) was found.

CONCLUSIONS

Low index scores tend to occur in water bodies with high pH (>7), which can be associated with algae blooms and macrophyte growth (Lillie, 2000). Scores tend to increase slightly when woodland riparian zones are present due to the inputs of leaves, which are favorable for shredders like caddisflies. The low index score for caddisflies in Stricker's Pond could be attributed to the sample site distribution; only one site was located near a woodland riparian zone. It is still surprising that more caddisflies were not found given the amount of woodland riparian zone and high-density lotus. Very few Anisoptera (dragonflies) were found, which could be attributed to low dissolved oxygen level and/or the abundance of purple martins, which prey heavily on large flying insects (purple martin houses are maintained by local residents on the northeastern side of the pond).

Figure 8.17: Amanda Smith collecting a D-net sample at the site located near the southern American lotus patch.

Overall, Stricker's Pond ranked relatively low, which is indicative of poor water quality. Although the taxa group Cladocera was not an index parameter, the absence of Daphnia is surprising, considering the amount of algae that could serve as its food source. The absence of another Cladocera, the spiny waterflea, may signify that the absence of Daphnia was caused by some other variable, such as fish predation.

Fish

PURPOSE

Fish populations can significantly impact aquatic systems and play an important role in food-web dynamics, ranging from predator of macroinvertebrates to prey for birds like herons. Depending on the species composition, certain morphological characteristics of fish can negatively impact water quality. For example, carp species such as goldfish tend to stir up sediment and displace rooted aquatic plants by the movement of their fins and bodies and by feeding on benthic food sources. They also compete with native fish for resources by filter feeding large amounts of phytoplankton, which would otherwise serve as the foundation for the native food web.

Fish can serve as water quality indicators because certain

TAXA GROUP							
Common Name	**Scientific Name**	**4/14**	**6/6**	**6/27**	**7/17**	**Total**	**Score**
Mollusks	*Mollsuca*	2	0	0	0	**2**	**1**
Annelids	*Annelida*	12	15	30	2	**59**	**5**
Damselflies	*Zygoptera*	6	25	6	10	**47**	**5**
Pigmy Backswimmers	*Notonectidae*	0	0	0	0	**0**	**0**
Water Boatmen	*Corixidae*	0	7	35	6	**48**	**5**
Caddisflies	*Trichoptera*	0	2	3	0	**5**	**1**
Phantom Midges	*Chaoboridae*	0	0	0	0	**0**	**0**
Soldier Flies	*Stratiomyidae*	0	0	0	0	**0**	**0**
Total Individuals		46	76	219	34	**375**	**1**
Total Taxa		**8**	**7**	**9**	**5**	**8**	**1**
						Average:	**1.9**

Table 8.6: Wisconsin Wetland Macroinvertebrate Biological Index results. On a 1-to-5 scale, the pond rated an average of 1.9. The index considers species diversity and high-conservation-value taxa.

taxa groups are more sensitive to environmental conditions than others. Species like fathead minnows and bullheads are considered to be more hardy fish that can withstand lower water quality, whereas species like brook trout tend to require pristine, flowing water. A fish inventory (types and quantities) was conducted at Stricker's Pond to provide insight into their role in the food web and water quality. Past fish surveys were also evaluated to account for changes in species composition over time.

METHODS

A fish survey was conducted on June 10, 2016, with associates from Underwater Habitats. A 10-foot sein net with one-inch diameter mesh was used to sample in chest-deep water along the northwestern and northern shores (30 minutes per site). Fish were identified, counted, and released. A second survey was conducted from July 29-30, 2016, using minnow traps. Four minnow traps with different sized openings were set in 3.3-foot (1 m) deep water, 9.8 feet (3 m) from the eastern shoreline. The location was the same as that of the electroshocking and fyke netting surveys conducted in 2000 and 2014 (Marshall & Healy, 2014). The minnow traps were submerged for 24 hours, and trapped fish were identified and their length measured. During the spring and early summer months when pond water clarity was high, fish were documented through visual observation.

RESULTS

Fathead minnows were the only species observed in both 2016 surveys. A total of 56 individual fish (4-6 cm in length) were caught (Figure 8.18). On multiple occasions, goldfish were observed in the pond (estimated length <10 cm). During a visit to the pond on March 15, 2016, numerous goldfish were dead along the shoreline or floating in the water (Figure 8.19).

The electroshocking and fyke netting survey conducted by the WDNR in 2000 yielded 429 bluegills, 182 black crappies, 2 pumpkinseed sunfish, 8 goldfish, 537 black bullhead and 2 yellow perch. In 2014, only fathead minnows (>500) and goldfish (67) were found. It was concluded that "a significant ecological change likely occurred in the pond that may either reflect winterkill or disease" (Marshall & Healy, 2014). Winterkill is the most likely explanation; temperatures had fallen below 0°F on 27 days during the previous winter (Wisconsin State Climatology Office, 2016).

CONCLUSIONS

The fish community in Stricker's Pond shows a severe lack of diversity. The fathead minnow (Pimephales promelas), though native to Wisconsin aquatic systems, is a hardy fish that can tolerate low water quality conditions (Held &

Figure 8.18: Fathead minnows that were caught in a minnow trap. The ruler is in centimeters.

Peterka, 1974). Goldfish (*Carassius auratus*) are not native to the pond and were likely introduced by humans via the aquarium trade (Strecker et al., 2011). It has also been speculated that the pond is used as a "bait pond" by fishermen who stock the pond with fathead minnows, a common bait fish for angling (Marshall, 2016; Nico et al., 2016).

Although the 2016 fish survey methodology differed from that of the WDNR (2000) and Marshall & Healy (2014), the results suggest that fish species other than fathead minnow and goldfish have been extirpated from the pond. The large increase in fathead minnows from 2000 to 2014 can likely be attributed to a lack of panfish predators. The fathead minnow and goldfish are likely contributing to the hypereutrophic state of the pond in many ways. With an average life span of only three years, frequent death and significant decomposition is likely occurring in the pond, depleting dissolved oxygen and adding nutrients (Held & Peterka, 1974). Fathead minnows also prey on filter-feeding macroinvertebrates, such as Daphnia, further reducing water quality. Lastly, the swimming and feeding action of these species tends to stir up benthic sediment, which releases more nutrients into the water column (Richardson et al., 1995).

Birds

PURPOSE

Wisconsin is home to over 300 species of birds, and enjoyment of birds is a recreational hobby for thousands of people across the state. Birds pollinate plants, disperse seeds, scavenge carcasses and recycle nutrients back into the earth. Many birds rely on wetland and aquatic ecosystems for food, shelter, breeding, nesting, and as important migratory habitats. A basic inventory indicates presence or absence of bird species. An inventory can also indicate general diversity of species using Stricker's Pond and surrounding areas and potentially document endangered or threatened bird species.

METHODS

Seven site visits were made between February and August 2016 to evaluate the avian community around Stricker's Pond. Site visits were conducted during times of peak bird activity, usually early morning or at dusk. Each site visit consisted of a minimum of one loop around the trail surrounding the pond and at least one hour of observation. Bird species were recorded when they were identifiable either by sight or sound, and approximate numbers of each species were noted. After each site visit, the number of individuals in each observed species was recorded to www.ebird.org. Additionally, the annual amount of phosphorus inputs to the pond from birds was estimated using methods outlined by Gremillion & Malone (1986) and the estimates of waterfowl numbers retrieved from www.ebird.org.

RESULTS

A total of 65 birds were observed during the seven observation times. According to www.ebird.org, the pond had 206 checklists submitted with 156 species of birds observed during 2016. One checklist equates to one visit to Stricker's Pond for bird watching. The most common birds that were observed were ringed-billed gulls, common grackles, mallards, red-winged blackbirds, and wood ducks. It was estimated that waterfowl contribute approximately 6.5 kg of phosphorus per year to Stricker's Pond.

CONCLUSIONS

Stricker's Pond and the surrounding conservancy lands provide quality bird watching opportunities to the local community as well as adequate habitat for a wide variety of birds. In order to maintain this quality resource, it is recommended that the cities of Middleton and Madison continue to restore the pond and conservancy areas to native habitats and continue removal of invasive vegetation. Improving water quality would provide increased food opportunities for species like wood ducks (Aix sponsa) that feed on aquatic invertebrates in the pond. The estimated phosphorus of 6.5 kg per year (14.3 lbs per year) is not anticipated to have a significant negative effect on the water quality of the pond. Unckless & Mararewicz (2007) found that nutrient input to mesocosms in a pond from Canada geese (Branta canadensis) had no significant effect on phosphorus and nitrate concentrations within the water column, since fecal material settles quickly to the bottom. The fecal material would only have an impact if the wind or benthic fish mix the sediment into the water column or if the productivity or community structure of benthic organisms is changed. Also, the estimated phosphorus (14.3 lbs/year) is low compared to the estimated TP loads from the watershed (Chapter 7).

Figure 8.19: Dead goldfish found in the forebay on March 15, 2016.

STAKEHOLDER ENGAGEMENT

Citizens who use Stricker's Pond and surrounding conservancy areas are invaluable in understanding the current state of the pond and influencing future actions taken by the City of Middleton and City of Madison.

Visitor use assessment

PURPOSE

Stricker's Pond is characterized by the cities of Middleton and Madison as a stormwater management pond, but to nearby residents it is a critical recreational and aesthetic resource. A recreational trail encircles three quarters of Stricker's Pond along which are many benches where residents can sit and enjoy nature. Adjacent to the pond is Stricker's Park, featuring a playground and athletic field, as well as basketball and tennis courts. Over time, the use of these facilities can impact residents' quality of life as well as the quality of the physical environment in which they live (National Park Service, 1997; NPS, 2009). Unintended uses of recreational resources around the pond that pose threats to the health and wellbeing of its users are a liability to the cities of Middleton and Madison. Therefore, monitoring visitor use of the recreational areas is critical to maintaining the quality of parklands and conservancy areas around Stricker's Pond.

Federal agencies have a long history of managing the recreational resources on their public lands. The U.S. Forest Service, the National Park Service, and the Bureau of Reclamation have each developed frameworks that allow these agencies to assess the quality of users' experiences, identify current and future recreational opportunities, evaluate the impacts of excessive use on the surrounding environment, and ultimately enhance the benefits provided to the end users of the recreational resource (NPS, 1997; NPS, 2009; Yuan et al., 1995; Haas, 2002; Bureau of Reclamation, 2011). One component of this type of framework is visitor use assessment, which is used to determine what activities users are engaging in, where they are engaging in these activities, and how many people are utilizing recreational resources. This information provides park managers with critical information that shapes their management practices (Yuan et al., 1995; NPS, 2009). A simplified approach to visitor use assessment was utilized to evaluate the intensity and scope of activities that visitors engage in around Stricker's Pond.

METHODS

Visitor use data for Stricker's Pond were collected via direct visitor observation (Yuan et al., 1995). Dates and times to complete direct observations were selected purposefully with the intent of capturing differences in user traffic (Yuan et al., 1995). It was assumed that weekend days (Saturdays and Sundays) would attract higher numbers of visitors, compared to weekdays (Monday-Friday), and that mornings and evenings would attract higher numbers of visitors than the middle of the day, as these are times in which individuals are not generally working. In addition, it was assumed that days with favorable weather conditions (sunny skies and moderately warm temperatures) would attract higher numbers of visitors relative to days with poor weather (rain, unseasonably cool temperatures). Seasonal differences in pond user behavior were captured by sampling two days during the summer (July 16 and August 4, 2016) and two days in the fall (November 1 and 27, 2016).

Figure 9.1: Visitor use observation monitoring location.

All observations were taken over a one-hour duration. Observations were collected using a standardized data collection sheet (see Appendix, Figure A6.1) and were taken from a fixed location (Figure 9.1). Data were collected on several different variables, including: weather; time of day; number of individuals in a group; recreational activities; location (e.g., Middleton Street, the trail adjacent to Voss Pkwy [Voss Trail]); presence of dogs and their leash status (on or off leash); as well as any other relevant notes on user behavior (e.g., on-trail, off-trail, etc.). These data were aggregated to create summary statistics about user behavior along the trail network surrounding Stricker's Pond, and used to identify future management opportunities as well as adverse impacts associated with visitor behavior around the pond. This methodology was adapted from a visitor use assessment completed in Managing Recreational Lands, a course offered at the University of Minnesota in 2012 (Schneider, 2012).

RESULTS

During the four sampling events, 138 observations were made of individuals or groups recreating around Stricker's Pond. In total, 202 individuals were viewed during these 138 observations, meaning a substantial number of observations involved groups of people. On average, over the course of each one-hour sampling period, 34-35 individuals or groups were observed recreating at Stricker's Pond. While data were collected on more than nine variables through this visitor use assessment, the results of three variables are especially relevant to this analysis: 1) the percentage of visitors participating in specific activities around the pond (Figure 9.2); 2) the percentage of visitors originating on specific trails (Figure 9.3); and 3) the percentage of visitors observed walking one or more dogs (Figure 9.4).

Approximately 79% of pond users utilize the trails adjacent to the pond for walking, jogging, or running. An additional 15% of pond users utilize these trails for biking (Figure 9.2). Biking on the conservancy trail is strictly prohibited; however, none of those observed were biking on this trail. Other activities engaged in by users near the pond included viewing wildlife and photography. In general, these results are consistent with the findings of the online survey and oral histories that were conducted, and therefore are likely representative of the activities pond users generally engage in during the summer and fall.

This visitor use assessment also provided critical information on the points from which pond users originate on the trails surrounding Stricker's Pond (Figure 9.3). Based on the observations made, 38% of pond users were first observed on Middleton Street; 35% were first observed on the Forebay Trail; 18% were first observed on the Voss Trail; and just 8% were observed on the conservancy trail. One explanation for the low percentage of visitors observed on the conservancy trail is variability in the visibility of this trail. During the summer, visibility was low due to vegetative growth in the conservancy area. In the fall, visibility of this trail was considerably higher due to the seasonal vegetation die-off. That said, it is essential to note that many pond users walk these trails in a circular fashion. In general, pond users stayed on the designated trails around the pond with the exception of Middleton Street, which is used as a defacto trail. The use of Middleton Street presumably results from the lack of a designated trail adjacent to the pond on the southeastern shore.

Of final relevance to this analysis is the number of visitors observed walking dogs around Stricker's Pond. Based on the data collected, 17% of observed visitors had one or more dogs with them (Figure 9.4). Of the observed dog-walkers, 100% had their dog(s) on-leash and all of them properly managed their pet waste. These findings are significant, as pet waste can be a significant source of phosphorus in urban landscapes. Improper management of pet waste can contribute nutrients to Stricker's Pond and exacerbate eutrophication (Fissore et al., 2012). In general, these results indicate that Stricker's Pond visitors follow the on-leash policy for dogs and manage pet waste properly.

Community survey

PURPOSE

The community survey was intended to gather data on residents' perceptions of the environmental quality of Stricker's Pond, their knowledge of best management practices, and perceived barriers to implementing these best management practices, and to gauge residents' willingness to voluntarily implement these best management practices in their own yards.

METHODS

The survey population was residents living at all addresses in the Stricker's Pond watershed. These addresses were retrieved from Dane County's public GIS database. The watershed boundary was delineated in GIS, and approximately 2,000 addresses were identified within the watershed through a county-level dataset. From this survey population, 1009 addresses were randomly selected and included in the sampling frame. A letter was mailed to each address in the sampling frame to provide background information on the Stricker's Pond watershed assessment, invite residents to participate in the survey, and provide them with a link to the survey, which was administered online using Qualtrics. The survey remained open for approximately one month.

The survey consisted of 18 questions, including one asking for participant consent to use their data (see Appendix A6.2). These questions came from two sources. Some were generated independently by the Water Resources Management cohort, and others were taken from the Social Indicators Data Management and Analysis Tool (Institute of Water Research, no date).

RESULTS

The survey had a final response rate of 7.73%. Of those who began the survey, 98.7% consented to the survey, giving a final response number of 77. Survey participants were first queried regarding their visits to Stricker's Pond. Of those surveyed, 48% had visited the pond more than 21 times in the past year, while 15% had visited 11-20 times per year, and only 9% had visited the pond 10 times or fewer. The most common activities undertaken during visits to the pond were wildlife viewing (92% of respondents engaged in this activity); and walking, jogging and running (89%). Other popular activities included dog walking (32%), sitting and enjoying nature (51%), and biking (46%).

When asked to rate the water quality of Stricker's Pond, 47% of respondents stated that they did not know. Only 5% of survey respondents viewed Stricker's Pond as having 'good' water quality, while 27% believed the water quality to be 'okay' and 21% viewed the water quality as 'poor.' Respondents' perceptions of pollutants in Stricker's Pond varied. More than half of respondents believed nutrients from fertilizers (60%) and invasive aquatic plants and animals (52%) were causes of pollution. More than 20% of respondents believed organic matter, trash and debris, cloudiness of water, lack of oxygen, and phosphorus to be water pollution problems in the pond. Of the respondents, 80% believed lawn fertilizer and pesticides contribute to pollution in Stricker's Pond. Other leading perceived causes of pollution included droppings from geese, ducks, and other waterfowl (50%); runoff from streets, highways, and parking lots (66%); and road salt andsand (59%).

Prior knowledge of stormwater management practices was strong among survey respondents, with rain gardens recognized by 75%; rain barrels by 86%; and the need to direct downspouts away from paved surfaces recognized by 74%. However, the rate of implementation of these practices

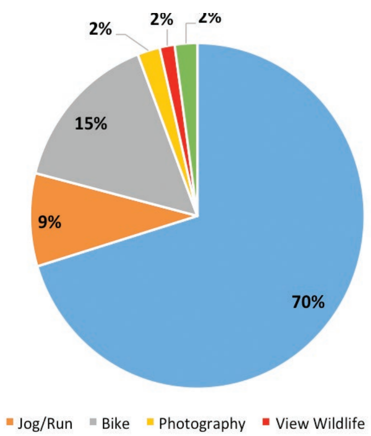


Figure 9.2: Percentage of observed activities engaged in by users.

was lower. Downspout management was the most implemented practice (reported implementation by 65% of survey respondents). Rain barrels and rain gardens were utilized by only 16% and 13% of respondents, respectively. While implementation of practices by respondents was low, their desire for additional information on practices was comparatively high. More than half of respondents were interested in obtaining additional information regarding infiltration basins (52%), bioswales (62.5%), rain gardens (56%), and rain barrels (56%). Interest in implementation of stormwater management strategies was also strong, with 51% of respondents interested in implementing one or more strategies in their own yards, and only 2.5% of respondents stating they were not able or interested in implementing stormwater management strategies. The greatest impacts on decisions to implement stormwater management practices were ease of implementing with current practices (41%), cost (38%), and lack of information regarding stormwater management practices (33%).

When asked about their personal lawn-care practices, more than 50% of respondents stated that they applied pesticides and herbicides per the manufacturer guidelines to their lawns or gardens (52%) and managed their grass, clippings, leaves and brush (83%). When asked if they would be interested in learning more about lawn-care practices, more than 40% of respondents stated they would like additional information regarding the application of pesticides and fertilizers (65%); management of grass clippings, leaves, and brush (42%); and use of phosphate-free fertilizers (50%). When asked if they would be interested in using lawn-care practices in their own yards, 71% stated they would be willing to avoid applying pesticides, herbicides and fertilizers, and 56% stated that they would be willing to use phosphate-free fertilizer. Cost (37%), ease of implementation (51%), and pre-existing views about effective lawn and garden mainte-

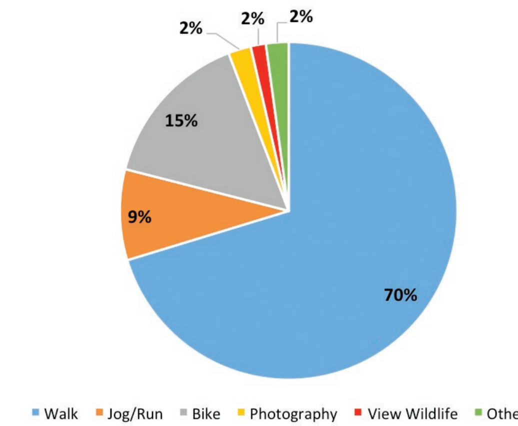


Figure 9.3: Percentage of observed visitors originating from each trail.

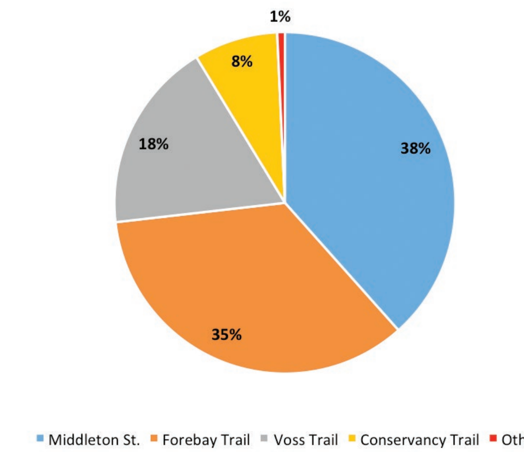


Figure 9.4: Percentage of observed visitors walking dogs.

nance (40%) were the most important factors influencing the lawn-care practices of respondents. In the watershed, 75% of respondents stated that they place their leaves on the edge of the curb for collection, and 54% of respondents stated that they mulch their leaves with a lawnmower.

The final question was an open-ended response question asking the participants what they would like to see happen at Stricker's Pond in the next five years. Open-ended responses were analyzed for recurring topics. The most popular topics included reducing the lotus population (47%) and improvement of water quality (33%).

Community meetings

PURPOSE

Town hall meetings were conducted to educate and gain feedback from the public about the project. Town hall meetings were also used to gauge the public's current and desired recreational or community uses for the pond, collect information on how the pond and surrounding parkland are being used by the community, how the area has urbanized over time, the public's assessment of the student research project, and views of the recommendations.

It is essential to understand community interests and concerns about proposed policy changes or implementation. Town hall meetings are a vehicle through which specific policies, practices, or new information can be presented, discussed, and potentially amended. Information gleaned from the Stricker's Pond meetings was used in conjunction with historical documents and current data to establish issues and document changes in the watershed with the rapid urbanization of the area.

In addition to town hall meetings, a guided tour of Stricker's and Tiedeman Ponds was facilitated and led by Mike Healy (principal ecologist with Adaptive Restoration and consultant for the Middleton ecological restoration project around Stricker's Pond). The purpose of the pond walk was to inform residents about the status of current restoration and management projects. The walk also provided an opportunity to inform residents about the ongoing research, and to foster community involvement and engagement.

METHODS

The most effective public meetings are inclusive of the targeted community, are informative, and utilize information collected during the meetings to influence decisions moving forward. Three town hall meetings were held in Middleton throughout the summer and fall 2016. Town hall meetings were marketed through word of mouth and by posting signs in local businesses and public places. Town hall meetings included a presentation and large-group discussion. The presentations were targeted toward residents within the Stricker's Pond watershed, key stakeholders, and the Middleton Water Resources Management Commission, and focused on the student group's research, findings, and recommendations. The third and final town hall meeting was the best attended, thanks to local advertising and residential interest.

The pond tour was conducted on August 1, 2016, in the early evening. Mike Healy discussed his firm's involvement with the ecological restoration plan proposed by the City of Middleton and detailed the steps in developing and implementing the prairie and oak savannah restoration. Our 2016 watershed assessment and preliminary findings were then described. Residents asked questions about both projects during the tour.

RESULTS

Town hall presentations were well received by community attendees. Presentations were interactive, with residents asking follow-up questions and offering insights to improve the project. Residents were extremely interested in the history of Stricker's Pond. They noted that becoming knowledgeable of both the hydrologic and cultural history and development of the pond helps them gain a better understanding of how to manage this resource. The majority of questions addressed the ecological and biological health of the pond. Attendees commented on the perceived change in fish populations and were surprised that only goldfish and fathead minnows were present in the pond. Some described previous years when the fish diversity was much higher. Others responded that fish diversity only increased when water levels were higher than normal. Attendees named improving water quality as a high priority. Some experienced mixed feelings when presented with the recommendation of eradicating the goldfish population as a way to improve water quality. Attendees wanted a guarantee that reducing goldfish populations would not negatively affect waterfowl (e.g., heron) populations that feed on fish. If measures are taken to eradicate goldfish, the fathead minnow and possibly other fish populations should be encouraged and protected.

Attendees were extremely interested in learning more about the American lotus. The town hall presentation described the introduction of the lotus population, its potential growth threshold, and both the positive and negative effects of lotus on the ecology of the pond. Follow-up discussion addressed residents' concerns pertaining to the American lotus within Stricker's pond. Many of these concerns (reduced water clarity, lack of open water, and lack of aquatic macrophyte diversity) reflected issues identified in the online survey. Some attendees were surprised to learn that lotus reduces nutrients by stabilizing sediment with its rhizomes.

Town hall meeting attendees approved of the recommendation to update educational signage around Stricker's Pond, including a sign about American lotus that might help change public perception of the plant. Attendees recommended including signage with information on ways pond residents could improve the ecological health of the resource. Finally, attendees recommended that pond signage encourage recreators to stay on the designated paths to reduce vegetation disturbance in the conservancy areas.

The pond walk was helpful in determining residents' questions, concerns, and interests regarding Stricker's Pond management. Concerns about the American lotus population included: build-up of leaves and organic materials, reduced water quality, lack of open water for recreation, and the area threshold for the lotus population. Residents were also interested in potential uses of the American lotus (e.g., seeds to be used for restoration initiatives). More general questions regarding current management of Stricker's Pond included: Is the pond being managed for biodiversity, water quality, or stormwater retention? What is the ideal water level for Stricker's Pond and how is it enforced? Residents are interested in more recreation at Stricker's Pond, including ice skating, kayaking and fishing.

Oral histories

PURPOSE

Beyond surveying and observing individuals around Stricker's Pond, our cohort conducted oral histories with watershed residents to learn about connections, stories, and experiences that residents have had with the pond and the surrounding watershed. These interviews helped elaborate on information gleaned from our survey and meetings with the community. We obtained qualitative information on a number of subjects, including past pond conditions, how the pond and watershed have changed over the years, and what concerns residents hold about the pond's future. We also gained a greater understanding of how residents used their land, which helped us form meaningful suggestions on how property-level modifications could improve the watershed as a whole.

Furthermore, and perhaps most importantly, our cohort wanted to ensure our assessment and recommendations make a lasting impact on the watershed. By incorporating residents' information, concerns, and suggestions gleaned during oral histories into our synthesis—and informing residents about the effects of their input—we help to ensure that the community has a stake in the project and its outcome. Wide community awareness and engagement will contribute to the project's success and longevity.

METHODS

Our cohort took oral histories from seven residents within the watershed. Collecting the oral histories was a three-step process, in which we first identified residents who would be appropriate to interview, conducted the interview with each resident, and subsequently analyzed the results.

IDENTIFYING RESIDENTS

Interviewees were identified through suggestions from community members at town-hall meetings and through the online survey. We received the names and contact information of three individuals from the town-hall meetings. We sent email inquiries to the three individuals and received one reply, which lead to a subsequent interview. Survey participants were given the option to leave their contact information on an anonymous Google sheet, which garnered a 29.5% response rate of all the individuals who took the survey. Potential interviewees were then contacted via email to confirm their interest and determine dates and times for an interview. Of the 19 inquiry emails that were sent, nine garnered a response, and three led to interviews.

CONDUCTING INTERVIEWS

Each interview was conducted by two members of the student cohort and ranged from roughly 20 minutes to over one hour. An oral historiyhistory was typically taken at the resident's home, with one member of the cohort conducting the interview and asking questions, and another member transcribing the interview onto a laptop. In three of the four cases, the original interviewee's spouse ended up participating in the interview as well, bringing the total number of interviewees to seven.

While the interviews fluctuated according to the interviewee's responses and the cohort member's supplemental questions, the interviews generally touched on the following questions:

- How long have you lived in the Middleton/Madison area?
- How long have you been visiting Stricker's Pond?
- Have you noticed any changes in the pond over the years?
- Have you noticed any changes in the land surrounding the pond over the years?
- What kinds of activities do you like to engage in at the pond?
- What changes would you like to see made to the pond or the area surrounding the pond?
- Do you have any other information to share with us regarding Stricker's Pond?

Interviewees were also asked if they had any tangible objects related to the pond, such as photographs and newspaper articles, which would shed light on its development. In response to this request, we received several newspaper clippings, photographs, and court documents regarding the case Tiedeman v. Village of Middleton, 25 Wis.2d 443 (1964).

ANALYZING RESULTS

After transcribing the interviews, four broad categories of responses were developed. After creating the categories, described in more detail below, the interviewees' experiences with Stricker's Pond were compared.

RESULTS

The seven residents interviewed had a wide range of experience with the pond and surrounding area. One of the interviewees had grown up around Stricker's Pond, and two others had lived next to the pond for over 40 years. In contrast, two of the interviewees had just recently moved to the area near Stricker's Pond, and had lived there for less than two years.

The interviewees' comments about the pond touched on similar subjects and can therefore be grouped into the following categories: past recollections of Stricker's Pond, activities conducted around the pond, concerns about the pond, and suggestions for pond and watershed management.

RECOLLECTIONS OF STRICKER'S POND

Residents who have lived in the area for decades had vivid memories of the pond before Middleton became more developed. Life around the pond was different before Gammon Road was paved. At this time, only a few houses existed near the pond. George Tiedeman, who owned land near Stricker's Pond before he sold it to the city, tried to run a muskrat ranch in Tiedeman Pond. The venture failed as he could not contain the animals, but to this day, muskrats live in the area and make their homes in Stricker's Pond.

Hunting in the area was common when the land was still privately owned, and individuals hunted duck on the kettle ponds. Even after Middleton acquired the land around the pond, a resident hunted pheasants in the vicinity, as the neighborhood did not have many houses. The long-time residents recalled a pond that contained more wildlife, including lizards, toads, turtles, salamanders, ducks, deer, and muskrats. While some of these animals still live around the pond, the residents have not seen others, such as salamanders, for decades.

Even more than the wildlife, these residents remembered the flooding events that occurred around the ponds before the city connected Stricker's Pond to Tiedeman Pond, and Tiedeman Pond to Lake Mendota. These residents are still displeased with the past flooding events.

ACTIVITIES CONDUCTED AROUND STRICKER'S POND

All of the interviewees regularly visit Stricker's Pond. Two of the interviewees walk around the pond daily, during which time they often see several other regular pond walkers. Others walk around the pond to look for wildlife, especially cranes and herons. A number of those interviewed stated that they enjoyed taking photographs around the pond, capturing birds, insects, wildflowers, and lotus blooms. Two of the interviewees have grandchildren who play in Stricker's Park, and two others have grown children who played around the pond and park when they were young. Residents who have lived around the pond for substantial periods also described ice skating on both Stricker's and Tiedeman

Ponds. One interviewee recalled ice skating on a smaller pond near Stricker's Pond that has since dried up.

Throughout all the interviews, it was clear that residents enjoy Stricker's Pond and view it as an important part of their community. These residents often see other regular visitors at the pond, so it is likely that other Middleton residents have similar views about the pond and park.

CONCERNS ABOUT STRICKER'S POND

The interviewees expressed various concerns about Stricker's Pond, mainly regarding the American lotus, water quality, and flooding. Although not all of those interviewed regarded the lotus as a nuisance (one interviewee said the lotus were beautiful), all of the interviewees had heard others speak negatively about the lotus. The community seems to be most concerned that the lotus will eventually take over the entire pond and cover the entirety of the open water. Part of the frustration also seems to be that community members do not know why the lotus was re-introduced into Stricker's Pond. Some speculated that the lotus was put in for water quality management.

The oral history results support the survey results regarding water quality in Stricker's Pond. The interviewees were not able to say with certainty whether the pond water quality was good, fair, or poor, but they generally did not think the water quality was good. The interviewees also expressed concern with the contents of storm water input and of pollutant concentrations in the sediment. Many of the interviewees would like more information about pond water quality and how individual activities impact the pond.

Longtime residents had vivid recollections of pond flooding events, and they want to make sure those events do not occur in the future. Almost all the interviewees were aware of the pond connections between Stricker's and Tiedeman, and of the pump between Tiedeman Pond and Lake Mendota. They did not know, however, how the city regulates water levels and reported feeling anxious when the water level in Stricker's Pond rises. One interviewee said that water quantity management in the watershed could be further improved. The interviewee stated that during large rain events, the amount of water flowing behind their property toward the pond "is like a river." They reported that Longmeadow Road floods during these rain events, and that this type of property and street inundation occurred as recently as summer 2016.

SUGGESTIONS FOR STRICKER'S POND AND WATERSHED MANAGEMENT

The interviewees offered several suggestions to mitigate their concerns regarding the pond:

- Improved drainage and water level management.
- Removal of invasive species around the pond, especially the reed canary grass.
- More information about nutrient management and best practices on individual lawns. (Two interviewees live in a homeowner's association, which contracts with a local company to provide lawn-care services to association properties. The interviewees would like an informational brochure on lawn-care practices and their effect on water quality to give to the company.)
- Assistance and encouragement from the city in creating rain gardens on their lawns, either through providing detailed information or through financial assistance. . (The interviewees were knowledgeable about the benefits of rain gardens, but they were unsure about how to install one on their own property.)

RECOMMENDATIONS

Based on the results of the visitor use assessment, one recommendation is to connect the Forebay Trail and the Voss Trail. As previously mentioned, Middleton Street is currently utilized by pond visitors as a defacto trail. This presents a safety hazard to visitors, as this street is adjacent to many residences and is frequently used by cars as well as bikers. Adjacent to Middleton Street, a terrace approximately five feet wide is currently maintained as mowed grass. A gravel or paved trail could be built along this right-of-way to protect visitors who walk, jog, and run around the park from bike and car traffic. In addition, this may discourage drivers from parking along this vegetated right-of-way, which has the potential to kill the grass beneath the tires and expose the bare soil.

Prior to completing the trail network around Stricker's Pond, the cities of Middleton and Madison should consider completing additional exploratory research to further their understanding of resident perceptions regarding the implementation of a trail along the grassy right-of-way on Middleton Street. Completing the trail network around the pond will not ensure its use by residents and visitors. This exploratory research could be completed through a survey, public meeting, or focus group with individuals who live near the pond and/or visit it frequently. Critical to the success of this exploratory research is ensuring that the sampled individuals taking part in the survey, focus group, or public meeting are representative of the target population (Luyet et al., 2012).

Public participation is essential to projects of this nature; it is a proven method for fostering public trust and acceptance of the outcomes of environmental management decisions — in this case, the decision for or against the implementation of a new trail (Luyet et al., 2012). The National Oceanic and Atmospheric Administration has produced a series of free, concise publications on conducting focus groups, surveys, facilitated meetings, and more generally public participation (NOAA, 2015a; NOAA, 2010). These materials offer key guidance and best practices for conducting successful, and most importantly, meaningful participation with the general public.

If the public expresses sufficient interest in completion of the trail around Stricker's Pond, several funding opportunities exist to cover the costs of planning and implementation. Specifically, the state's Knowles-Nelson Stewardship Grant (WDNR, 2016a) and Recreation Trail Aids Program (WDNR, 2016b) both make funding available for the development and improvement of recreation trails. These competitive funding opportunities could also be utilized to complete additional trail improvements around the pond (e.g., paving the trail adjacent to Voss Parkway and restoring eroded portions of the conservancy trail).

Based on the results of the community survey, residents of the watershed are interested in additional information regarding the pond, its ecology, and its uses. We recommend the City of Middleton install educational signage throughout the Stricker's Pond Conservation Park highlighting specific portions of the watershed ecology. Suggestions for educational sign topics include invasive plants around the pond, native plants around the pond, birds around the pond, common sources of pollution and impacts to pond water, how stormwater is managed in the system, and how plants are managed around the pond. These would improve on the outdated and faded signage that already exists in the park and include new informational topics. Signs should be placed along the walking path that runs through the prairie and the woods.

10

LEAF SURVEY

PURPOSE

Many municipalities collect leaves in the fall, and studies indicate that such measures are beneficial to water quality. Several studies suggest plant debris can be a major source of nutrients in stormwater (Selbig, 2016). These nutrients, in turn, can lead to eutrophication in urban water bodies. Removing leaf litter before precipitation events could lead to significant nutrient load reductions (Selbig, 2016).

Leaf management practices in the Stricker's Pond watershed were surveyed to determine whether these had the potential to play a role in nutrient loading to the pond. If leaf management was consistent and followed city guidelines, then this potential would likely be low. If management did not follow city policy, then the potential for impacting nutrient loading would likely be higher.

METHODS

Our cohort surveyed several streets in the Stricker's Pond watershed in November 2015, around the time of leaf pickup. Thirteen streets in the area were visited in both Middleton and Madison, for a total of 97 properties. The survey was limited because leaf removal had already occurred on many streets. The streets on which leaf removal had not yet occurred were traveled, and the placement and configuration of leaves for each residence were recorded. The presence of several storm drains was also recorded, and whether they were clear or blocked with leaves was noted.

After the survey, observations of each property were grouped into three categories: good management, fair management, and poor management. These categories were developed based on the City of Middleton's Leaf and Garden Waste Collection policy, which directs residents on how to assist the city with leaf removal. Properties that practice "good" leaf management were those that closely followed city guidelines and piled their leaves onto grass areas near the street in a windrow configuration. Properties that exhibited "fair" leaf management only somewhat followed city guidelines: leaves were piled on the grass, but the piles were often messy or too large, which allowed leaves to spill onto the street. Leaves in these yards were occasionally mixed with brush and other yard waste, which the leaf collection policy advises against, cautioning that city trucks will not collect these piles. Properties that displayed "poor" leaf management did not follow city guidelines. Leaves on these properties were piled on the street or on driveways, which the leaf collection policy specifically advises against. Other properties exhibiting poor management practices were those on which leaves had not been raked or piled, preventing city collection.

RESULTS

The majority of surveyed properties do not practice good leaf management; 41 homes practiced poor leaf management, 39 homes used good leaf management practices, and 17 homes had fair management behavior (Figure 10.1).

These results demonstrate that watershed residents would benefit from more education on proper leaf management. It is unclear how much leaf litter impacts stormwater nutrient levels, although the impact could be substantial (Selbig, 2016). If this is true, then individual management and leaf collection timing could have a large impact on autumn nutrient levels in the pond. Furthermore, poor leaf management can cause blocked storm drains and prevent them from functioning properly.

CONCLUSIONS

Based on the results of the leaf survey, more outreach is needed to educate citizens about proper leaf management. We therefore recommend that the City of Middleton take more steps to communicate with residents in the watershed about the importance of leaf management, and ways to do it properly (the survey results indicate that the City of Madison would benefit from improved leaf management as well.) Currently, the City of Middleton Public Works Department publishes the leaf management policy and leaf pickup schedule on their website. The city also publishes information in the Middleton Times-Tribune. In addition to these efforts, the city should consider publishing a flyer or brochure and mailing it to residents (either citywide or within the Sticker's Pond watershed). Along with showing residents how to mulch leaves or stack them on terraces, the publication should inform residents that leaf management is an important way to keep leaves out of storm drains and nutrients out of urban waterways. Residents may not realize that the actions they perform on their individual properties can have a large impact downstream. Targeted outreach could persuade residents to modify their lawn-care practices.

Residents may change the way they manage their own lawns if their neighbors' management were more visible. The City of Middleton could consider making a stronger connection with the Madison Area Municipal Storm Water Partnership (MAMSWAP). MAMSWAP conducted a pilot project in several Middleton neighborhoods to find the optimal way to keep leaves out of streets. One of the methods used was to encourage posting signs in neighborhood lawns when a rain event was imminent. During these times, pilot participants cleared leaves from streets to prevent nutrients from leaching from wet leaves into storm sewers and waterways. These signs were publicly visible, and using them in a uniform way throughout the watershed could encourage residents who do not normally pay attention to leaves or leaf management to rake and stack leaves properly, or to clear leaves from clogged storm drains.

Figure 10.1 Leaf management rankings from the survey area. Good management: piling leaves on curb in windrows. Fair management: haphazard piles on curb. Poor management: Piles in streets or driveways, or not collected.

11 SUMMARY OF RECOMMENDATIONS

This section describes and elaborates on what the cohort has deemed as the most crucial and arguably most feasible actions which should be taken by the cities of Middleton and Madison. Along with the nature of this assessment, these recommendations cover a wide range of topics, including ecological concerns, recreational improvements, and management performance metrics.

Some of the recommendations discussed are simple, with near-term benefits to the cities. Others may be considered more challenging to implement but with enormous long-term impacts. Regardless of their scale and complexity, the cohort views these recommendations as essential to improving the quality of Stricker's Pond as a resource to the community.

The summarized recommendations are listed in order of increasing complexity and scale of implementation. They are not prioritized in order of overall importance to the improvement of or impact on the pond and watershed.

1 DESIGN A PROPER PROTOCOL FOR DRAINAGE VALVE MANAGEMENT.

Stormwater is a significant challenge in the Stricker's Pond watershed and contributes to the current water quality issues in the pond. Best management practices have the potential to reduce both the flow volume and pollutant load the pond receives during and after a rain event.

The outlet valve that controls outflow from Stricker's Pond was a source of uncertainty in modeling because the amount of water leaving the pond at a given time was unknown. Therefore, it is important to standardize the opening/closing and associated record-keeping to determine how much water flows out of the pond. This will help with stormwater management and enable assessment of best management practice implementation in the future.

2 IMPROVE EXISTING EDUCATIONAL SIGNAGE AROUND THE POND.

Based on information provided by the community survey, town hall meetings, and oral histories, residents of the Stricker's Pond watershed are interested in more publicly available information regarding the pond. Therefore, we recommend updating existing educational signage in the conservancy area to provide this information to those community members who utilize the pond.

Currently, educational signage exists at the pond, but is sorely outdated and in disrepair. New educational signage should provide information to the community on watershed practices that may be implemented to improve water quality in the pond (e.g., rain barrels and rain gardens). Signage regarding current water quality and associated issues in the pond will help raise awareness and could motivate residents to implement stormwater best management practices on their own properties. Information on the current state of vegetation, including the presence of native species with high conservation value, and the control and management of invasive species in the conservancy, may draw support for additional conservation and restoration efforts. Signs describing the bird and animal populations in the conservancy might increase interest in birding or wildlife viewing at the pond, as people become more knowledgeable of the rare species that visit the pond. Information regarding the value of the American lotus to the pond will help to educate concerned citizens and potentially provide evidence that the city is engaged in a lotus management strategy. Information on the fish species in the pond, and the effects that goldfish have on the pond environment, may discourage dumping of fish into the pond and may help draw public support for fish management in the pond. These signs should be placed along the walking path around the pond in locations relevant to the information provided.

3 CLEARLY ESTABLISH AND COMMUNICATE AMERICAN LOTUS MANAGEMENT OBJECTIVES.

We recommend that the cities of Middleton and Madison establish a management plan for the lotus. Since there are community concerns about the aesthetics associated with open water and the potential for decreased water quality associated with the dominance of the American lotus patches in Stricker's Pond, it is imperative to communicate the management objectives and purpose to the local community. The lotus management plan should consider the positive and negative ways that lotus affects the water quality of the pond, promote the ecosystem services the lotus provides to the pond (e.g., attracting wildlife and stabilizing sediments), and focus on promoting public acceptance of the presence and the cultural history of the lotus.

There are several strategies the cities could use to manage the lotus. First, they could leave the lotus to expand naturally. There is the possibility that the lotus could cover the entire pond if unmanaged and the pond stage is low enough to allow for this. On other ponds, lotus populations have shown cyclical patterns; Stricker's population could also diminish on its own over time. This strategy would allow for the lotus to enhance sediment deposition within the pond and remove nutrients from the water column. There is a trade-off with the nutrient reduction because of the release of nutrients and decrease in DO through leaf decomposition. An educational program (outreach, signage, and community walks) could be developed to inform and gain public support. It will be important to promote the beauty of the flowers, the potential for using the seed heads in dried floral arrangements, and the cultural heritage as a food source to Native Americans. An event focusing on the beauty of lotus could be organized annually while the flowers are in blossom. Lotus-inspired arts and crafts could help build community acceptance of the plant, and the plant could be harvested for culinary uses.

Another management strategy would be to determine the optimal extent of the lotus in Stricker's Pond and to remove lotus exceeding that extent. Control of the lotus population could be achieved through manual removal or herbicide application. Both strategies would require a WDNR permit and would need to prove that removal would positively impact pond water quality (Graham, 2016). Lotus removal would likely be approved only if the plant densely occupied the entire pond resulting in homogenous aquatic habitat. Mechanical removal may include manual cutting and removal of the flower heads prior to seed formation, cutting the stem below the water's surface multiple times a season, or drawing down the pond level in the fall to induce winter kill of lotus rhizomes. The main barrier to mechanical removal is that it is highly labor intensive. Aquatic herbicide treatments can be very costly and have low levels of public approval. Removal strategies could be tested on small portions of the lotus population to determine the most effective technique. Lotus plants form extensive rhizomes and have large numbers of seeds that are viable for decades. Therefore, removal is expected to be a continuous effort.

4 FORMULATE A COHERENT VEGETATION MANAGEMENT STRATEGY.

To improve the vegetation quality around Stricker's Pond, both cities must work together and commit financial resources. The cities should clearly state their available resources and define their management priorities. For invasive removal and prescribed burns, the cities could hire the same contractor. Invasive populations need to be controlled before additional native plants are reintroduced; this is especially important for Madison's conservancy lands. Ideally, a vegetation management strategy focusing on restoring prairie, woodland, and wetland habitat would be created by a common contractor and financed by both cities. Special attention should be given to additional wetland plants that tolerate fluctuating water levels.

In addition to comprehensive vegetation management efforts, expanding volunteer efforts could provide another opportunity for invasive species management in the conservancy areas. Thus far, volunteer days have focused on garlic mustard removal, but they could expand to include dame's rocket and buckthorn. This could engage the many visitors who consistently recreate at the pond.

5 ERADICATE GOLDFISH AND ESTABLISH A NATIVE FISH COMMUNITY.

Both the ecology and water quality of the pond would benefit from the removal of the goldfish population. Goldfish are related to carp, which is a nuisance or invasive species in the United States that competes with native species for food. They are also benthic feeders that tend to stir up sediment, which increases nutrients in the water column and uproots submerged aquatic plants that could otherwise sequester excess nutrients. The increase of suspended solids also limits light availability to plants, further hindering nutrient sequestration. It is likely that at one point in time the fish put significant pressure on the filter-feeding macroinvertebrate population, which is currently very limited as shown by the WWMBI results. If the goldfish were removed, the macroinvertebrate population may rebound and reduce harmful algal blooms.

There are a number of ways to implement this recommendation. The most feasible option is to contract a small commercial fishing operation that would utilize nets to collect the goldfish while preserving the native fish (e.g., fathead minnows). While costly, this is the most ethical option. Electrofishing could also be used to capture fish. A pond stage drawdown could induce a winterkill, resulting in complete sanitation of the pond. While this option would likely be less costly and the most efficient, there are viability, ethical, and ecological concerns. A drawdown during a year with a warm winter season could be unsuccessful. Winterkill occurs when the ice is thick enough or lasts long enough to completely remove dissolved oxygen in the water column, thus suffocating organisms. The Stricker's Pond area has an abundant herpetological community (e.g., snapping turtles, red-eared sliders, western painted turtles, midland painted turtles, American toads, spring peepers, gray tree frogs, and green tree frogs) which poses further complications (Linton, 2013). Turtles and frogs overwinter either deep within the water column or within the near-shore substrate. If the pond stage were lowered, the timing would need to be planned such that turtles and frogs were not subsequently killed.

Visitors to Stricker's Pond have expressed concern that eradicating the goldfish would threaten the popular fish-eating birds (e.g., green herons and great blue herons). While this is a valid concern, the impact on these birds could be minimized if pond managers reestablished the native fish community. Overall, the intended outcome of goldfish removal is to improve water quality — specifically water clarity, dissolved oxygen, and nutrient concentrations — and to improve the native biological diversity of the pond.

6 IMPLEMENT WATERSHED-SCALE INITIATIVES TO ENHANCE WATER QUALITY.

While the quality of aquatic and terrestrial plants, fish and wildlife habitat, and water levels in Stricker's Pond can be enhanced by implementing management practices within the pond and the surrounding parkland, improving the quality of the water entering the pond will require action at the watershed scale. Results from the community survey indicated that more than 50% of respondents were interested in implementing rain gardens and/or rain barrels in their own homes and yards. From a water-quality standpoint, implementation of these types of site-scale green infrastructure is associated with significant reductions in total suspended solids and total nitrogen (Jaffe et al., 2010). In addition, the HydroCAD and WinSLAMM model results showed that the implementation of rain gardens could significantly reduce the total volume of stormwater as well as the nutrient loads entering Stricker's Pond if implemented at sufficient scale.

One benefit of adopting a site-scale stormwater management strategy is that the cities of Middleton and Madison can rely on empowered and motivated residents to assist with its implementation. Several resources are available that could be leveraged by the two cities to conduct the training necessary to enable residents to implement rain gardens and rain barrels on their own. For example, the City of Madison has rain garden plans for various types of available light conditions, which provide guidance on appropriate native plants and dimensions (these plans are free on the City of Madison website). In addition, the city has a program that allows communities to have a terrace rain garden implemented when their street is replaced. Residents on the block being reconstructed are expected to share some of the cost of the rain garden, and in exchange the city designs and builds the rain garden. The City of Madison also allows residents to purchase rain barrels in bulk through the city, and receive a discounted rate.

There are also several technical assistance programs available that staff from the cities of Middleton and Madison could use to educate residents on rain garden and rain barrel installation. For example, University of Wisconsin Extension has a rain garden educator kit available online that costs just $12 (WDNR, 2012). The WDNR and the Portland Bureau of Environmental Services have rain garden and rain barrel installation guidebooks available for free online (Bannerman & Considine, no date; Portland Bureau of Environmental Services, 2011). Finally, there are free videos online that provide step-by-step installation instructions for rain barrels. With the use of these readily available resources, the cities of Middleton and Madison could host several public trainings for site-scale green infrastructure installation. Residents can be encouraged and empowered to implement these practices in their own lawns, and in so doing enhance the quality of the water entering Stricker's Pond at a fairly low cost.

That said, it is not realistic to expect residents of these cities to bear the full cost of improving the water quality of Stricker's Pond. Since large-scale infiltration was modeled to be effective for reducing runoff, the cities could also invest in implementing those types of projects. Middleton and Madison should consider completing more in-depth modeling to identify locations for green infrastructure that would provide the most water quality benefits. This modeling effort is necessary because green infrastructure provides different benefits based on its placement in the landscape. Once ideal locations for green infrastructure are identified, the cities of Middleton and Madison should pursue grant funding to implement these projects. Taken together, this strategy could help reduce pollutant and nutrient loads from the watershed and improve the quality of the water in Stricker's Pond.

7 IMPLEMENT TRANSDISCIPLINARY, TRANSBOUNDARY, LONG-TERM MANAGEMENT.

Defining pond management objectives, given the shared nature and competing uses of this natural resource, presented a significant challenge when completing this assessment. While the staff at the City of Middleton may currently manage the pond solely as a flood control asset, residents have clearly expressed the desire to see the pond managed primarily as an ecological, recreational, or water quality asset. These conflicts of interest are compounded by the fact that Stricker's Pond and its watershed are shared by Middleton and Madison; both of these local governments have different budgets, time commitments, and management objectives for the pond. As a consequence, there is a disconnect between not only the public and the cities of Middleton and Madison, but also between these local government entities themselves. This has allowed several of the issues described in this report to intensify.

8 CREATE A HOLISTIC MANAGEMENT PLAN TO HARMONIZE MANAGEMENT OF STRICKER'S POND.

The lack of harmonization between the cities of Middleton and Madison's management practices for the pond and its surrounding parkland has had several adverse impacts on the quality of this natural resource. For example, the city of Middleton has invested significant resources into restoration initiatives for mesic prairie and oak savanna habitats around the pond. This effort has involved the management of invasive species, seeding and installation of native species, and prescribed burns. In recent years, the city of Madison has not taken similar measures, and its lack of a vegetation management strategy is evident though the prevalence of invasive species and a dense shrub layer in the woodland area. As a result, the Middleton's efforts to manage invasive species and improve the quality of the habitat surrounding Stricker's Pond will likely be less effective if similar efforts are not taken around the entire pond.

Together, the cities of Middleton and Madison should work to build and maintain a collaborative relationship, and to establish clear management objectives for the quality of the habitat within and surrounding Stricker's Pond. Essential parties in the development of this management plan include: staff from the City of Middleton Public Works Department; the City of Middleton Department of Parks, Public Lands and Forestry; the City of Middleton Water Resources Management Commission; the City of Middleton Conservancy Lands Committee; the City of Middleton Recreation and Forestry Commission; the City of Madison Engineering Department; and the City of Madison Parks Division, as well as stakeholder groups such as the Friends of Stricker's Pond and the Friends of Kettle Ponds (Schreiber Anderson Associates, 2010).

The involvement of these groups is critical to the successful implementation of the recommendations made in this report because management decisions made in isolation can result in unintended consequences. As is true of any complex system, a change in one aspect of the system is associated with a response elsewhere. For example, the decision on how to manage the water level of Stricker's Pond will have cascading impacts on the fish, birds, vegetation, and surrounding homes. As a result, effective management of Stricker's Pond will require collaborative decision-making and deliberative planning. To ensure that these agreed-upon management objectives, goals, and strategies are codified, they should be compiled into a management plan for the pond, and updated regularly.

9 DEVELOP AN INTERGOVERNMENTAL AGREEMENT TO ENSURE MANAGEMENT OBJECTIVES ARE UNIFORMLY IMPLEMENTED.

Collaboration requires significant amounts of time and effort, and may prove to be a barrier to implementation of harmonized management practices around Stricker's Pond. As a result, the cities of Middleton and Madison should consider creating an intergovernmental agreement that would essentially transfer responsibility for the management of the pond to one municipality. This intergovernmental agreement should also require the city that is relinquishing its management responsibilities to compensate the managing city financially for the additional labor, equipment, and management activities conducted to ensure that both municipalities remain invested in the management of Stricker's Pond. Intergovernmental agreements between two municipalities are authorized by Wisconsin Statues 66.30, which states that "any municipality may contract with other municipalities and with federally recognized Indian tribes and bands in this state, for the receipt or furnishing of services or the joint exercise of any power or duty required or authorized by law" (WI SS. 66.30, no date; UW Extension Local Government Center, 2000). These types of contractual agreements, while temporary, can help lower the cost of developing plans for resources that cross jurisdictional boundaries and improve the consistency of how they are managed (UW Extension Local Government Center, 2000). Finally, this approach to managing Stricker's Pond is beneficial because it does not require any type of annexation to occur, thus allowing both communities to maintain their current municipal boundaries and tax bases (UW Extension Local Government Center, 2000).

Examples of this type of contractual agreement, while not common, do exist between cities and sometimes between cities and counties. For example, Cullinan Park, an approximately 750-acre park located on the border of Sugar Land, Texas, which is a few miles outside of Houston's city limits, was created by the Houston Parks Board in 1989 through donations from the Cullinan estate, the City of Houston, the State of Texas Parks and Wildlife Department, and a local foundation. It is renowned for the hiking, birding, fishing and other recreational opportunities it provides for nearby residents. It is also a vital piece of protected open space, located in an area that is reportedly urbanizing rapidly (Cullinan Park Conservancy, no date). Although the City of Houston and the Houston Parks Board currently hold title to the land, the park is operated and maintained by the City of Sugar Land Turner, 2015; City of Houston & City of Sugar Land, 2015).

In this case, the City of Sugar Land took over the maintenance and operational responsibilities for the park in order to enhance its management (Turner, 2015). To achieve this end, the City of Sugar Land has partnered with the Cullinan Park Conservancy to raise the funds necessary to implement planned improvements to the park that will enhance its accessibility for residents (Turner, 2015). This division of labor was outlined in a 30-year inter-local agreement, which is a binding contract that formally established this maintenance agreement between the cities of Houston and Sugar Land, and the Houston Parks Board (City of Sugar Land, no date; Turner, 2015; City of Houston & City of Sugar Land, 2015). The cities of Middleton and Madison should look to this maintenance agreement as an example of how these types of intergovernmental contracts can be leveraged in order to enhance the management of natural resources.

12 CONCLUSION

Stricker's Pond is a critical natural resource shared by the cities of Middleton and Madison. This pond has been valued by residents of these cities for generations, who visit the pond to use the surrounding parkland, view wildlife, and enjoy nature. Stricker's Pond also provides vital habitat for fish and wildlife. That said, the quality of this natural resource has been compromised due to changes in land use over time. Propagation of invasive species, flooding, and eutrophication are some of the most intractable problems that managers must address. The purpose of this assessment was to evaluate the drivers and potential solutions to these problems. Based on the results of this assessment, the 2015 Water Resources Management cohort recommends that the cities of Middleton and Madison:

1. **Design a proper protocol for drainage valve management,**
2. **Improve existing educational signage around the pond,**
3. **Clearly establish and communicate American lotus management objectives,**
4. **Formulate a coherent vegetation management strategy,**
5. **Eradicate goldfish and establish native fish communities,**
6. **Implement watershed-scale initiatives to enhance water quality,**
7. **Create a holistic management plan to harmonize management of Stricker's Pond, and**
8. **Consider creating an intergovernmental agreement to ensure management objectives are uniformly implemented.**

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APPENDICES

Water Quality

Site	Site Description	Latitude	Longitude
1	Madison forebay	43.08477	-89.50809
2	Forebay input to pond	43.08485	-89.50848
3	Stormwater input	43.08869	-89.50855
4	Open water	43.08747	-89.51094
5	Deep hole	43.08660	-89.50969
6	Edge of lotus	43.08566	-89.50878
7	Pond outlet	43.08805	-89.50831

Table A1.1: Locations and coordinates for each water quality sampling site.

Date	Sample Period	pH	EC (µs/cm)	DRP (mg/L)	TP (mg/L)	TN (mg/L)	TKN (mg/L)	Nox (mg N/L)	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	Hrs	Storm	Season
11/20/15	1	6.95	107	0.031	0.25	2.09	2.09	0	107.5	37.5	70	208	no	3
11/20/15	1	6.48	101	0.129	0.18	0.9	0.9	0	90	15.78947	74.210526	208	no	3
11/20/15	1	6.62	103	0.047	0.21	1.67	1.67	0	112.5	25	87.5	208	no	3
11/20/15	1	6.95	95	0.016	0.31	2.57	2.57	0	125	46.2963	78.703704	208	no	3
3/15/16	2	7.01	1290	0.014	0.12	1.09	0.96	0.13	711.429	10.2439	701.18467	59	no	1
3/15/16	2	6.83	523	0.025	0.2	1.81	1.81	0	320	30.26316	289.73684	59	no	1
3/15/16	2	6.79	420	0.021	0.2	1.77	1.77	0	262.857	12.42604	307.57396	59	no	1
3/15/16	2	7.55	453	0	0.15	1.83	1.83	0	280	27.11864	252.88136	59	no	1
3/15/16	2	7.75	459	0.01	0.12	1.7	1.57	0.13	305.714	15.38462	290.32967	59	no	1
4/13/16	3	8.12	407	0.01	0.17	1.47	1.47	0	242.857	16.66667	226.19048	176	no	1
4/13/16	3	8.05	425	0.011	0.21	2.22	2.22	0	260	32.27513	227.72487	176	no	1
4/13/16	3	6.79	438	0	0.24	2.13	2.13	0	271.429	37.91209	233.51648	176	no	1
4/13/16	3	8.59	425	0	0.19	2.58	2.58	0				176	no	1
4/13/16	3	8.77	425	0	0.18	2.71	2.63	0.08	254.286	33.33333	220.95238	176	no	1
4/13/16	3	8.9	424	0	0.2	2.56	2.56	0	262.857	30.34826	232.50888	176	no	1
4/13/16	3	8.87	418	0	0.18	2.47	2.47	0	257.143	29.41176	227.73109	176	no	1
4/28/16	4	6.71	227	0.062	0.37	2.39	2.11	0.28	185.714	14.59227	171.12201	7	yes	1
4/28/16	4	6.47	217	0.067	0.41	2.52	2.27	0.25	168.571	15.13353	153.4379	7	yes	1
4/28/16	4	6.55	57.8	0.044	0.18	1.16	0.86	0.3	65.7143	9.939148	55.775138	7	yes	1
4/28/16	4	9.4	435	0.013	0.19	3.2	3.2	0	271.429	33.83459	237.59399	7	yes	1
4/28/16	4	9.28	437	0.013	0.2	2.94	2.94	0	274.286	34.18803	240.09768	7	yes	1
4/28/16	4	9.36	437	0	0.15	2.37	2.37	0	277.143	34.78261	242.36025	7	yes	1
4/28/16	4	9.31	439	0.012	0.18	3.04	3.04	0	274.286	38.84892	235.43679	7	yes	1
5/27/16	5	6.5	254	0.109	1.04	4.95	4.81	0.14	288.571	48.88889	239.68254	33	no	1
5/27/16	5	6.61	268	0.021	0.6	3.46	3.46	0	265.714	55.40541	210.30888	33	no	1
5/27/16	5	6.88	1020	0.129	0.47	15.49	13.85	1.64	808.571	7.494647	801.07678	33	no	1
5/27/16	5	9.93	393	0.011	0.35	5.19	5.01	0.18	305.714	54	251.71429	33	no	1
5/27/16	5	9.68	386	0.018	0.38	4.43	4.43	0	308.571	53.84615	254.72527	33	no	1
5/27/16	5	9.16	377	0.025	0.5	4.85	4.85	0	311.429	87.34177	224.0868	33	no	1
5/27/16	5	9.53	384	0	0.37	4.23	4.23	0	311.429	75	236.42857	33	no	1
6/14/16	6	6.68	187	0.087	0.49	2.24	2.24	0	131.429	21.42857	110	51	no	2
6/14/16	6	7.73	169	0.09	0.72	3.53	3.53	0	97.1429	47.25738	49.885473	51	no	2
6/14/16	6	6.45	1007	0.069	0.48	9.84	9.84	0	682.857	218.9542	463.90289	51	no	2
6/14/16	6	10.35	404	0	0.44	5.1	5.1	0	194.286	66.01942	128.2663	51	no	2
6/14/16	6	9.42	364	0	0.56	4.05	4.05	0	277.143	98.73418	178.40868	51	no	2
6/14/16	6	8.55	359	0	0.68	4.73	4.73	0	300	112.0879	187.91209	51	no	2
6/14/16	6	9.76	370	0	0.51	5.71	5.71	0	257.143	91.48936	165.6535	51	no	2
6/15/16	7	6.4	94.6	0.07	0.22	1.17	1.09	0.08	54.2857	9.52381	44.761905	13	yes	2
6/15/16	7	6.53	104	0.028	0.22	1.48	1.4	0.08	74.2857	30.65693	43.62878	13	yes	2
6/15/16	7	6.4	69.1	0.052	0.13	0.88	0.81	0.07	282.857	8.9701	273.88704	13	yes	2
6/15/16	7	9.49	318	0	0.41	4.26	4.26	0	611.429	76.92308	534.50549	13	yes	2
7/12/16	8	6.46	169	0.097	0.54	3.23	3.23	0				92	no	2
7/12/16	8	6.38	251	0.034	0.44	3.67	3.67	0	105.714	65.71429	40	92	no	2
7/12/16	8	6.53	295	0.04	0.32	2.53	2.53	0	71.4286	22.22222	49.206349	92	no	2
7/12/16	8	8.53	261	0	0.49	3.86	3.86	0	134.286	102.5	31.785714	92	no	2
7/12/16	8	8.71	261	0.013	0.51	3.77	3.77	0	140	108.9286	31.071429	92	no	2
7/12/16	8	6.86	262	0	0.39	2.74	2.74	0				92	no	2
7/12/16	8	8.33	261	0	0.42	2.44	2.44	0	120	97.56098	22.439024	92	no	2
8/22/16	9	6.94	116	0	0.3	2.39	2.39	0	117.143	37.87879	79.264069	50	no	2
8/22/16	9	8.28	118	0	0.31	3.82	3.82	0	128.571	50.84746	77.723971	50	no	2
8/22/16	9	6.57	115	0	0.25	2.79	2.79	0	97.1429	38.74346	58.399402	50	no	2
8/22/16	9	9.91	136	0	0.33	3.52	3.52	0	142.857	73.13433	69.722815	50	no	2
8/22/16	9	9.59	128	0	0.37	3.79	3.79	0	120	75.34247	44.657534	50	no	2
8/22/16	9	8.59	122	0	0.37	3.74	3.74	0	120	69.23077	50.769231	50	no	2
8/22/16	9	9.94	136	0	0.31	3.9	3.9	0	131.429	66.12903	65.299539	50	no	2
9/22/16	10	6.32	111	0.248	0.5	1.63	1.63	0	68.5714	27.55556	41.015873	13	yes	3
9/22/16	10	6.25	120	0.157	0.54	2.94	2.94	0	94.2857	34.3949	59.89081	13	yes	3
9/22/16	10	6.16	89	0.259	0.43	1.13	1.13	0	42.8571	15.45455	27.402597	13	yes	3
9/22/16	10	8.27	91.7	0	0.25	2.94	2.94	0	77.1429	44.61538	32.527473	13	yes	3
9/22/16	10	7.84	91.2	0	0.3	3.26	3.26	0	74.2857	55.17241	19.113301	13	yes	3
9/22/16	10	6.78	94.8	0	0.37	3.65	3.65	0	97.1429	63.63636	33.506494	13	yes	3
9/22/16	10	7.09	76.5	0	0.31	3.54	3.54	0	82.8571	54.73684	28.120301	13	yes	3

EXPLANATION OF WATER QUALITY DATA

A sampling period was defined as following a storm event if more than 0.25 inches of precipitation were recorded within the preceding 24 hours. Samples from March to May were defined as spring collections (season 1). Summer samples (season 2) were taken from June through August, and fall sampling (season 3) occurred from September through November. Zero DRP values were below the detection limit of 0.01 mg/L. Zero NOx results were below the detection limit of 0.06 mg/L.

Table A1.2: Water quality data collected at Stricker's Pond from November 20, 2015, to September 22, 2016.

OTHER WATER QUALITY PARAMETER RESULTS

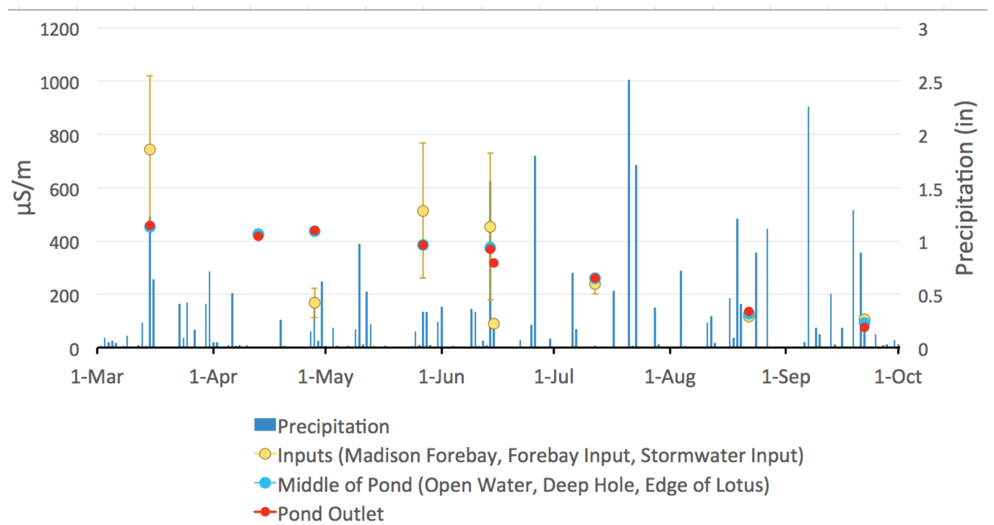


Figure A1.1: Average electric conductivity at Inputs, Middle of Pond, and Outlet of Stricker's Pond from March-September 2016. Bars represent standard error. Daily precipitation is also shown. EC measures potential electrical current and reflects the amount of dissolved cations (+) and anions (-) of minerals and chemicals in the water body (Marshall and Healy, 2014). In urban areas, salt runoff from roads is the greatest source of EC to water bodies. EC levels generally decreased throughout the season. Input locations exceeded output locations during certain periods of the year. No significant differences were found between clusters of sites when analyzed over the entire period. However, there were statistically significant differences between seasons. Differences were found between spring and summer, spring and fall, and summer and fall.

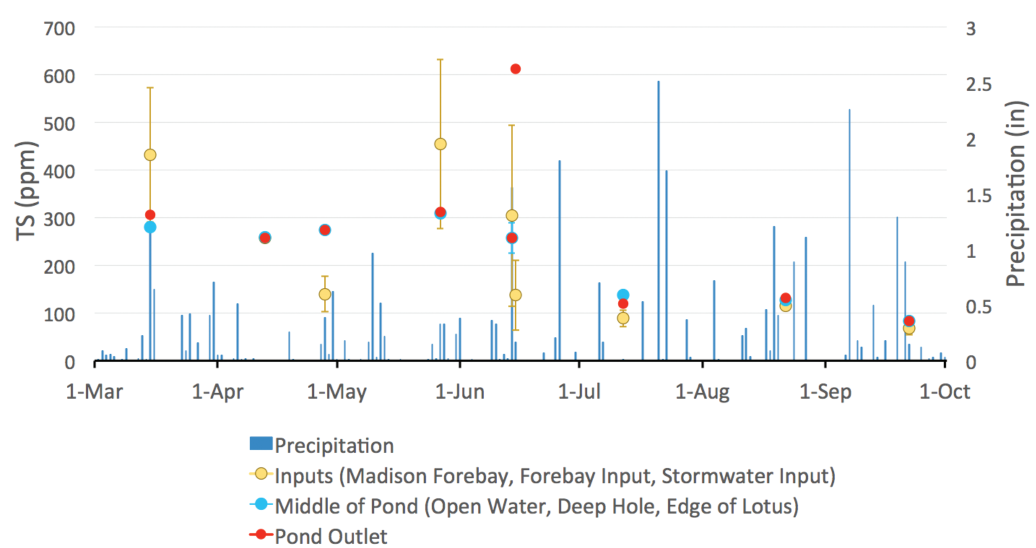


Figure A1.2: Total solids results from Inputs, Middle of Pond, and Outlet of Stricker's Pond from March – September 2016. Bars represent standard error. Daily precipitation is also shown. Total solids includes both total suspended solids and total dissolved solids. TS is associated with EC and turbidity (water clarity). Increased solids within a water body will decrease water clarity. Decreased water clarity can result in the reduction of submerged aquatic macrophyte populations due to lack of light penetration. Stricker's Pond TS levels were higher from spring to midsummer, and fall sampling events showed significantly lower amounts.. TS levels were consistently higher at the stormwater input on the Middleton side of the pond during the spring and summer seasons. TS entering the Stricker's Pond watershed is attributed to urban runoff comprised of debris from streets, residential neighborhoods, and construction projects. Reducing TS in Stricker's Pond would hopefully increase water clarity.

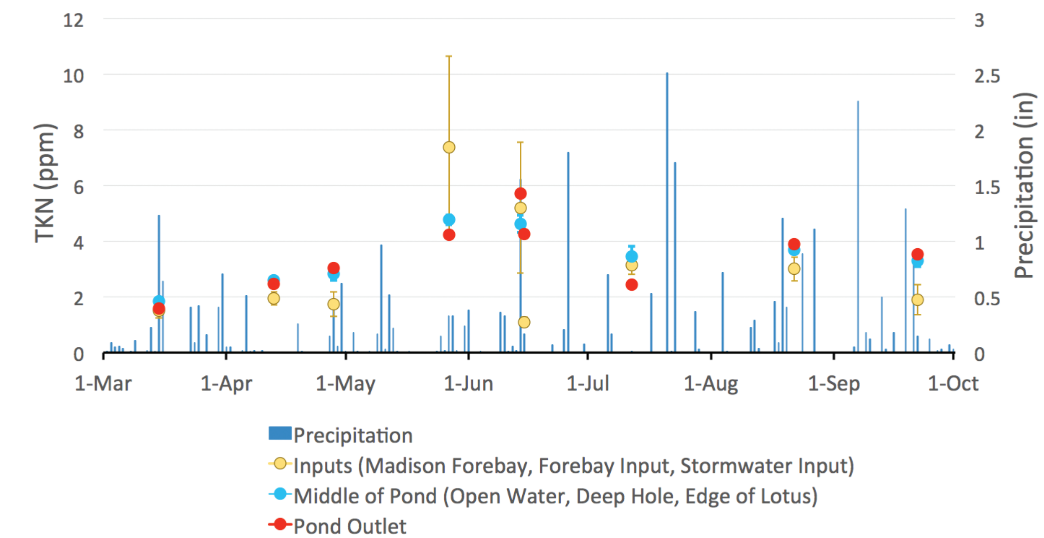


Figure A1.3: Average Total Kjeldahl nitrogen (TKN) at Inputs, Middle of Pond, and Outlet of Sticker's Pond from March – September 2016. Bars represent standard error. Daily precipitation is also shown. TKN includes the total concentration of organic nitrogen and ammonia. Mirroring the TN results, TKN showed increasing concentrations throughout spring and into early summer. The outlier described in TN is also reflected in the TKN results, with the highest TKN at the Stormwater Input site in May. The lowest concentrations were observed in March with Middle of the Pond and the Outlet sites having higher TKN thereafter.. The data, when grouped into seasons and clusters had interactive effects, so there were no significant differences detected.

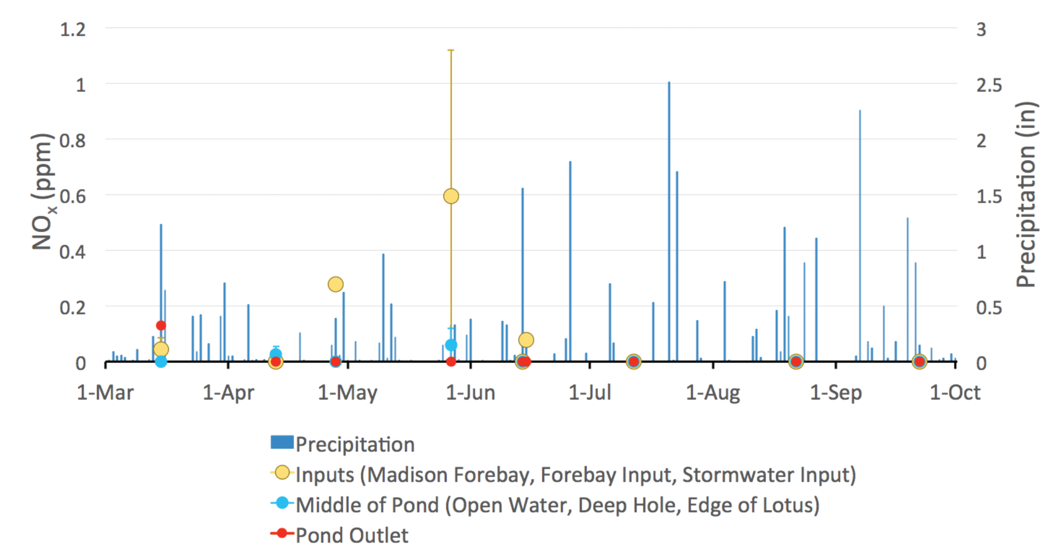
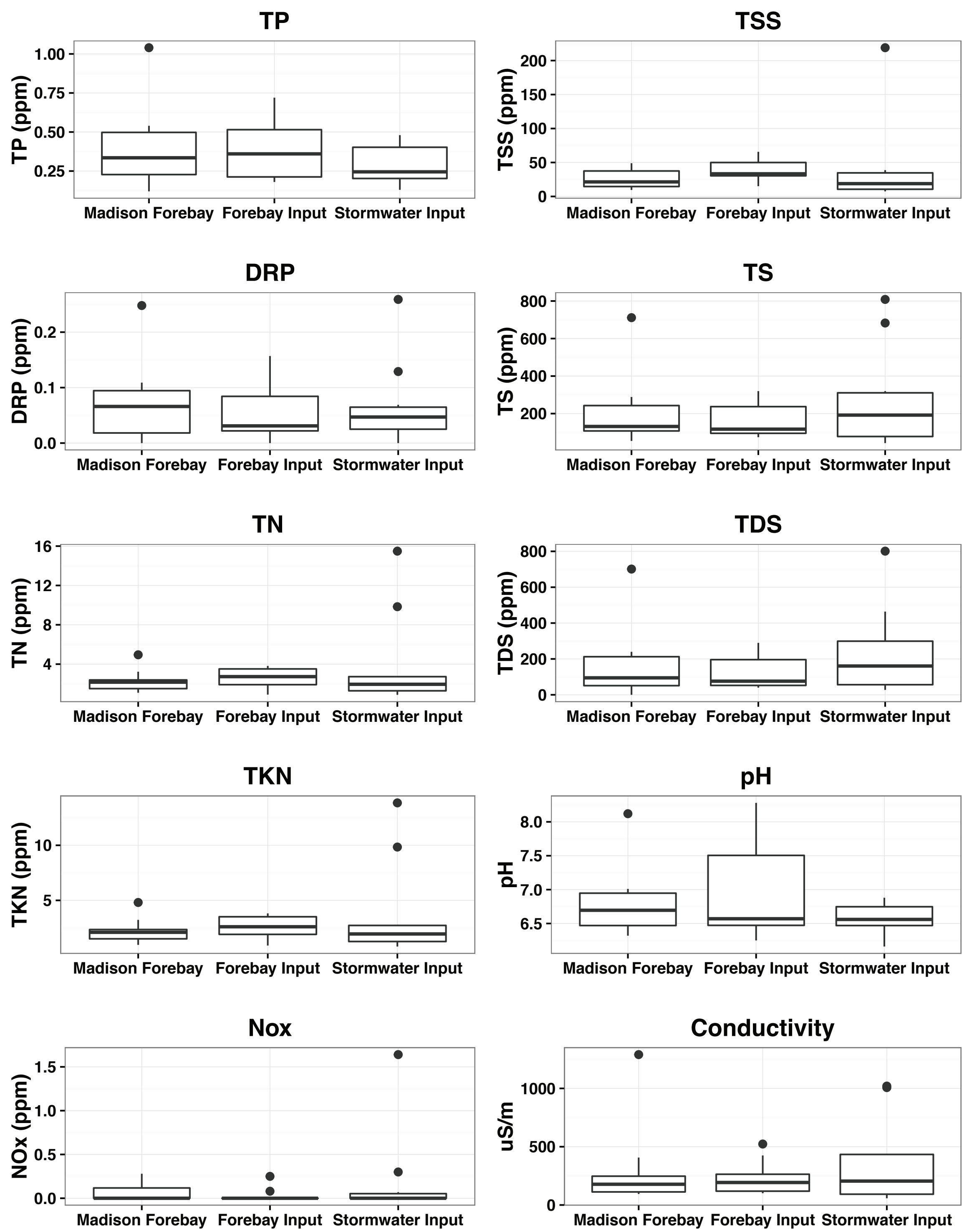


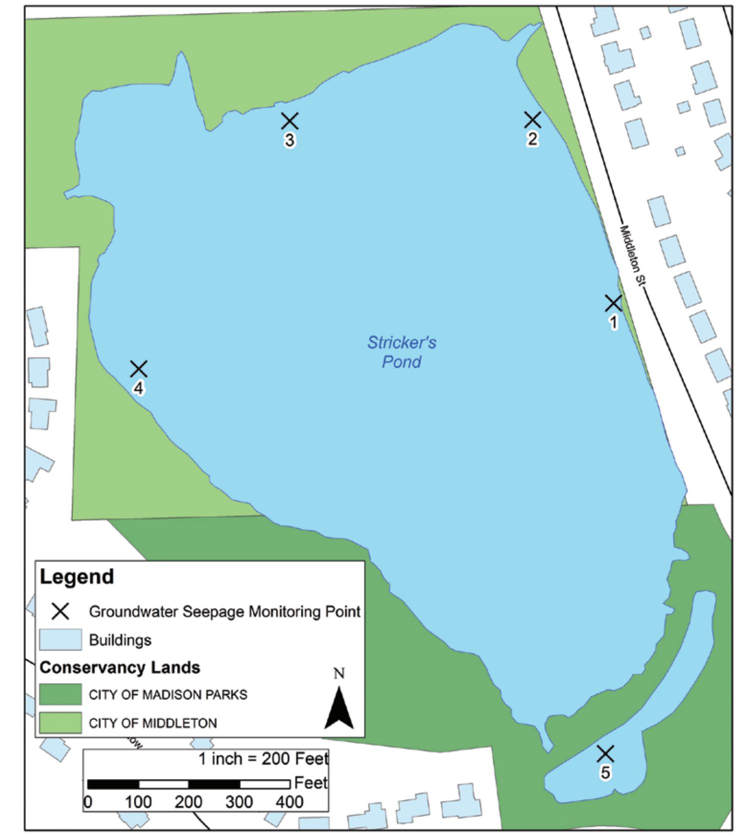
Figure A1.4: NOx results from Inputs, Middle of the Pond, and Outlet sites of Stricker's Pond from March – September 2016. Bars represent standard error. Daily precipitation is also shown. Points at zero were below the detection limit of 0.06 ppm. All samples from July, August, and September were below detection limits. The outlet only had detectable NOx during March sampling. NOx levels at the inputs were detectable more often. The outlier described in TN is also reflected in the NOx results The data, when grouped into seasons and clusters had interactive effects, so there were no significant differences detected. Interestingly, after multiple storm events (>1 inch of precipitation) the NOx concentrations remained below detection limits.



FigureA1.5: Comparison of water quality at Input sites of Stricker's Pond. Data from November 2015-September 2016. Center line represents median, box shows first and third quartiles, and dots show outliers.

Modeling

WATER BUDGET



Groundwater seepage measurement locations

Lamoreux (1962) method:

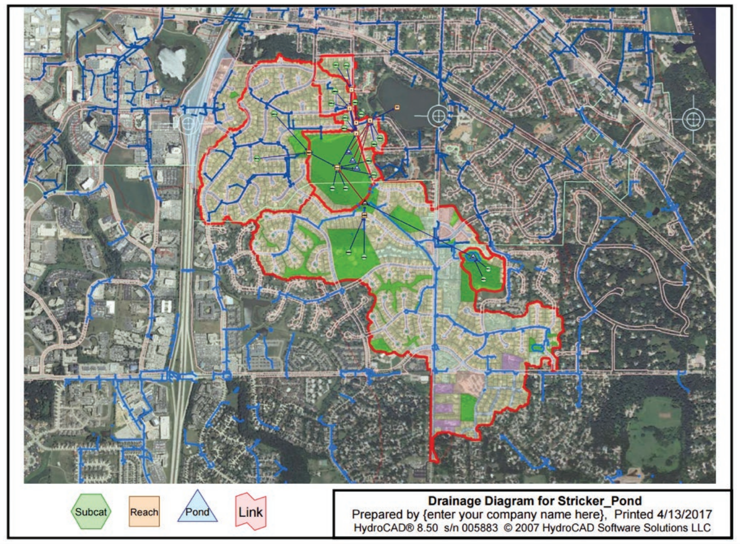
$$E_L = [\epsilon^{(T_a - 212)(0.1024 - 0.01066 \ln R)} - 0.0001 + 0.0105(e_s - e_a)^{0.88}(0.37 + 0.0041u_p] \times [0.04686(0.0041T_a + 0.676)^7 + 0.01497]^{-1}$$

E_L is estimated daily pond evaporation (in), T_a is average air temperature (°F), T_d is the dewpoint (°F), R is solar radiation (Langleys/day), e_s - e_a is the vapor pressure deficit (calculated as below) (in Hg), and u_p is average wind speed (miles/day).

$$e_s - e_a = (0.0041T_a + 0.676)^8 - (0.0041T_d + 0.676)^8 - 0.000019(T_a - T_d)$$

LAND USE STATISTICS FOR WATERSHED PER MUNICIPALITY (ACREAGE).

	Middleton	Madison
Residential	123.2	215.0
Commercial	6.9	7.2
Open	3.5	75.3
Paved	39.9	60.9
Sub-Total	173.5	358.4



Overview of original HydroCAD model

Close up of HydroCAD model.

RAIN SERIES	BMP	TOTAL PHOSPHROUS (LBS)		TOTAL SUSPENDED SOLIDS (LBS)	
		Madison	Middleton	Madison	Middleton
1981	Existing	311.5	169.4	79461	41072
	Permeable Pavement	199.5	107.1	37731	19897
	Regional Infiltration	156.1	169.6	34752	41080
	Distributed Rain Gardens (5%)	211.6	107.5	67229	32840
2016	Existing	328.2	179.6	81756	42533
	Permeable Pavement	308.5	142.8	39755	21220
	Regional Infiltration	156.4	179.8	35992	42541
	Distributed Rain Gardens (5%)	171.8	144.1	66949	32717
Rainfall Increase	Existing	816.4	456.8	165329	88686
	Permeable Pavement	646.1	363	107366	60627
	Regional Infiltration	616.7	457.2	113714	88695
	Distributed Rain Gardens (5%)	514.9	261.8	128388	62832
100-Year Event	Existing	156.2	88.8	31745	17583
	Permeable Pavement	122.9	70	19468	11188
	Regional Infiltration	150.7	88.8	30633	17582
	Distributed Rain Gardens (5%)	124.9	66.2	27909	14565

Table A2.1: TSS and TP loads entering Stricker's Pond for each rainfall time series and best management practice scenario.

	Water-shed	1001	1002	1003	2001	2002	2003	3001	3002	4000	4001
	Area (Acres)	7.1	1.4	7.6	2.8	3.3	12.6	133.3	17.1	351.6	13.7
Time Series											
1981											
TSS (lbs)		1701.8	335.2	1824.9	668.4	806.9	3008.5	30771.6	1969.5	79461.1	1103.3
TSS/Acre		238	237.9	238	238	238	238	230.8	115.1	226	80.2
TP (lbs)		6.9	1.3	7.4	2.7	3.2	12.2	125.9	9.7	311.4	6.1
TP/Acre		1	1	1	1	1	1	0.9	0.6	0.9	0.4
2016											
TSS (lbs)		1762.7	347.3	1890.4	692.4	835.8	3116.6	31870.2	2031.1	81756.4	1133.9
TSS/Acre		246.5	246.5	246.5	246.5	246.5	246.5	239	118.8	232.5	82.5
TP (lbs)		7.3	1.4	7.8	2.8	3.4	12.9	133.3	10.4	328.1	6.6
TP/Acre		1	1	1	1	1	1	1	0.6	0.9	0.5
Projected Rain Fall Increase											
TSS (lbs)		3690.4	727.1	3957.8	1449.6	1750.1	6524.6	66609.1	4005.9	160458.6	2141.4
TSS/Acre		516.1	516.1	516.1	516.1	516.1	516.1	499.5	234.2	456.4	155.7
TP (lbs)		18.5	3.6	19.8	7.2	8.7	32.7	337.9	27.8	816.4	17.9
TP/Acre		2.6	2.6	2.6	2.6	2.6	2.6	2.5	1.6	2.3	1.3
100-Year Storm											
TSS (lbs)		730.3	143.9	783.2	286.9	346.3	1291	13191.2	815.3	31744.7	444.1
TSS/Acre		102.1	102.1	102.1	102.1	102.1	102.1	98.9	47.7	90.3	32.3
TP (lbs)		3.5	0.7	3.8	1.4	1.7	6.3	65.6	5.5	156.1	3.6
TP/Acre		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.4	0.3

Table A2. 2: Total pollutant load that each subwatershed in the Stricker's Pond watershed contributes to the pond for existing watershed conditions. Each subwatershed has a pollutant load for total suspended solids (TSS/acre) and total phosphorus (TP/acre).

Aquatic Vegetation

AMERICAN LOTUS (*NELUMBO LUTEA*)

Physiology. Of particular interest to this watershed assessment is the American lotus (*Nelumbo Lutea*), a type of emergent aquatic macrophyte. It has completely rounded leaves with no slit or lobes, unlike other floating leaved species such as the white water lily (*Nymphaea odorata*) or spatterdock (*Nuphar variegata*), which are often mistaken for the N. lutea (Borman et al., 1997). The concave leaves can be 1-2 ½ feet in diameter and often rise above the surface of the water. The leaves can be positioned anywhere from ½ to 3 feet above the water (Hilty, 2016).

Reproduction. Large white to pale yellow flowers reaching nearly 10 inches in diameter bloom mid growing season for about 1 ½ months and rely on bees and flies for pollination. Once the flower is finished blooming, the receptacle of the flower which contains 10-12 seeds, turns brown in color and bends downwards towards the water to release the seeds. N. lutea is a perennial that utilizes a thick starchy root structure called a rhizome which is produced in late summer to early fall (Hilty, 2016Rhode Island Department of Environmental Management, 2010).

Distribution. *N. lutea* is native to eastern and central parts of North America and California (see distribution map from NRCS plants database). The species is protected in three states — Michigan (threatened), New Jersey (endangered), and Pennsylvania (endangered) —but is listed as a PIB (potentially invasive, banned) noxious weed by the State of Connecticut (NRCS, 2016). Waterbodies that have a mucky to sandy substrate are preferred. On a local level, N. lutea colonies have been known to display significant colonization. In a coastal wetland of Lake Eric, a colony of 2.84 hectares grew to be 19.24 hectares in 16 years (Whyte, 1997). Throughout the few *N. lutea* growth studies, some have highlighted the cyclical growth patterns which have been assumed to be the new rhizome growth and the recession of the expired rhizome; another theory is that the rhizome and seeds go dormant until preferred environmental conditions are met (Whyte, 1997; Henson, 1990). Whichever the case, *N. lutea* has the potential to grow to such a dense population that other native species become suppressed.

Terrestrial Vegetation

TERM DEFINITIONS

Term	Description	Calculation
Total species richness	Total number of native and non-native species.	
Total mean C	Mean conservatism coefficient for all native and non-native species.	
Transect-level cover-weighted mean C	The sum of each native and non-native species' conservatism coefficient multiplied by its mean cover divided by the sum of each species' mean cover.	
Total FQI	Floristic quality index: total mean C multiplied by the square root of the total species richness.	
Cover-weighted FQI	Cover-weighted total mean C multiplied by the square root of the total species richness.	
Relative frequency (%)	The frequency of this species or physiognomic group divided by the frequency of all species or physiognomic groups.	
Relative coverage (%)	The total coverage of this species or physiognomic group divided by the total coverage of all species or physiognomic groups.	
Relative importance value	The average of relative frequency and relative coverage.	

Table A4.1.1: Defined terminology from Universal FQA (Freyman et al., 2016a)

JUNE HERBACEOUS SURVEY

Figure A4.2.1: Vegetated areas at Stricker's Pond. June assessment surveyed V1, V2, V4, and V7.

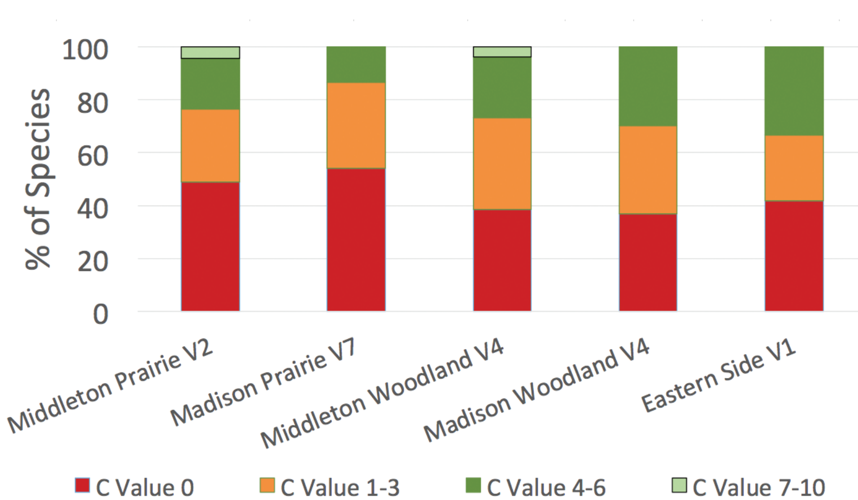


Figure A4.2.2: Percentage of June species observed in each conservation value category. Middleton prairie and woodland areas were the only plots with high conservation species (C value 7-10).

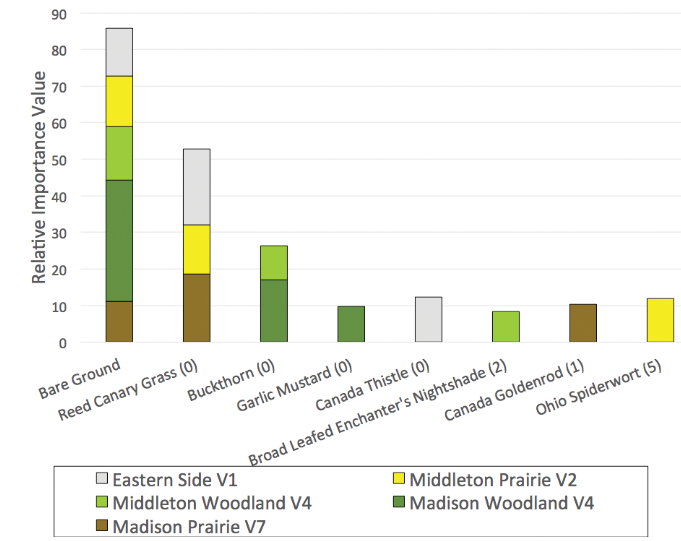
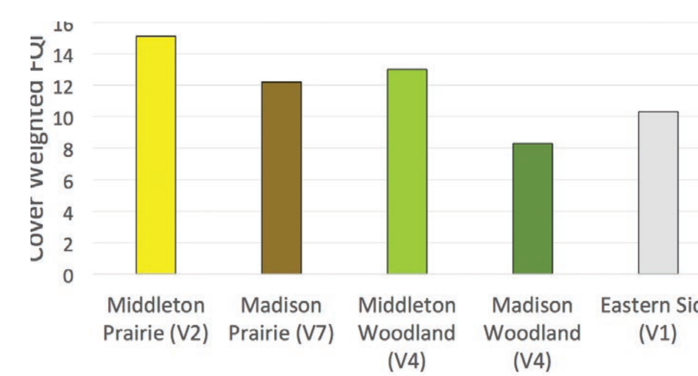


Figure A4.2.3: Relative importance values of June covers within each vegetated area. The three highest relative importance values within each plot are shown. Numbers in parentheses represent the cover's C value.



FigureA 4.2.4: June cover weighted FQI for vegetated areas adjacent to Stricker's Pond.

Vegetation species list

Scientific Name	Family	C	Common Name	Plot
Abutilon theophrasti	Malvaceae	0	Velvet-leaf	V3
Acalypha rhomboidea	Euphorbiaceae	0	Three-seeded Mercury	V4 Middleton
Acer negundo	Sapindaceae	0	Box Elder	V4 Madison, V4 Middleton
Achillea millefolium	Asteraceae	1	Common Yarrow	V2
Agastache scrophulariaefolia	Lamiaceae	4	Figwort Giant Hyssop	V2
Ageratina altissima	Asteraceae	1	White Snakeroot	V2, V4 Madison, V4 Middleton
Agrimonia gryposepala	Rosaceae	2	Common Agrimony	V4 Madison
Agrostis stolonifera	Poaceae	0	Creeping Bent Grass	V4 Middleton
Alliaria petiolata	Brassicaceae	0	Invasive Garlic Mustard	V2, V3, V4 Madison, V4 Middleton, V5, V7
Allium cernuum	Liliaceae	7	Nodding Wild Onion	V2
Ambrosia artemisiifolia	Asteraceae	0	Common Ragweed	V2, V5, V7
Ambrosia psilostachya	Asteraceae	2	Western Ragweed	V3, V4 Middleton
Ambrosia trifida	Asteraceae	0	Giant Ragweed	V2, V5
Andropogon gerardii	Poaceae	4	big blue-stem	V2, V7
Arctium minus	Asteraceae	0	Common Burdock	V2, V3, V4 Madison, V4 Middleton, V5, V7
Arisaema triphyllum	Araceae	5	Jack-in-the-pulpit	V4 Madison, V4 Middleton
Arnoglossum atriplicifolium	Asteraceae	4	Pale Indian-plantain	V2
Artemisia absinthium	Asteraceae	0	Absinth Wormwood	V2
Artemisia ludoviciana	Asteraceae	3	Louisiana Sage-wort	V2
Asclepias incarnata	Asclepiadaceae	5	Marsh Milkweed	V2, V3, V4 Madison, V4 Middleton, V5
Asclepias syriaca	Asclepiadaceae	1	Common Milkweed	V1, V2, V3, V5, V7
Asclepias tuberosa	Asclepiadaceae	6	Butterfly Milkweed	V2
Astragalus canadensis	Fabaceae	8	Canadian Milk-vetch	V2
Baptisia alba	Fabaceae	8	White Wild Indigo	V2, V7
Barbarea vulgaris	Brassicaceae	0	Yellow-rocket	V2, V5, V7
Berteroa incana	Brassicaceae	0	Hoary-alyssum	V1, V2, V5
Bidens frondosa	Asteraceae	1	Common Beggar-ticks	V4 Middleton
Boehmeria cylindrica	Urticaceae	6	Small-spike False Nettle	V2
Brassica nigra	Brassicaceae	0	Black Mustard	V5
Bromus inermis	Poaceae	0	Smooth Brome	V2, V5, V7
Campanulastrum americanum	Campanulaceae	4	American Bellflower	V4 Madison
Carduus acanthoides	Asteraceae	0	Spiny Plumeless Thistle	V2, V5, V7
Carduus nutans	Asteraceae	0	musk thistle	V2, V5
Carex brevior	Cyperaceae	3	Fescue Sedge	V7
Celtis occidentalis	Ulmaceae	4	Northern Hackberry	V4 Madison, V4 Middleton
Cephalanthus occidentalis	Rubiaceae	9	Buttonbush	V2
Chenopodium album	Chenopodiaceae	0	Common Lambs-quarters	V7
Cichorium intybus	**Asteraceae**	**0**	**Blue-sailors**	**V2, V7**
Circaea canadensis	Onagraceae	2	Broad-leaf Enchanters-nightshade	V2, V3, V4 Madison, V4 Middleton, V7
Cirsium arvense	Asteraceae	0	Canada Thistle	V1, V2, V3, V4 Middleton, V5, V7
Cirsium vulgare	Asteraceae	0	Bull Thistle	V4 Madison, V5, V7
Convolvulus arvensis	Convolvulaceae	0	Field Bindweed	V5
Cornus racemosa	Cornaceae	2	Gray Dogwood	V4 Middleton, V5
Dactylis glomerata	Poaceae	0	Orchard Grass	V5
Daucus carota	Apiaceae	0	Queen Annes-lace	V1, V2, V3, V4 Middleton, V5, V7
Desmodium canadense	Fabaceae	4	Showy Tick-trefoil	V7
Drymocallis arguta	Rosaceae	7	Prairie Cinquefoil	V2
Dryopteris carthusiana	Dryopteridaceae	7	Spinulose Wood Fern	V4 Madison
Echinacea purpurea	Asteraceae	0	Broad-leaved Purple Coneflower	V2, V7
Echinocystis lobata	Cucurbitaceae	2	Balsam-apple	V7
Elymus repens	Poaceae	0	Quackgrass	V5, V7
Eragrostis spectabilis	Poaceae	3	Purple Love Grass	V2
Erigeron annuus	Asteraceae	0	Annual Fleabane	V2, V3, V4 Middleton, V5, V7
Erigeron canadensis	Asteraceae	0	Canadian Horseweed	V2
Eryngium yuccifolium	Apiaceae	8	Rattlesnake-master	V2
Euphorbia corollata	Euphorbiaceae	4	Flowering Spurge	V2
Euphorbia esula	Euphorbiaceae	0	Invasive Leafy Spurge	V5, V7
Euthamia graminifolia	Asteraceae	4	Common Flat-topped Goldenrod	V2
Eutrochium maculatum	Asteraceae	4	Spotted Joe-pye-weed	V2
Eutrochium purpureum	Asteraceae	6	Purple joe-pye-weed	V3, V4 Middleton
Galium aparine	Rubiaceae	2	Annual Bedstraw	V3
Galium asprellum	Rubiaceae	7	Rough Bedstraw	V4 Middleton
Galium triflorum	Rubiaceae	5	Fragrant Bedstraw	V4 Madison, V4 Middleton
Geranium maculatum	Geraniaceae	4	Wild Geranium	V3, V4 Madison
Geum canadense	Rosaceae	2	White Avens	V4 Madison, V4 Middleton, V7
Glechoma hederacea	Lamiaceae	0	Creeping-charlie	V5
Hackelia virginiana	Boraginaceae	3	Virginia Stickseed	V3, V7
Helianthus grosseserratus	Asteraceae	2	Saw-tooth Sunflower	V2
Helianthus pauciflorus	Asteraceae	7	Few-leaved sunflower	V2
Helianthus strumosus	Asteraceae	4	Pale-leaved Woodland Sunflower	V2
Helianthus tuberosus	Asteraceae	2	Jerusalem-artichoke	V7
Heliopsis helianthoides	Asteraceae	5	False Sunflower	V1
Heracleum maximum	Apiaceae	3	American Cow-parsnip	V3

Hesperis matronalis	Brassicaceae	0	Dames Rocket	V3, V4 Middleton, V5
Hydrophyllum virginianum	Hydrophyllaceae	4	Johns-cabbage	V4 Middleton
Hypericum ascyron	Hypericaceae	6	Giant St. Johns-wort	V1, V2
Hypericum perforatum	Hypericaceae	0	Common St. Johns-wort	V5
Impatiens capensis	Balsaminaceae	2	Orange Jewelweed	V2, V3, V4 Madison, V4 Middleton
Ipomoea purpurea	Convolvulaceae	0	Common Morning-glory	V5
Juglans nigra	Juglandaceae	3	Black Walnut	V2
Lactuca serriola	Asteraceae	0	Compass-plant	V2, V3, V4 Middleton, V5, V7
Leonurus cardiaca	Lamiaceae	0	Motherwort	V3, V4 Madison, V4 Middleton, V5, V7
Lespedeza capitata	Fabaceae	5	Round-headed Bush-clover	V2
Liatris pycnostachya	Asteraceae	7	Prairie Blazing-star	V2
Linaria vulgaris	Scrophulariaceae	0	Butter-and-eggs	V2
Lonicera morrowii	Caprifoliaceae	0	Morrows Honeysuckle	V4 Madison, V4 Middleton, V7
Lotus corniculatus	Fabaceae	0	Birds-foot Trefoil	V2, V5, V7
Maianthemum racemosum	Liliaceae	5	Feathery False Solomons-seal	V4 Madison, V4 Middleton
Maianthemum stellatum	Liliaceae	5	Starry False Solomons-seal	V4 Madison
Malus coronaria	Rosaceae	5	American Crabapple	V1
Melilotus altissimus	Fabaceae	0	Tall Yellow Sweet-clover	V7
Melilotus officinalis	Fabaceae	0	Yellow Inasive Sweet-clover	V1
Mentha arvensis	Lamiaceae	3	Wild Mint	V7
Miscanthus saccariflorus	Poaceae	0	Amur Silver Grass	V2
Monarda didyma	Lamiaceae	0	Oswego-tea	V2
Monarda fistulosa	Lamiaceae	3	Wild Bergamot	V2, V3, V7
Morus alba	Moraceae	0	White Mulberry	V2
Nepeta cataria	Lamiaceae	0	Catnip	V2, V4 Middleton, V5
Oenothera biennis	Onagraceae	1	Common Evening-primrose	V1, V2, V3, V5, V7
Oenothera gaura	Onagraceae	2	Biennial Bee-blossom	V2
Oxalis stricta	Oxalidaceae	0	Common Yellow Wood-sorrel	V2, V4 Madison, V4 Middleton, V5, V7
Panicum virgatum	Poaceae	4	Switch Grass	V2, V7
Parthenocissus quinquefolia	Vitaceae	5	Virginia Creeper	V1, V2, V3, V4 Madison, V4 Middleton, V5, V7
Penstemon digitalis	Scrophulariaceae	0	Tall Beard-tongue	V1, V2, V3, V4 Middleton
Persicaria amphibia	Polygonaceae	5	Water Smartweed	V2
Persicaria maculosa	Polygonaceae	0	Ladys Thumb Smartweed	V2, V3, V5, V7
Persicaria pensylvanica	Polygonaceae	1	Pennsylvania Smartweed	V4 Middleton
Phalaris arundinacea	Poaceae	0	Reed Canary Grass	V1, V2, V3, V4 Madison, V4 Middleton, V5, V7
Phleum pratense	Poaceae	0	Timothy	V7
Physostegia virginiana	Lamiaceae	7	False Dragonhead	V2
Plantago lanceolata	Plantaginaceae	0	English Plantain	V5
Plantago major	Plantaginaceae	0	Broad-leaved Plantain	V5

Poa pratensis	Poaceae	0	Kentucky Bluegrass	V2, V5, V7
Polygonatum biflorum	Liliaceae	4	Giant Solomons-seal	V4 Middleton
Potentilla norvegica	Rosaceae	0	Rough Cinquefoil	V1, V2, V3,V7
Prunus virginiana	Rosaceae	3	Chokecherry	V4 Middleton
Pycnanthemum virginianum	Lamiaceae	6	Common Mountain Mint	V2
Quercus macrocarpa	Fagaceae	5	Bur Oak	V4 Middleton
Ratibida pinnata	Asteraceae	4	Globular Coneflower	V2, V7
Rhamnus cathartica	Rhamnaceae	0	Common Invasive Buckthorn	V4 Madison, V4 Middleton
Ribes cynosbati	Grossulariaceae	3	Eastern Prickly Gooseberry	V4 Madison
Ribes missouriense	Grossulariaceae	4	Missouri Gooseberry	V4 Madison, V4 Madison
Rosa multiflora	Rosaceae	0	Multiflora Invasive Rose	V4 Madison
Rubus occidentalis	Rosaceae	2	Black Raspberry	V1, V2, V3, V4 Madison, V4 Middleton
Rudbeckia hirta	Asteraceae	4	Black-eyed Susan	V1, V2, V5, V7
Rudbeckia laciniata	Asteraceae	6	Cut-leaved Coneflower	V2, V3
Rudbeckia subtomentosa	Asteraceae	7	Sweet Black-eyed Susan	V2, V4 Middleton
Rudbeckia triloba	Asteraceae	4	Brown-eyed Susan	V2
Rumex altissimus	Polygonaceae	2	Pale Dock	V5
Rumex crispus	Polygonaceae	0	Curly Dock	V2, V3, V5, V7
Sambucus nigra	Caprifoliaceae	3	American Elderberry	V2, V4 Madison, V4 Middleton, V5
Schizachyrium scoparium	Poaceae	4	Little Bluestem	V2
Schoenoplectus tabernaemontani	Cyperaceae	4	Soft-stem Bulrush	V5, V7
Securigera varia	Fabaceae	0	Invasive Crown-vetch	V5, V7
Senecio hieraciifolius	Asteraceae	2	American Burn-weed	V4 Middleton, V7
Setaria italica	Poaceae	0	Italian Foxtail	V7
Silene latifolia	Caryophyllaceae	0	White Campion	V2, V3, V5, V7
Silene stellata	Caryophyllaceae	7	Starry campion	V2
Silphium integrifolium	Asteraceae	6	Prairie Rosinweed	V2, V7
Silphium laciniatum	Asteraceae	8	Compass-plant	V2
Silphium perfoliatum	Asteraceae	4	Cup-plant	V1, V2, V3
Silphium terebinthinaceum	Asteraceae	7	Prairie-dock	V2, V7
Smilax lasioneura	Smilacaceae	4	Hairy Carrion-flower	V4 Madison
Solanum dulcamara	Solanaceae	0	Bittersweet Nightshade	V1, V2, V3, V4 Madison, V4 Middleton, V5, V7
Solanum ptychanthum	Solanaceae	1	Eastern Black Nightshade	V4 Middleton
Solidago altissima	Asteraceae	1	Tall Goldenrod	V4 Middleton
Solidago canadensis	Asteraceae	1	Canada Goldenrod	V1, V2, V3, V4 Middleton, V5, V7
Solidago gigantea	Asteraceae	3	Giant Goldenrod	V3
Solidago rigida	Asteraceae	5	Stiff-leaved Goldenrod	V2, V7
Solidago speciosa	Asteraceae	5	showy goldenrod	V2
Sonchus oleraceus	Asteraceae	0	Common Sow-thistle	V4 Middleton
Stachys palustris	**Lamiaceae**	**5**	**Marsh Hedge-nettle**	**V1**

Symphyotrichum lanceolatum	Asteraceae	4	White Panicle Aster	V4 Middleton
Symphyotrichum novae-angliae	Asteraceae	3	New England Aster	V2, V5, V7
Symphyotrichum pilosum	Asteraceae	1	Frost Aster	V2, V4 Madison, V4 Middleton
Taraxacum officinale	Asteraceae	0	Common Dandelion	V1, V2, V3, V4 Madison, V4 Middleton, V5, V7
Thalictrum dasycarpum	Ranunculaceae	4	Tall Meadow-rue	V3
Thlaspi arvense	Brassicaceae	0	Field Pennycress	V5
Tradescantia ohiensis	Commelinaceae	5	Ohio Spiderwort	V1, V2, V3
Tragopogon dubius	Asteraceae	0	Fistulous goats-beard	V5
Trifolium pratense	Fabaceae	0	Red Clover	V5
Trifolium repens	Fabaceae	0	White clover	V5
Typha angustifolia	Typhaceae	0	Narrow-leaved Cat-tail	V3
Typha latifolia	Typhaceae	1	Broad-leaved Cat-tail	V3, V5
Urtica dioica	Urticaceae	1	Stinging Nettle	V3, V5, V7
Verbascum thapsus	Scrophulariaceae	0	Common Mullein	V1, V2
Verbena hastata	Verbenaceae	3	Blue Vervain	V7
Verbena stricta	Verbenaceae	3	Hoary Vervain	V2
Verbena urticifolia	Verbenaceae	2	White Vervain	V2, V4 Middleton, V7
Vernonia fasciculata	Asteraceae	5	Common Ironweed	V2
Veronicastrum virginicum	Scrophulariaceae	6	Culvers Root	V2, V4 Middleton
Viburnum opulus	Caprifoliaceae	0	European Highbush-cranberry	V4 Madison, V4 Middleton
Viburnum recognitum	Caprifoliaceae	0	Southern Arrow-wood	V4 Madison
Viola sororia	Violaceae	3	Common Blue Violet	V1, V2, V4 Madison, V4 Middleton
Vitis riparia	Vitaceae	2	Riverbank Grape	V1, V2, V3, V4 Madison, V4 Middleton, V7

Table A4.3.1: Species observed at Stricker's Pond June-August 2016. List includes common names and coefficient of conservative values used in the Wisconsin-Northcentral-Northeast Region database from Universal FQA (Freyman et al., 2016).

Birds

SPECIES

Cackling Goose
Canada Goose
Wood Duck
Gadwall
Mallard
Blue-winged Teal
Northern Shoveler
Northern Pintail
Green-winged Teal
Canvasback
Redhead
Ring-necked Duck
Lesser Scaup
Bufflehead
Common Goldeneye
Hooded Merganser
Common Merganser
Red-breasted Merganser
Ruddy Duck
Wild Turkey
Common Loon
Pied-billed Grebe
Horned Grebe
Double-crested Cormorant
American White Pelican
American Bittern
Great Blue Heron
Great Egret
Green Heron
Black-crowned Night-Heron
Turkey Vulture
Osprey
Sharp-shinned Hawk
Cooper's Hawk
Bald Eagle
Broad-winged Hawk
Red-tailed Hawk
American Coot
Sandhill Crane

Killdeer
Dunlin
Least Sandpiper
Pectoral Sandpiper
Semipalmated Sandpiper
Spotted Sandpiper
Solitary Sandpiper
Greater Yellowlegs
Lesser Yellowlegs
Bonaparte's Gull
Ring-billed Gull
Herring Gull
Caspian Tern
Forster's Tern
Rock Pigeon
Mourning Dove
Great Horned Owl
Chimney Swift
Ruby-throated Hummingbird
Belted Kingfisher
Red-headed Woodpecker
Red-bellied Woodpecker
Yellow-bellied Sapsucker
Downy Woodpecker
Hairy Woodpecker
Downy/Hairy Woodpecker
Northern Flicker
Pileated Woodpecker
Olive-sided Flycatcher
Eastern Wood-Pewee
Willow Flycatcher
Eastern Phoebe
Great Crested Flycatcher
Eastern Kingbird
Yellow-throated Vireo
Blue-headed Vireo
Philadelphia Vireo
Warbling Vireo
Red-eyed Vireo

Blue Jay
American Crow
Northern Rough-winged Swallow
Purple Martin
Tree Swallow
Bank Swallow
Barn Swallow
Cliff Swallow
Black-capped Chickadee
Tufted Titmouse
Red-breasted Nuthatch
White-breasted Nuthatch
Brown Creeper
House Wren
Winter Wren
Sedge Wren
Marsh Wren
Blue-gray Gnatcatcher
Golden-crowned Kinglet
Ruby-crowned Kinglet
Eastern Bluebird
Veery
Gray-cheeked Thrush
Swainson's Thrush
Hermit Thrush
Wood Thrush
American Robin
Gray Catbird
Brown Thrasher
European Starling
Cedar Waxwing
Ovenbird
Northern Waterthrush
Golden-winged Warbler
Blue-winged Warbler
Black-and-white Warbler
Tennessee Warbler
Orange-crowned Warbler
Nashville Warbler

Mourning Warbler
Common Yellowthroat
American Redstart
Cape May Warbler
Northern Parula
Magnolia Warbler
Bay-breasted Warbler
Blackburnian Warbler
Yellow Warbler
Chestnut-sided Warbler
Blackpoll Warbler
Bay-breasted/Blackpoll Warbler
Palm Warbler
Pine Warbler
Yellow-rumped Warbler
Black-throated Green Warbler
Wilson's Warbler
American Tree Sparrow
Chipping Sparrow
Clay-colored Sparrow
Field Sparrow
Fox Sparrow
Dark-eyed Junco
White-crowned Sparrow
White-throated Sparrow
Song Sparrow
Swamp Sparrow
Eastern Towhee
Northern Cardinal
Rose-breasted Grosbeak
Indigo Bunting
Red-winged Blackbird
Rusty Blackbird
Common Grackle
Brown-headed Cowbird
Baltimore Oriole
House Finch
Purple Finch
Pine Siskin
American Goldfinch
House Sparrow

Table 5.0.0 All bird species seen at Stricker's Pond in 2016.

BIRD SPECIES OBSERVED

Canada Goose
Wood Duck
Mallard
Blue-winged Teal
Lesser Scaup
Bufflehead
Hooded Merganser
Red-breasted Merganser
Ruddy Duck
Pied-billed Grebe
Great Blue Heron
Green Heron
Sharp-shinned Hawk
Red-tailed Hawk
Killdeer
Spotted Sandpiper
Solitary Sandpiper
Bonaparte's Gull
Ring-billed Gull
Rock Pigeon
Mourning Dove
Belted Kingfisher
Red-bellied Woodpecker
Yellow-bellied Sapsucker
Downy Woodpecker
Hairy Woodpecker
Northern Flicker
Willow Flycatcher
Eastern Phoebe
Eastern Kingbird
Blue Jay
American Crow
Purple Martin
Tree Swallow
Barn Swallow
Black-capped Chickadee
Red-breasted Nuthatch
White-breasted Nuthatch
Brown Creeper
House Wren
Blue-gray Gnatcatcher
Golden-crowned Kinglet
Wood Thrush
American Robin
Gray Catbird
European Starling
Cedar Waxwing
Common Yellowthroat
American Redstart
American Tree Sparrow
Chipping Sparrow
Dark-eyed Junco
White-crowned Sparrow
Song Sparrow
Northern Cardinal
Red-winged Blackbird
Rusty Blackbird
Common Grackle
Brown-headed Cowbird
Baltimore Oriole
House Finch
Purple Finch
Pine Siskin
American Goldfinch
House Sparrow

Table 5.0.1 Birds observed by the WRM cohort during their 2016 field season.

STRICKERS POND OBSERVATION DATA SHEET

Date Day of Week Time

Location

Weather Sunny Cloudy Raining Other Temperature: F

Observer name:

Group #	Group size	Mode of Travel (W, B, J/R, Other)	On Path? (if applicable y/n)	Type of use (Rec or commuter)	# of dogs	On leash? (y/n)	Other activity	Notes/Observations

W=walk, B= Bike, J/R=jog/Run; O=other y = yes, n= no; Rec=recreationist, Com=commuter

Figure A6.1.1 Recreation resource user assessment:

TITLE OF THE STUDY: Proposal to Conduct Watershed Assessment of Stricker's Pond

PRINCIPAL INVESTIGATOR: Anita Thompson (phone: 608-262-0604) (email: amthompson2@wisc.edu)

STUDENT RESEARCHER: Water Resources Management 2016 Cohort (phone: 901-300-0853)

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about the Stricker's Pond watershed. Students from the University of Wisconsin- Madison Water Resources Management 2016 Cohort are conducting a survey regarding the recreational uses and water quality management strategies of this valuable local natural resource.

You have been asked to participate because your residence or business lies within the Stricker's Pond watershed. You may have also voluntarily taken action to access survey (actions include but are not limited to: emailing the research team, requesting information about this survey by word of mouth, or by responding to a flyer requesting participation in this survey).

The purpose of the research is to assess the health of Stricker's Pond and its watershed, to gain a better understanding of its usage patterns and to assess potential water quality management strategies.

This study will include all willing participants residing in the Stricker's Pond watershed. All research will be completed by the research participant on a computer or personal mobile device.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research you will be asked to complete an online survey on either a mobile device or computer. Completion of this online survey will take approximately 5-10 minutes.

ARE THERE ANY RISKS TO ME?

The main risks associated with taking part in this study is the possibility that an IP address may be traced to a specific individual's survey responses. Efforts will be taken to ensure the confidentiality of the participants.

ARE THERE ANY BENEFITS TO ME?

There are no direct benefits to participants.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

Neither your name nor any other identifiable information will be recorded.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

You may ask questions about the research at any time. If you have questions about the research, you should contact the Principal Investigator, Anita Thompson, at 608-262-0604. You may also call the Water Resources Management 2016 Cohort at 901-300-0853.

If you are not satisfied with the response of the research team, have more questions, or would like to speak with someone regarding your rights as a research participant, you should contact the Education and Social/Behavioral Science IRB Office at 608-263-2320.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study you may do so without penalty.

Proceeding to the survey indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research, and voluntarily consent to participate. You may print a copy of this form for your records.

DO VOLUNTARILY CONSENT TO PARTICIPATE IN THIS RESEARCH?

1. Yes
2. No (Note that if a respondent answer's "no" the survey will automatically skip to end/exit survey page)

HAVE YOU EVER VISITED STRICKER'S POND?

1. Yes
2. No (Note selecting "no" will forced participants to skip to end/exit the survey)

HOW FREQUENTLY DO YOU VISIT STRICKER'S POND? PLEASE PROVIDE US WITH AN ESTIMATE.

1. I have never been to Stricker's Pond (Note selecting "no" will forced participants to skip to end/exit the survey)
2. Once per year
3. 2-10 times per year
4. 11-20 times per year
5. 21+ times per year

WHAT DO YOU ENJOY DOING WHEN YOU VISIT STRICKER'S POND? SELECT ALL THAT APPLY.

1. Walk, jog, or run
2. View wildlife
3. Bike
4. Sit and enjoy nature
5. Walk my dog
6. Other (please explain)

OVERALL, HOW WOULD YOU RATE THE QUALITY OF THE WATER IN STRICKER'S POND?

1. Poor
2. Okay
3. Good
4. I do not know

IN YOUR OPINION, WHICH OF THE FOLLOWING ARE WATER POLLUTION PROBLEMS IN STRICKER'S POND? SELECT ALL THAT APPLY.

1. Dirt and soil
2. Nutrients from fertilizers
3. Phosphorous
4. Bacteria and viruses (such as E. coli)
5. Street salt or sand
6. Toxic materials (such as PCBs)
7. Not enough oxygen
8. Invasive aquatic plants and animals
9. Cloudiness of the water
10. Oil or antifreeze from cars and trucks
11. Trash and debris
12. Organic matter (such as fallen trees, branches, grass clippings)
13. Other (please explain)

IN YOUR OPINION, WHICH OF THE FOLLOWING ARE SOURCES OF POLLUTION TO STRICKER'S POND? SELECT ALL THAT APPLY.

1. Discharges from industry
2. Discharges from sewage treatment plants or storm sewers
3. Soil erosion from construction sites
4. Lawn fertilizers and pesticides
5. Grass clippings and leaves
6. Households wastes (cleaning chemicals, cooking oils, etc.)
7. Improper disposal of used motor oil or antifreeze
8. Street salt or sand
9. Runoff from streets, highways, and/or parking lots
10. Droppings from geese, ducks, and other waterfowl
11. Pet waste
12. Land development or redevelopment
13. Large turf-grass areas (such as golf courses and sports fields)
14. Other (please explain)

WHICH OF THE FOLLOWING STORMWATER MANAGEMENT PRACTICES HAVE YOU HEARD OF BEFORE TAKING THIS SURVEY? SELECT ALL THAT APPLY.

1. Rain barrels
2. Rain gardens
3. Direct downspouts away from paved surfaces
4. Bioswales
5. Infiltration basins
6. Other (please explain)

DO YOU CURRENTLY USE ANY OF THE FOLLOWING STORMWATER MANAGEMENT PRACTICES IN YOUR OWN YARD? SELECT ALL THAT APPLY.

1. Rain barrels
2. Rain gardens
3. Direct downspouts away from paved surfaces
4. Bioswales
5. Infiltration basins
6. Other (please explain)

WOULD YOU BE INTERESTED IN LEARNING MORE ABOUT ANY OF THE FOLLOWING STORMWATER MANAGEMENT PRACTICES? SELECT ALL THAT APPLY.

1. Rain barrels
2. Rain gardens
3. Direct downspouts away from paved surfaces
4. Bioswales
5. Infiltration basins
6. Other (please explain)

WOULD YOU BE INTERESTED IN USING ANY OF THE FOLLOWING STORMWATER MANAGEMENT PRACTICES IN YOUR OWN YARD? SELECT ALL THAT APPLY.

1. Rain barrels
2. Rain gardens
3. Direct downspouts away from paved surfaces
4. Bioswales
5. Infiltration basins
6. Other (please explain)

WHICH OF THE FOLLOWING HAVE THE BIGGEST IMPACT ON YOUR DECISION TO IMPLEMENT STORMWATER MANAGEMENT PRACTICES IN YOUR OWN YARD? SELECT ALL THAT APPLY.

1. Cost
2. My own views about effective stormwater management
3. How easily a new practices fits with my current practices
4. My own physical abilities
5. The need to learn new skills or techniques
6. Legal restrictions on my property
7. Not having access to the equipment that I need
8. Lack of available information about a practice
9. Approval of my neighbors and homeowner's association
10. Environmental damage caused by the practices
11. I do not own the property
12. Concerns about resale value
13. I do not know where to get information and/or assistance
14. Other (please explain)

DO YOU CURRENTLY USE ANY OF THE FOLLOWING LAWN CARE PRACTICES IN YOUR OWN YARD? SELECT ALL THAT APPLY.

1. Apply pesticides and herbicides at manufacturer's guidelines for your lawn or garden
2. Avoid applying pesticides, herbicides, and fertilizers
3. Use phosphate free fertilizer
4. Manage grass clippings, leaves and brush
5. Other (please explain)

WOULD YOU BE INTERESTED IN LEARNING MORE ABOUT ANY OF THE FOLLOWING LAWN CARE PRACTICES? SELECT ALL THAT APPLY.

1. Apply pesticides and herbicides at manufacturer's guidelines for your lawn or garden
2. Avoid applying pesticides, herbicides, and fertilizers
3. Use phosphate free fertilizer
4. Manage grass clippings, leaves and brush
5. Other (please explain)

WOULD YOU BE INTERESTED IN USING ANY OF THE FOLLOWING LAWN CARE PRACTICES IN YOUR OWN YARD? SELECT ALL THAT APPLY.

1. Apply pesticides and herbicides at manufacturer's guidelines for your lawn or garden
2. Avoid applying pesticides, herbicides, and fertilizers
3. Use phosphate free fertilizer
4. Manage grass clippings, leaves and brush
5. Other (please explain)

WHICH OF THE FOLLOWING HAVE THE BIGGEST IMPACT ON YOUR OWN LAWN CARE PRACTICES? SELECT ALL THAT APPLY.

1. Cost
2. My own views about effective lawn and yard maintenance
3. How easily a new practices fits with my current practices
4. My own physical abilities
5. The need to learn new skills or techniques
6. Legal restrictions on my property
7. Not having access to the equipment that I need
8. Lack of available information about a practice
9. Approval of my neighbors and homeowner's association
10. Environmental damage caused by the practices
11. I do not own the property
12. Concerns about resale value
13. I do not know where to get information and/or assistance
14. Other (please explain)

IN THE FALL, WHAT DO YOU DO WITH LEAVES THAT FALL INTO YOUR YARD?

1. Place on the edge of my lawn for collection
2. Place in the street for collection
3. Place in a waste bag for collection
4. Mulch using a lawn mower
5. I do not do anything with the leaves that fall into my yard
6. Other (please explain)

WHAT WOULD YOU LIKE TO SEE HAPPENING AT STRICKER'S POND IN THE NEXT FIVE YEARS? PLEASE EXPLAIN YOUR IDEAS TO US BRIEFLY IN 2-3 SENTENCES.

Open ended

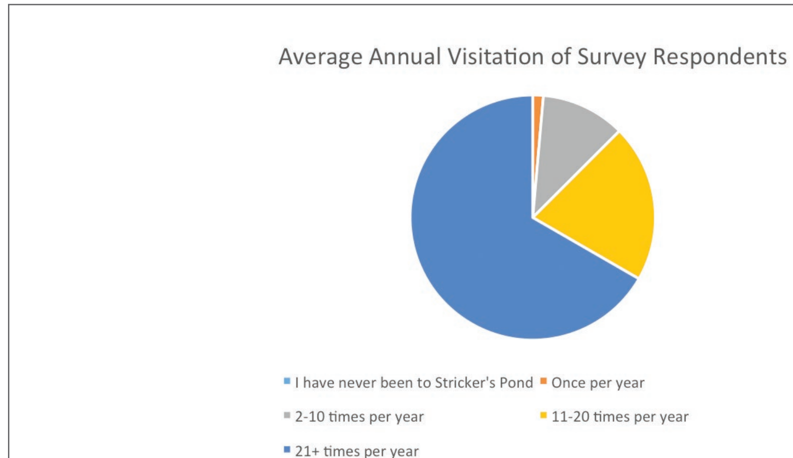
WHAT ARE YOUR BIGGEST CONCERNS ABOUT STRICKER'S POND? PLEASE EXPLAIN YOUR CONCERNS TO US BRIEFLY IN 2-3 SENTENCES.

Open ended

End Survey.

End of Survey Message (posted on last page after survey data has been submitted):
We thank you for your time spent taking this survey. Your responses have been recorded. If you have any questions, comments, or concerns please contact the Water Resources Management 2016 Cohort at wrm2015@nelson.wisc.edu.

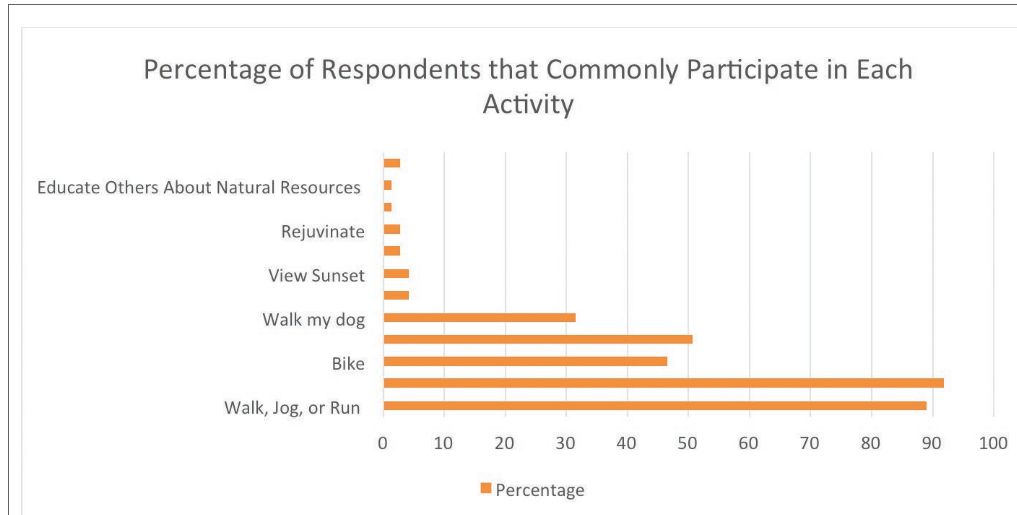
Figure A6.2.1 Water resources management resident survey:



Question 3: How frequently do you visit Stricker's Pond?

Response rate: 94.8%

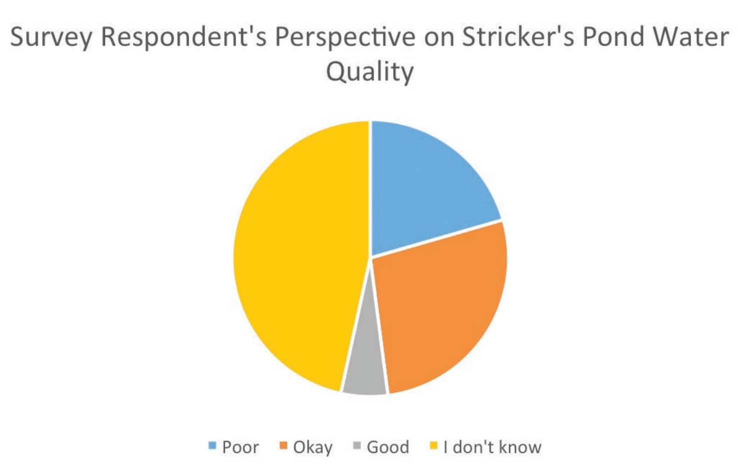
Figure A6.3.1 Water Resources Management resident survey results:



Question 4: What do you enjoy doing when you visit Stricker's Pond? Select all that apply.

Response rate: 94.8%

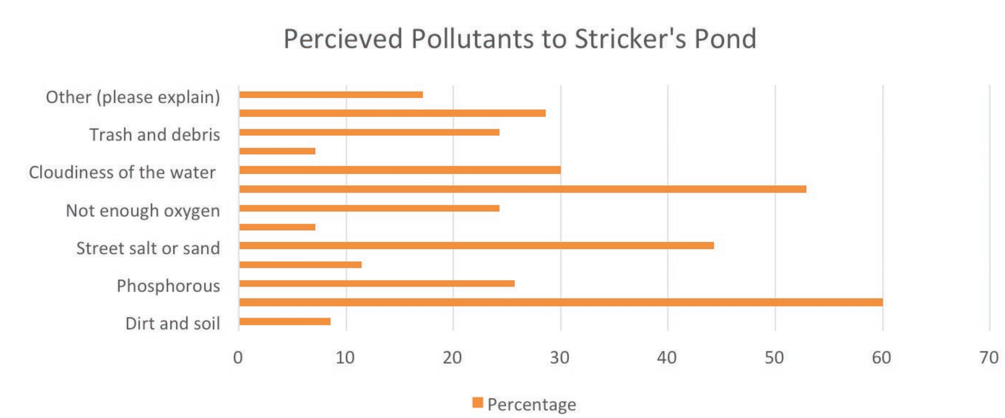
Figure A6.3.2



Question 5: Overall, how would you rate the quality of the water in Stricker's Pond?

Response rate: 90.9%

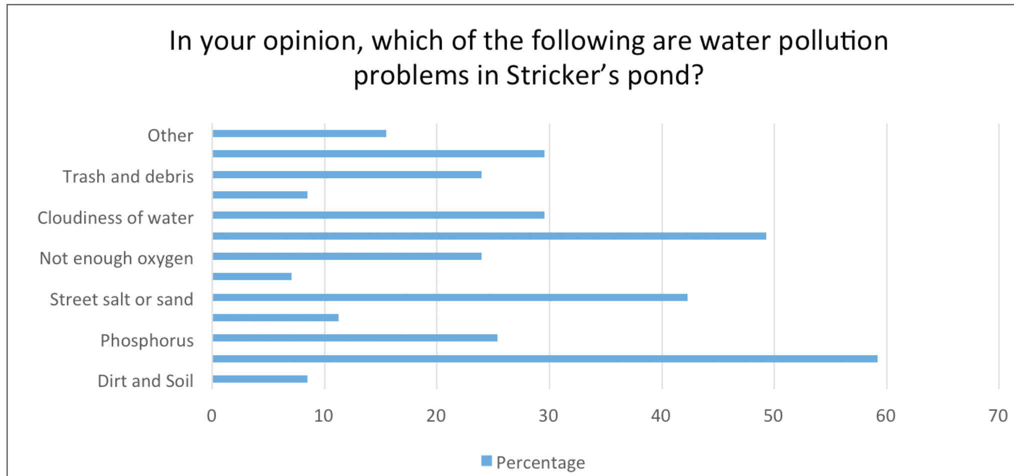
Figure A6.3.3



Question 6: In your opinion, which of the following are water pollution problems in Stricker's Pond? Select all that apply.

Response Rate: 92.2%

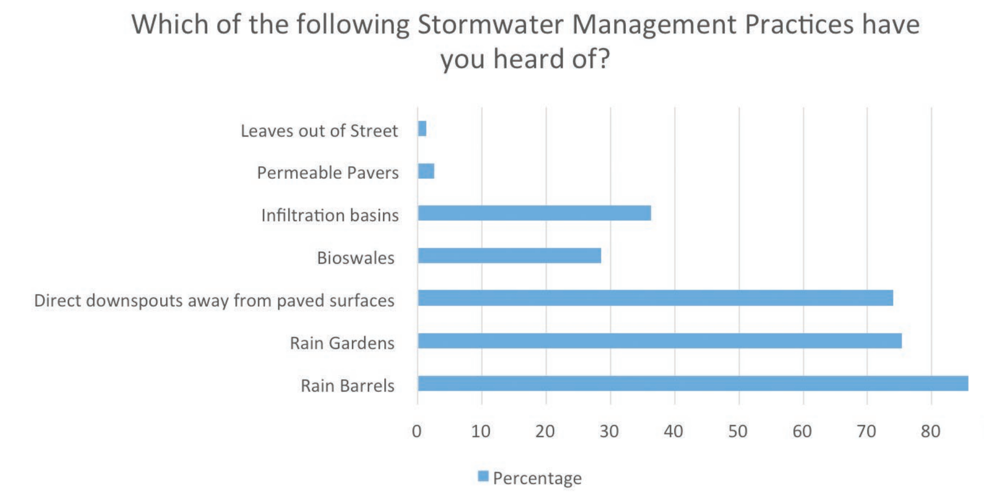
Figure A6.3.4



Question 7: In your opinion, which of the following are sources of pollution to Stricker's Pond? Select all that apply.

Response rate: 90.9%

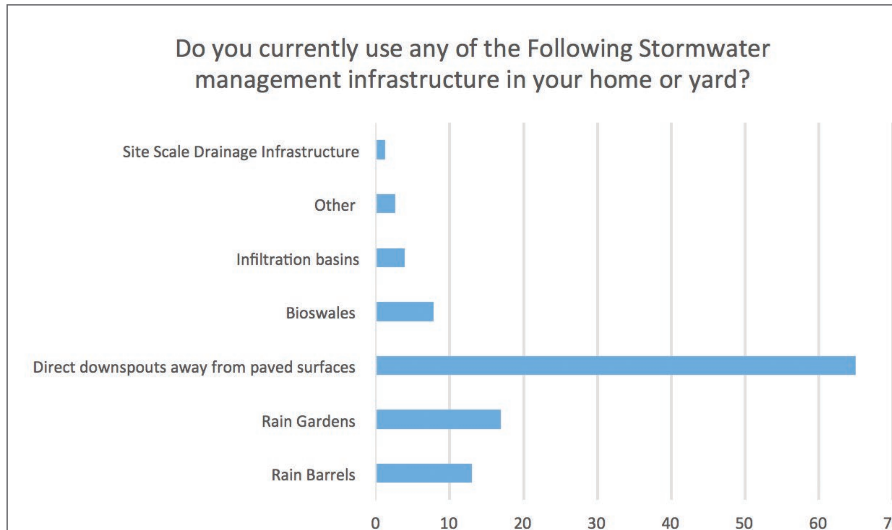
Figure A6.3.5



Question 8: Which of the following stormwater management practices have you heard of before taking this survey? Select all that apply.

Response rate: 92.2%

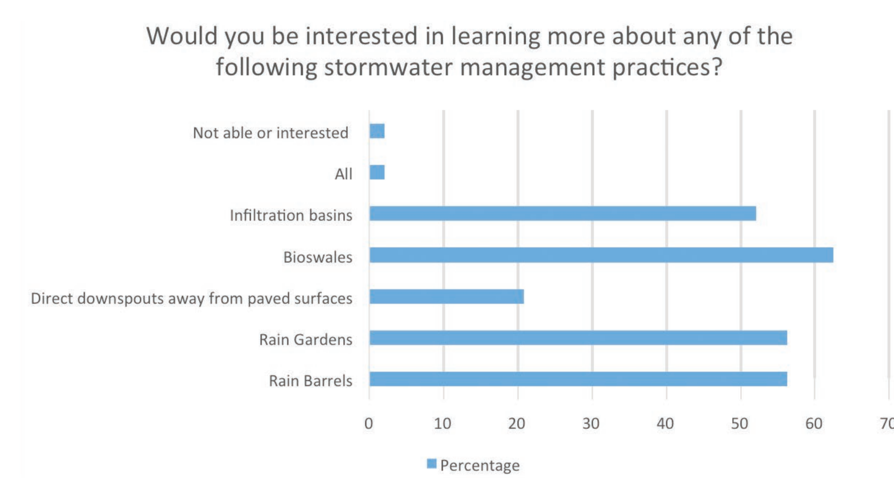
Figure A6.3.6



Question 9: Do you currently use any of the following stormwater management practices in your own yard? Select all that apply.

Response rate: 69.7%

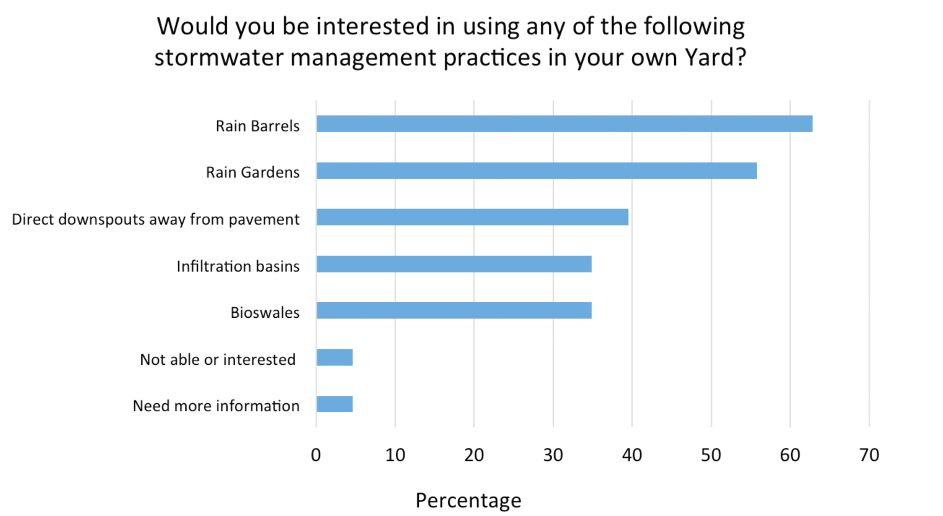
Figure A6.3.7



Question 10: Would you be interested in learning more about any of the following stormwater management practices? Select all that apply.

Response rate: 62.3%

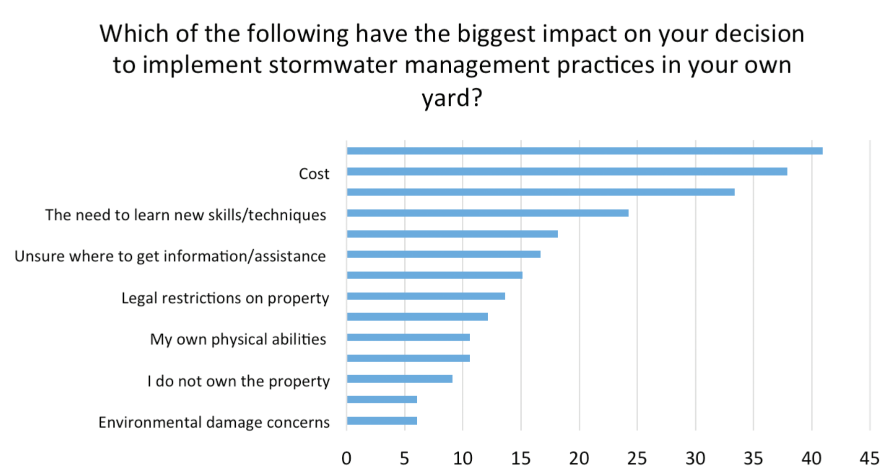
Figure A6.3.8



Question 11: Would you be interested in using any of the following stormwater management practices in your own yard? Select all that apply.

Response rate: 55.8%

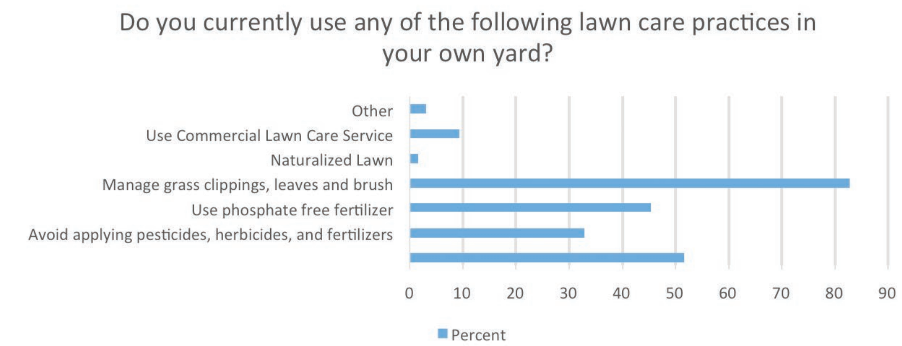
Figure A6.3.9



Question 12: Which of the following have the biggest impact on your decision to implement stormwater management practices in your own yard? Select all that apply.

Response rate: 85.7%

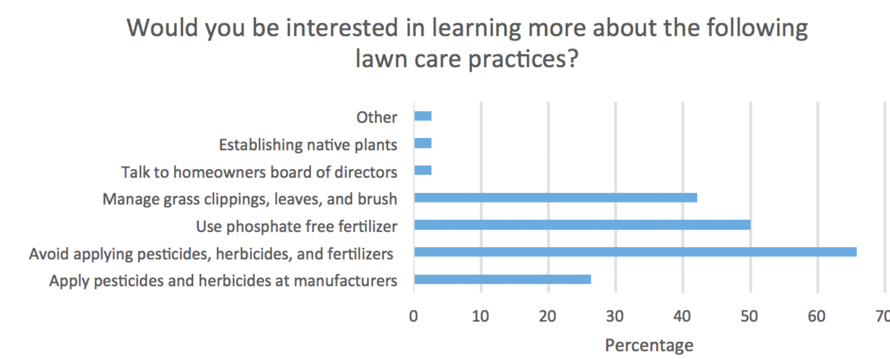
Figure A6.3.10



Question 13: Do you currently use any of the following lawn care practices in your own yard? Select all that apply.

Response rate: 83.1%

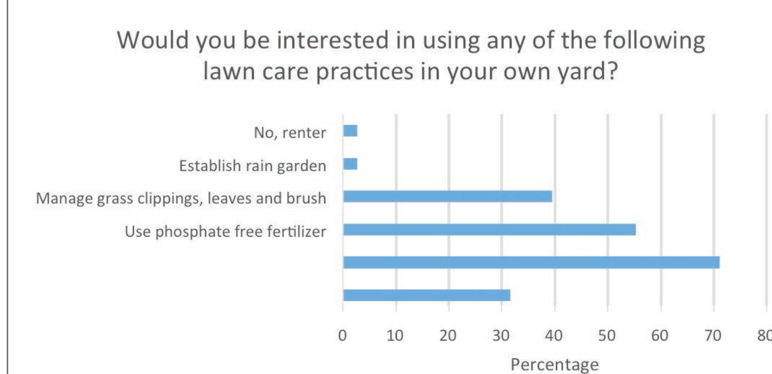
Figure A6.3.11



Question 14: Would you be interested in learning more about the following lawn care practices? Select all that apply.

Response rate: 49.3%

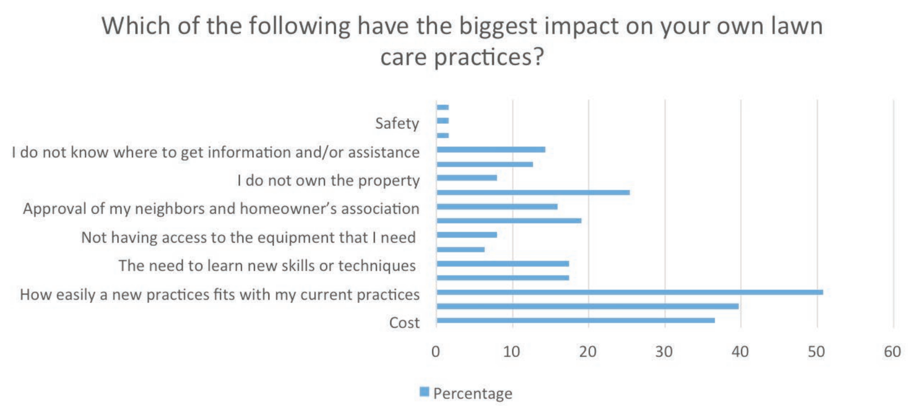
Figure A6.3.12



Question 15: Would you be interested in using any of the following lawn care practices in your own yard? Select all that apply.

Response rate: 49.3%

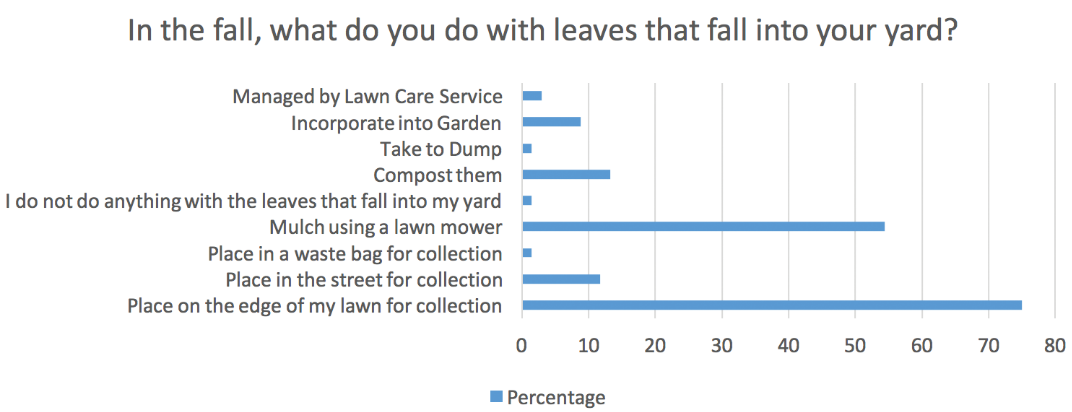
Figure A6.3.13



Question 16: Which of the following have the biggest impact on your own lawn care practices? Select all that apply.

Response rate: 81.8%

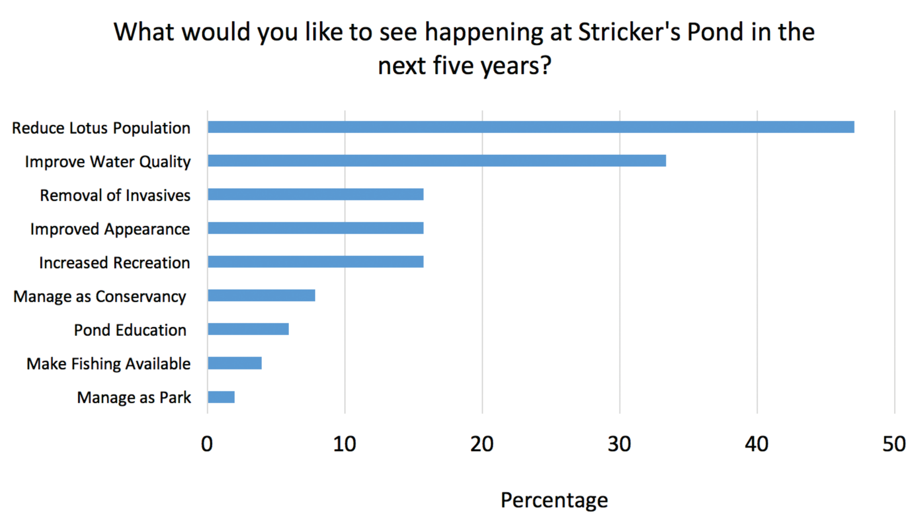
Figure A6.3.14



Question 17: In the fall, what do you do with leaves that fall into your yard?

Response rate: 88.3%

Figure A6.3.15



Question 18: What would you like to see happening at Stricker's Pond in the next five years? Please explain briefly.

Response rate: 66.2%

Figure A6.3.16

Oral history documents:

Figure A6.4.1 Map of Middleton from 1861, provided by a Middleton resident.


Serving the Good Neighbor City Since 1893

THURSDAY, OCTOBER 23, 2003 SINGLE COPY PRICE: $1.00

Middleton by air

Photo submitted by Van Nutt

The aerial photgraph, taken a few weeks ago, shows Middleton from a southern approach. Westfield Road is in the foreground, with Stricker and Tiedeman ponds further northeast.

For more aerial photographs, please turn to pages 6 and 7.

Figure A6.4.2 Aerial photo of Middleton from 2003. Newspaper article provided by a Middleton resident.

Figure A6.4.3 Photo of a sandhill crane with a young colt. Photo provided by Middleton resident.

Photo of good leaf management: piling leaves on curb in windrows.

Photo of fair leaf management: haphazard piles on curb.

Photo of poor leaf management: Piles in street or driveways, or not collected.

Figure A7.1. Leaf Management Survey

Nelson Institute for
Environmental Studies
UNIVERSITY OF WISCONSIN–MADISON