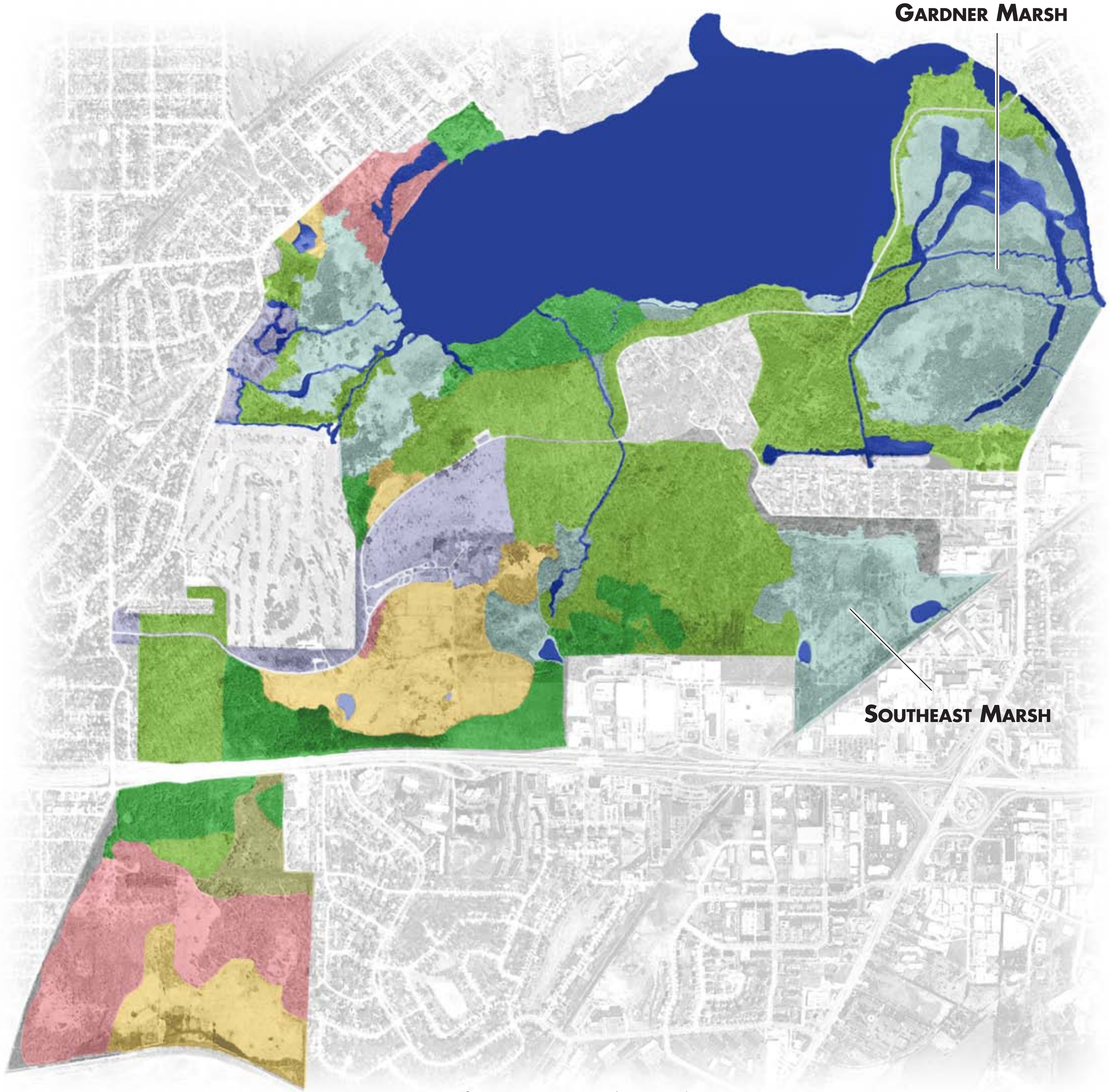
Restoration of the Arboretum's Eastern Wetlands



University of Wisconsin–Madison Arboretum

Restoration of the Arboretum's Eastern Wetlands

PREFACE

The Water Resources Management (WRM) Program is a graduate program leading to a Master of Science degree from the Gaylord Nelson Institute for Environmental Studies at the University of Wisconsin–Madison. WRM students approach water resources management from an interdisciplinary perspective, balancing biological and physical sciences with social and political issues. As part of the program of study, WRM students complete a practicum designed to give the students applied experience. The purpose of the practicum is to provide students with the opportunity to tackle an issue outside of their academic program and apply an interdisciplinary approach to a complex water resources problem. Graduate students spend the spring planning fieldwork and research that is executed over the summer and fall.

Authors (alphabetical order)
Josh Brown
Elizabeth Finlay
Matthew Krueger
Molli MacDonald
Emily Sievers
Amy Singler
Marisa K. Trapp

Faculty Advisor and Editor
Joy B. Zedler

Summer Supervisor
Michael T. Healy

The 2007 WRM Practicum was supported in part by the
University of Wisconsin–Madison Arboretum.

Inquires regarding this publication can be directed to:
Chair, Water Resources Management Program
70 Science Hall
550 North Park Street
Madison, WI 53706

This report is also available online from both the University of Wisconsin
Arboretum and the Nelson Institute for Environmental Studies.
http://uwarboretum.org/research
http://www.nelson.wisc.edu/wrm/workshops/2007/arb

Please cite this report as:
WRM. 2008.
Report from the 2007 Water Resources Management Practicum.
University of Wisconsin–Madison Arboretum, Madison, WI.

Acknowledgements

We would like to thank our advisor Joy Zedler for her guidance, review and editing throughout the entire project, Mike Healy for his summer field training and report review, and Kandis Elliot for her invaluable layout assistance and editing.

There were times we would have been lost without the invaluable technical advice and review from the following people: Dick Lathrop, Erica Schmitz, David Liebl, Ken Potter, John Panuska, Quentin Carpenter, Cynthia Stiles, Ed Dunkinson, Cami Peterson, Bernard Michaud, Ted Cochrane, Kurt Welke, Wendy Woyczik and Tom McClintock.

We appreciated the time and insight of the Arboretum Adaptive Restoration Task Force for their comments and review throughout the process: Brad Herrick, Steve Glass, Mike Healy, Paul Zedler, Joy Zedler and Kevin McSweeney.

We thank the staff at the Arboretum for their assistance with everything from keys to library books and database information, and Arboretum Director Kevin McSweeney for his leadership and advice throughout this process.

For assistance with our survey we thank Sheri Carter, President of the Arbor Hills Neighborhood Association, for her involvement and endorsement in the survey. Also to Brett Shaw, Assistant Professor, Life Science and Communication, for assistance evaluating the survey data.

Finally, we thank our family and friends for their support and occasional fieldwork assistance throughout this process.

We hope that this report will serve as a useful tool in the ongoing work to restore the wetlands at the University of Wisconsin–Arboretum.

Thank you
Water Resources Management Practicum, 2007–Arboretum

Watershed view.

Executive Summary

The Eastern Wetlands of the University of Wisconsin–Madison Arboretum (Southeast Marsh and Gardner Marsh) cover areas of approximately 75 acres (30.4 hectares) and 150 acres (60.1 hectares), respectively. The wetlands today bear the scars of 150 years of manipulation and impacts of being located in an urban environment. Asked by the Arboretum to address the problems facing Southeast and Gardner Marshes, the 2007 Water Resource Management (WRM) Practicum identified significant problems, including poor stormwater quality, high stormwater quantity, and invasive species.

This WRM Report provides a history of human activities in the marshes, a description of the current ecological conditions, and a detailed vegetation map of these areas as of 2007. Through fieldwork and information gathering on soil, water quality, vegetation and stormwater, we developed two alternative plans for wetland restoration based on options for handling stormwater and restoration methods. The plans include on-site experimentation within an adaptive restoration framework, which is consistent with the mission of conserving Arboretum lands, advancing restoration ecology, and fostering the land ethic.

In pre-settlement times, Southeast and Gardner Marshes were one continuous wetland on the eastern shores of Lake Wingra. The marshes were cut off from the lake and each other in the early 20th century with the development of the Carver-Martin Street neighborhood. During the succeeding century, the marshes were ditched, filled, dredged and overwhelmed with urban runoff, as development expanded in and around them. Presently, Southeast and Gardner Marshes are connected only by a narrow culvert underneath the neighborhood.

Present-day Problems and Considerations

As the City of Madison and the surrounding towns developed, changes in land use and land cover significantly increased runoff. The Arboretum wetlands occur low in the watershed and thus collect water from the surrounding communities. To deal with the high volume of water, sediment, and accompanying contaminants from the watershed, Ponds 3 and 4 were built to collect stormwater entering Southeast Marsh. Both ponds are inadequate. Pond 3 is filled with sediment and two outlet structures have failed. The outlet from Pond 4 eroded in the late 1990s so that no water is retained or treated. Thus, runoff enters the Arboretum at high velocity, carrying excessive nutrients, metals and sediment. Structures built in Gardner Marsh for water level control and research are in disrepair. The CCC Dam that separates the marsh from Wingra Creek is deteriorating—the berm surrounding the dam culverts is overgrown and eroded.

Invasive plant species have already degraded the Eastern Wetlands and seriously threaten the ecological integrity of sedge meadow remnants in Gardner and Southeast Marshes. Gardner Marsh has been extensively ditched and dredged both for development and ecological study. Dredge spoils were left in the marsh but not planted or seeded, allowing invasive species such as buckthorn (*Rhamnus* spp.) to take hold. Reed canary grass (*Phalaris arundinacea*) and cattail (*Typha* spp.) thrive in the nutrient-rich stormwater entering the marshes, allowing them to outcompete native species and form monotypic stands. This report documents the presence of invasive species in the Eastern Wetlands as well the remaining quality habitats, mainly sedge meadow.

Opportunities for restoration

The goal of restoring native plant communities in Southeast and Gardner Marshes can be achieved, given hydrological control and invasive species management. Our plan sets goals to:

- reduce stormwater inflow and improve water quality,
- control invasive plant species, and
- restore native sedge meadow communities.

Our two restoration plans differ in the amount of time, level of management, and expense required for implementation. We recognize the options presented here greatly impact the current wetlands and require an intensive dedication, persistence and commitment of resources. However, discussions with managers and supporters of the Arboretum led us to conclude that the Arboretum is committed to such an investment and the plans presented are in keeping with its goals.

Stormwater Management

The first, and arguably most important, step is to improve stormwater management in Southeast Marsh by rebuilding Pond 4 and repairing Pond 3. Thus, we support the 2006 recommendations of the Arboretum Stormwater Committee to enlarge Pond 4 and renovate Pond 3 by dredging the sediment and fixing the outfalls. Additionally, we recommend adjusting the design of Pond 4 to facilitate adaptive restoration (experimentation with water depths and planting of native species).

To reduce the volume of stormwater flowing from the upstream neighborhood into Southeast Marsh, we suggest utilizing the potential for infiltration and ponding in the Arbor Hills Greenway and rain gardens at Leopold Elementary School. Our community-based marketing survey documents strong public support for an infiltration swale where native plant species could grow—these opinions of the Arbor Hills neighborhood should prove useful to engineers in re-designing the Greenway. In the survey, Arbor Hills residents favored changes to the current Greenway using native plants, but did not support creating ponds. The Arboretum should encourage and support upstream efforts to reduce runoff and improve infiltration, as this will ultimately benefit the wetlands.

Vegetation and Hydrological Management in the Marshes

A reduction in stormwater to Southeast Marsh will improve water quality and slow the high velocity flows that erode channels in the marsh. Thus, we recommend installing a weir at the marsh outlet to increase the retention time of water in the marsh. This would allow managers to regulate water levels and inundate the marsh for longer periods after storm events, improving water quality to downstream areas. Higher water levels for longer periods would allow for increased invasive species control and native species establishment options.

To restore native vegetation in Gardner Marsh, we recommend experimentally testing invasive species control and native community establishment. Our preferred alternative involves hydrologic manipulations that would require substantial investment by the Arboretum. We suggest diverting stormwater around the marsh by reconnecting the fish ponds along the eastern border of the marsh with Wingra Creek, creating water-level controls at the CCC Dam structure on the northeastern side of the marsh, and reconnecting Gardner Marsh with Lake Wingra via a culvert underneath Arboretum Drive. Schmidt Lagoon, at the southern boundary of the marsh, would be cut off from the rest of Gardner Marsh. In this scenario, managers could:

- control water levels,
- reestablish a preferred hydroperiod to control invasive plants and improve sedge meadow conditions,
- manipulate the system experimentally, and
- remove carp by using Gardner Marsh as a trap.

Outreach and Education

While recognizing that the hidden nature of the marshes reduces direct human disturbance, we suggest a series of outreach and educational activities to target the Eastern Wetlands. The Arboretum has many opportunities to highlight the unique and valuable functions of wetlands, which are often underappreciated by the general public. Outreach activities on site and in the visitor center could help foster local interest in protecting Southeast and Gardner Marshes from the harmful impacts of stormwater and invasive species.

Moving Forward from a Strong Base

The Arboretum has already stated its strong commitment to the environment and open space in its Comprehensive Master Plan (UW–Madison 1996). In addition, the Arboretum has the potential to provide critical leadership to improve the climate for stronger stormwater regulations and inspire stakeholders to take action beyond regulatory requirements. The Arboretum is well known as a leader in prairie restoration. With the renewed interest in the Eastern Wetlands, the Arboretum has an opportunity to also become a leader in wetland restoration by implementing adaptive wetland restoration at a large scale.

Chapter 1 • Overview

The 2007 Water Resource Management Practicum addressed the Eastern Wetlands (Southeast Marsh and Gardner Marsh, totaling approximately 225 acres, 90.5 ha.; Figures 1.1, 1.2). In the following report, Chapters 2 through 6 include the site inventory and analysis, information on the history of the wetland and watersheds (Figures 1.3, 1.4, 1.5), current upstream watershed conditions, water quality, soils, vegetation, and the hydrology of the site. This background information is important to the restoration options discussed in subsequent chapters.

Chapters 7 through 11 detail the various components of the restoration plan, including our different options and scenarios. Vegetation management begins by controlling invasive shrubs, reed canary grass and hybrid cattails. As a wetland system, the hydrology of the site plays a critical role in what ecological communities the marshes can sustain. Balancing options for raising water levels in some areas of the marsh and cutting off water flow to others could greatly increase the ability to restore native communities. Chapter 11 explores the importance of the marshes for wildlife habitat, which are a key component of the goals and opportunities for restoration.

In Chapter 12 we explore the future of the marshes if no action is taken. We present this option as a reminder of the importance of moving forward with restoration in the marshes. Without preventative action by Arboretum managers, wetland functions will be lost as native vegetation communities like sedge meadows continue to shrink as a result of encroaching shrubs, monotypic stands of cattail, and reed canary grass.

Chapters 13 and 14 combine the recommended components of the restoration options in two detailed restoration plans that focus upon restoring key wetland functions. Plan 1 focuses on vegetation management within the marshes, highlighting the preferred methods of eradicating invasive species while promoting a native sedge meadow community. Plan 2 is a restoration effort on a larger scale, offering greater restoration potential. Plan 2 adds hydrologic modification of the marshes in addition to vegetation management. A broader

Figure 1.1, above: Aerial view of present-day Gardner Marsh, taken from the southeast.

Figure 1.2, left: Aerial view of present-day Southeast Marsh, taken from the south.

scale modification, as suggested in this plan, allows managers to control water levels in the marshes, effectively manipulating the marshes' hydrologic regime to benefit native species and manage invasive species. Both plans highlight the need for at least minimal stormwater control through improvement and rebuilding of the stormwater Ponds 3 and 4, respectively, in Southeast Marsh.

Because many people are unfamiliar with restoration, Chapter 15 offers various options for public education at the Arboretum Visitor Center and identifies opportunities to promote wetland protection.

This report is intended to be the beginning of dedicated efforts to understand and restore the ecological integrity of Arboretum wetlands. Thus, Chapter 16 presents opportunities for future research, and Chapter 17 suggests funding opportunities.

It is important to note that the scope of our research and data collection was limited and influenced by several factors. First, irregular precipitation levels throughout the summer may have affected the distribution and prevalence of biota and the timing natural processes in the marsh. The early part of the summer was characterized by near-drought conditions interrupted several times by intense storms; the month of August brought record rainfalls and the marsh was inundated for weeks. Secondly, our research was limited by the brief tenure of our study, i.e., May through August. Lastly, a comprehensive diagnosis of a system as complicated as a highly-disturbed wetland requires a varied skill set. While a diverse range of disciplines was represented in our group, we did not possess expertise in all fields that would have contributed to a complete diagnosis and associated restoration plan for the marshes. Because of this we feel that prior to undertaking any large-scale restoration efforts such as the ones recommended in the following plan, additional hydrologic modeling, analysis and final engineering designs are necessary.

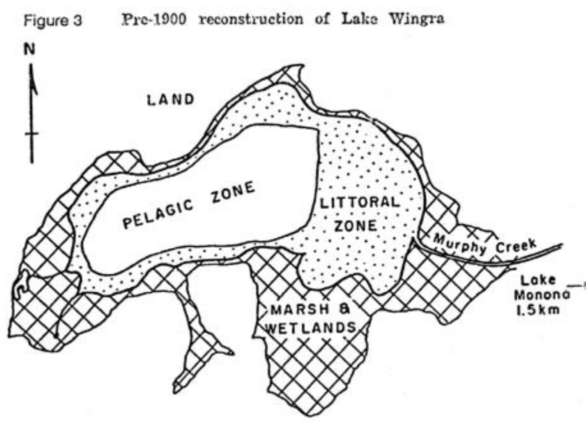


Figure 1.3: Pre-1900 reconstruction of Lake Wingra, its wetlands and littoral zone. Scaled to map by U.S. Geological Survey (1959). Source: Baumann et. al. 1974.

Figure 1.4: Southeast Marsh in 1947, with agricultural crop land.

Figure 1.5: Southeast Marsh in 1990, without crop land and with the onset of urbanization in the watershed.

Chapter 2 • Historical Land Use of the Eastern Wetlands

2.1 Watershed history

The present-day Eastern Wetlands are Gardner Marsh (Figure 1.1) (formerly "East Marsh") and Southeast Marsh (Figure 1.2). Historically, these marshes were part of the littoral zone of Lake Wingra (Figure 1.3) and the larger wetland system on the southeastern edge of the lake (Sachse 1965). Anthropogenic changes, both to the surrounding watershed and within the marshes, significantly altered the physical structure as well as the natural processes of the marshes. Knowledge of these changes is essential to understanding the present status and condition of the wetlands and to determining proper restorative actions.

According to the 1830s field notes of surveyors Lorin Miller and Orson Lyon, the pre-settlement landscape of the marshes consisted of gently rolling hills with oak savanna and patchy low-lying marshes (PLSW 2007). By the mid-1840s, however, settlers had converted much of the landscape to agricultural cropland, planting mostly corn, oats and pasture in rotation in what is now Southeast Marsh (Figure 1.4). The land was regularly farmed until urban development began in the mid-20th century, suggesting that the site was only seasonally wet or drained (Figure 1.5).

Prior to European settlement along the shores of Lake Wingra, the area was used extensively by Native Americans for fishing and hunting (Sachse 1965). In 1837, "500 to 1000 Winnebago Indians were camped around Lake Wingra" (Baumann et al. 1974). In 1841, one of the only routes to the Lake Wingra area was a Native American trail (now Fish Hatchery Road) adjacent to the southeastern extent of present-day Southeast Marsh (ibid.). The bounty of natural resources on the shores of Lake Wingra was recognized and used by the Winnebago.

The outlet of Lake Wingra was Murphy's Creek, which drained through the large marsh system to the south and east of the lake (Sachse 1965). Murphy's Creek likely lacked a well-defined channel and, for that reason, many people thought the lake—formerly known as Dead Lake—was "dead" and had no outlet (Noland 1951). On its way to Lake Monona, the creek flowed through the area of present-day Gardner Marsh, which was characterized by emergent vegetation such as cattails (Baumann et al. 1974).

2.2 Anthropogenic alterations

The present-day physical structure of the Eastern Wetlands is highly modified. In the early 1900s, settlers began draining, dredging and filling to allow habitation and parkland. As a result of these actions, Gardner Marsh was greatly damaged and still bears the scars of historical manipulations. Major changes were part of "civic improvement," undertaken by the Madison Park and Pleasure Drive Association (Sachse 1965). Between 1905 and 1906, Murphy's Creek was dredged (in the present-day Wingra Creek) as part of the creation of Vilas Park on the northeastern shore of Lake Wingra (Noland 1951, Bedford et al. 1974). The channel extended from Fish Hatchery Road (then referred to as "Fitchburg Road") bridge to where present-day Randall Avenue (then referred to as "Warren Street"), if extended north, would meet the shore of Lake Wingra. A wooden lock was constructed upstream of the Fish Hatchery Road bridge to maintain the original water level of Lake Wingra (Noland 1951, Baumann et al. 1974). The remaining distance of Murphy's Creek from the Fish Hatchery Road dike to Lake Monona was dredged from 1907-1908 (ibid.) to allow "pleasure boats" to pass from Lake Wingra to Lake Monona (Irwin 1973).

The period from 1914-1920 was characterized by the Lake Forest Land Company's efforts to convert Gardner Marsh into a "superb modern suburb" called Lake Forest (Noland 1951; Sachse 1965; Baumann et al. 1974; Bedford et al. 1974; Groy 1981). The development company, reorganized and renamed in 1916 as the Lake Forest Company, had grandiose plans, including "Venetian style" lagoons, a mall and circle, shops, a park, street cars, electricity and sewer service, and a double boulevard, among other amenities (Figure 2.1) (Sachse 1965; Groy 1981).

Before development could proceed, the marsh had to be drained. To maintain the original water level of Lake Wingra, a dike was constructed to separate the marsh from the lake (Noland 1951; Baumann et al. 1974). Present-day Arboretum Drive (referred to as "McCaffrey Drive") is located on this dike. Canals (still visible in present-day Gardner Marsh) were dredged west to east across the marsh to aid drainage. Subsequent

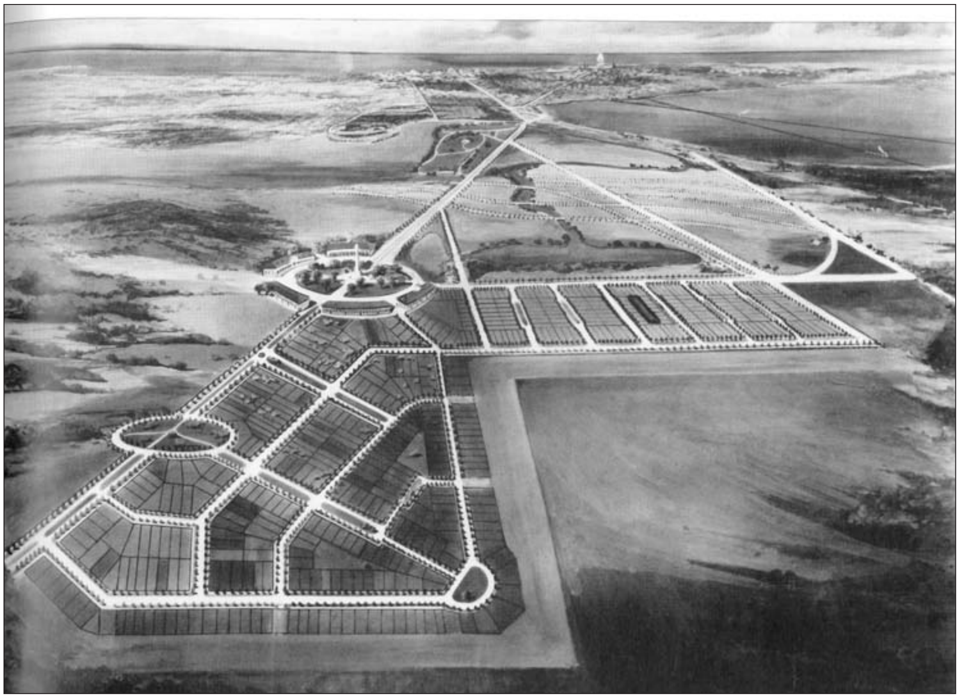


Figure 2.1: Plans for the Lake Forest Development. Carver and Martin streets and Schmidt Lagoon are centrally located in the image. Source: Mollenhoff, 2004..

downstream dredging operations to enlarge Murphy's Creek lowered water levels significantly in the marsh, draining it downstream of the wooden lock near the Fish Hatchery Road bridge (Noland 1951; Baumann et al. 1974; Bedford et al. 1974).

Water level fluctuations were not confined to the marsh. During the summer of 1917, the dike separating the marsh and lake was breached to allow passage of a dredging barge (Noland 1951), resulting in an approximate 3.28-ft (1-m) fall of Lake Wingra's water levels (Noland 1951; Baumann et al. 1974). In order to increase Lake Wingra water levels, a lock and spillway were constructed at the site of the current Wingra dam and the dike breach was repaired (Noland 1951).

Streets built for the Lake Forest development severed the marsh and disconnected the exchange of surface water with Lake Wingra. Also, the construction of Capitol Avenue (Figure 2.2), begun in 1920, extended southwest from Mills Street across the peat and marl of the marsh (Sachse 1965). Remnants of the avenue are still visible (Figure 2.3). Carver and Martin streets were built toward the southern end of the Eastern Wetlands, effectively dividing the area into two separate marsh areas, known today as Gardner and Southeast marshes.

The Lake Forest Company's peculiar decision to develop the marsh—because it was "the only large, undeveloped and desirable plat with lake frontage in the immediate Madison area" (Groy 1981)—was ultimately their undoing (Noland 1951; Sachse 1965; Baumann et al. 1974; Bedford et al. 1974; Groy 1981). Developments repeatedly sank into the peat and marl of the marsh. The project was abandoned, as the company went bankrupt in 1922 (Sachse 1965; Baumann et al. 1974; Groy 1981).

The area is known today as the "Lost City," (Noland 1951; Sachse 1965; Groy 1981) and remains of the failed development (Figure 2.4) are still visible. Present-day features such as Wingra Creek, Arboretum Drive, Wingra Dam, the Carver/Martin Street neighborhood, and the canals that used to drain Gardner Marsh are all testaments to the human manipulations. Homes on Carver and Martin streets did not sink into the marsh and were thus inhabited. Following purchase by the Arboretum (see Section 2.3), further alterations were undertaken as habitat improvement and restoration, rather than development.

Historical aerial photographs from the 1930s show residential land use along the southern edge of the Arboretum, just south of where the West Beltline Highway meets Fish Hatchery Road today. The Beltline was built in the 1940s, and within a decade of its construction, a small subdivision, Burr Oaks, was built to the southeast of the Arboretum just off the highway (Appendix A). The Arbor Hills Neighborhood, directly south of the Beltline at Todd Drive, was established in 1956, and it grew throughout the 1960s (Hurst 1992). Development of the South Beltline Commercial District, just north of the Beltline, began in the 1950s, and numerous businesses were operating

Figure 2.2: Construction of Capitol Avenue by a CCC work crew in the 1930s. Source: Sachse 1965.

Figure 2.3: An overgrown section of remnant Capitol Avenue on the large island in Pond E–90.

Figure 2.4: Foundation remains from Lake Forest Development in present-day Gardner Marsh.

by the end of the next decade (Appendix A). The majority of development in the Southeast Marsh watershed was completed by the late 1970s. However, the area north of the Beltline and west of Fish Hatchery Road was designated as Arboretum land in the mid-1930s, and it was never developed. A similar parcel of land, the Grady Tract, west of the Arbor Hills Neighborhood, was also designated as Arboretum property.

2.3 Arboretum acquisition history

The Arboretum was officially dedicated on June 17, 1934, with Aldo Leopold stating in his address: "This, in a nutshell, is the function of the Arboretum: a reconstructed sample of old Wisconsin, to serve as a benchmark, a starting point, in the long an laborious job of building a permanent and mutually beneficial relationship between civilized men and a civilized landscape" (Jordan 1984). Because Sachse (1965) extensively documented the social and political forces behind the formation of the Arboretum; we focus on the acquisition of the Eastern Wetlands.

From the 1922 bankruptcy of the Lake Forest Company to the dedication of the Arboretum in 1934, the marsh saw no further development (Sachse 1965). The homes on Carver and Martin streets were the only residences that did not sink into the marsh and were sparsely inhabited. The partially developed marsh was characterized by grass and weeds that "pushed through to make a mock of the expensive masonry. The half-dredged lagoons became drainage canals, choked with weeds and deadfalls, and on Sunday mornings the woods continued to ring with illegal shooting," The future of the marsh was uncertain at this point. Its fate was determined in December 1935 when businessman and namesake of the marsh, Louis Gardner, provided the funds necessary for the Arboretum to purchase the 190-acre (76.89 ha) northern marsh parcel (Sachse 1965). Additional parcels of the marsh and failed Lake Forest lots were acquired as they became available in the years following the dedication of the Arboretum (ibid.). Prior to purchase by the Arboretum in 1969, the parcel south of Martin Street, referred to today as Southeast Marsh, was under cultivation, even as late as 1958 (Kline 1992). The area was intended primarily for stormwater control (ibid.).

Figure 2.5: General overview of Gardner Marsh hydrologic features.

2.4 Post-acquisition alterations

Gardner Marsh canals, lagoons, dam • After passing into University of Wisconsin ownership, Arboretum lands became viable research sites and manipulation of the wetland continued. According to Sachse (1965), the Arboretum employed the Civilian Conservation Corps (CCC) to widen existing canals and dredge a large, open lagoon in the north portion of Gardner Marsh ("Pond E-90") as a shorebird and waterfowl refuge. In 1937, the CCC completed construction on a dam between Wingra Creek and Gardner Marsh (Irwin 1973), known as the "CCC Dam." It was built so that "water levels could be controlled artificially, lowered in August or September to leave exposed mud flats, and raised in the spring to reproduce the condition of a flooded pasture" (Sachse 1965). Water level control was not possible, however, due to a downstream dam at Lake Waubesa, which was owned by a power company (ibid.). Overall, these actions probably did not achieve the intent of creating more wildlife habitat (see Chapter 11).

Gardner Marsh fish ponds • Beginning in 1939 and continuing into the 1940's, five small "fish ponds" and six small "minnow ponds" (Figure 2.5) were dredged on the eastern edge of Gardner Marsh for the University of Wisconsin–Madison Center for Limnology to conduct experiments on macrophytes, plankton and fish (Jones 1947; Beckel and Egerton 1987). The attempt to use dynamite to create the ponds was a "spectacular failure, the charge shooting into the air like a geyser, while the centuries old base of marl and peat merely shifted a little" (Sachse 1965). A team and drag eventually excavated the ponds in the winter (ibid.).

Figure 2.6: Human encampments near the Gardner Marsh fish ponds.

Initially, one large pond, Gardner Pond, was excavated along the east side of the marsh, between October 1939 and November 1941, with the marl and peat deposits cast alongside to form spoil banks surrounding the pond (Jones 1947). In 1943, Gardner Pond served as the location for minnow culture experiments, and a cinder dam measuring approximately 6 ft wide (1.8 m) at the top was placed across the middle of the pond, resulting in the creation of North and South Ponds. Two additional cinder dams were added in 1944-45, creating four ponds, named A, B, C and D. The last cinder dam was added in 1945–46, creating the fifth and final Pond E.

Figure 2.7: Structure remains from past experiments conducted in Gardner Marsh fish ponds.

When constructed, the deepest ponds (A and B) measured 8.2 ft (2.5 m) deep. Pond D was the shallowest, measuring less than 6.2 ft (2 m) in the middle. All ponds were sloped from the western edge toward the middle and all but Pond E dropped off abruptly at the eastern edge. Groundwater flowed into the southern end of Gardner Pond and it was assumed that "while there may be some movement of water from pond to pond, it must necessarily be slight" (Jones 1947).

The fish ponds received Rotenone, Forest-Duff briquettes, agricultural superphosphate and commercial soybean meal at various points between 1944 and 1945 (Jones 1947). The rotenone killed all fish in

Figure 2.8: Remains of "mouse pen" experiments in present-day Gardner Marsh.

the ponds, the majority of which were carp (approximately 150 lbs/acre (168.13 kg/ha)). These fish had entered the Gardner Pond during high water from a small ditch located in the northwest corner of the pond (ibid.).

In 2007, the fish ponds were no longer in use, as limnological research had ceased in the mid 1970s (James Kitchell, personal communication, 2007). The berms surrounding the ponds are heavily vegetated with buckthorn, as are the cinder dams separating the ponds. The continued growth of the shrubs located on the cinder dams could cause the dams to fail, if roots create 'tunnels' that erode the berm structure until the dams are fully breached, or if trees fall down and add stress to the dam. Heavily-worn trails surround the spoils around the ponds, with signs of human encampment (Figure 2.6) and frequent use.

Directly to the west of the fish ponds are six small minnow ponds, each approximately 6 ft (1.8 m) in diameter and 3 ft (0.9 m) deep. These were used by University of Wisconsin professor Dr. James Kitchell and his students to study food web dynamics comparing insect populations in ponds with and without fish (James Kitchell, personal communication, 2007). A chain-link fence topped with barbed wire surrounds minnow ponds 4 and 5. The minnow ponds are still present, full of algae and likely amphibians and insects. Within the fence (which is no longer intact) are two attached electrical sheds housing fuse boxes, circuit breakers, wires and other electrical equipment (Figure 2.7). This equipment was part of an experiment to manipulate water temperatures to extend the breeding season of fish species in the ponds (James Bruins, personal communication, 2007), but the exact date and nature of the experiments are unclear.

Beginning at Pond E, water constantly flows north. This groundwater flow continues through eroded channels located on the cinder dams (between D and C) and to the western edge of the ponds (between E and D, C and B). The depths of the larger fish ponds are difficult to determine. Aquatic vegetation is abundant and fish are present, but species were not identified. The ponds are surrounded by dense shrubs and trees. A pair of great blue herons nested on the southern edge of Pond C during summer 2007. Short of providing some wildlife habitat, the present function of the fish ponds and how they affect marsh hydrology are unclear.

Gardner Marsh "mouse pens" ✦ Additional research was conducted in central Gardner Marsh on the effects of population pressures on small mammals (Irwin 1973; Jordan 1984). Metal enclosures referred to as "mouse pens" housed populations of mice for study of reproduction and survival rates in relation to density (ibid.). It is unknown when this research took place, but remnants of the pens are still obvious (Figure 2.8).

Southeast Marsh WHA-AM radio tower ✦ Within the northeastern part of Southeast Marsh is the University of Wisconsin's WHA –AM radio tower (Figure 2.9). Built in 1972, the tower consists of radial, buried copper wires in a 500-ft (152.4 m) diameter area. The tower is perched on a 10x10-ft concrete platform to prevent submergence during flooding events. The tower is 200 ft (60.96 m) high and secured by three guy wires. Due to corrosion, it is scheduled to be replaced in 2008.

Although only 4.5 acres or 6.25% of the total area of Southeast Marsh supports tower features (Ayres-Associates 2007), the location of the tower—in the lowest portion of the marsh—is cause for concern. During flood conditions, standing water surrounds the tower for long periods of time. This inundation combined with salt used on nearby roadways in winter could corrode the buried copper wires. Also of concern is the impact that tower replacement will have on the marsh. Heavy equipment will compact sensitive peat soils and dredging may release sediment into the marsh and disturb native species already vulnerable to invasive plants.

An environmental impact assessment (EIA) was written by Ayres Associates in 2007, as required for the proposed tower replacement. At an April 25, 2007, EIA public hearing, WRM students and other environmentally concerned citizens provided input to Ayres Associates on the potential environmental impacts of the proposed tower's replacement (Appendix B). Our concerns about marsh soil compaction helped delay the project until the winter months when heavy machinery in the marsh would likely have low impact. Despite the environmental concerns, a finding of no significant impact was returned in June 2007 and a replacement tower is imminent.

Southeast Marsh stormwater ponds and berm • In the mid-1980s, both the City and the Town of Madison negotiated with the Arboretum to establish a stormwater detention facility in Southeast Marsh to capture the high volumes of storm runoff (David Liebl, personal communication, 2007). Flooding in the Carver and Martin streets neighborhood had become more frequent due to intensive urbanization upstream in the watershed (Chapter 3) (Donohue and Associates 1981). A berm measuring 2,250 ft (685.8 m) long and with a maximum height of 6.5 ft (1.98 m) (ibid.) was built running west-to-east across the northern section of the marsh, just south of Martin Street. Ponds 3 and 4 were designed to remove up to 70% of sediment for storm intensities up to 1-year events and to withstand a 10-year event. The preliminary engineering designs also estimated sediment accumulation rates of up to 53 tons/year for Pond 3 and 27 tons/year for Pond 4 (ibid.).

2.5 Ecological consequences of alterations

The extensive history of anthropogenic alterations to the Eastern Arboretum Marshes has resulted in irreversible ecological damage. Robert McCabe, Professor of Wildlife Ecology at UW–Madison, performed research in the marsh and spoke critically of the early manipulations: "The drying up of the marsh caused by ditching and pond digging has all but ruined the marsh flora to which the botanists can testify. Wish to restore water levels in hopes of encouraging native marsh flora at the expense of post-draining weed flora and equal emphasis to alleviate the fire hazard in an already partly-oxidized peat" (Irwin 1973).

Bedford et al. (1974) addressed other ecological damages that resulted from the dredging of Gardner Marsh, stating: "The dredging of the littoral zone…almost eliminated the deep water-shallow water gradation with its large number of niches for plant and animal species. Cover-water interspersion must certainly have decreased greatly, along with microhabitats and species diversity of macrophytes and invertebrates, as the drop-off became more abrupt. Since the gradual shoreline is mostly gone, there are no longer many moist places for seedlings of emergents to start."

During the "high-impact" era of 1914-1920, Arboretum Drive was diked, which isolated Gardner Marsh from Lake Wingra and "diverted water from four southern springs away from the lake" (Baumann et al. 1974). Fill was deposited on submergent marsh vegetation, in order to build foundations on the peat and marl. Many areas of marsh that had previously been disturbed are today populated with invasive vegetation (see Chapter 5 for further information on invasive species).

Hydrologic conditions were also altered. The draining of the marsh to a level approximately 3.28 ft (1 m) lower than Lake Wingra caused the subsidence of peat soils underlying much of the marsh area (Baumann et al. 1974; Monthey 1974). Irwin (1973) states "downward flow of water in and around… [Gardner Marsh] may be affected by the two city [of Madison] wells and the Town of Madison well in the vicinity."

In 1970, a weir was constructed at Beld Street on Wingra Creek, in order to maintain higher water levels in the marsh relative to downstream Lake Monona. While this did not occur directly in or adjacent to Gardner Marsh, its effects may have altered water levels in the marsh.

Figure 2.9: The WHA-AM radio transmission tower in the background of Southeast Marsh.

Chapter 3: Land Use and Description of the Eastern Wetlands (1993–2008)

Figure 3.1: Overview of Southeast Marsh.

3.1 Southeast Marsh

Southeast Marsh encompasses approximately 75 acres (30.1 ha), including some upland areas (Figure 3.1). The marsh is a patchwork of sedge meadow, invasive stands of cattail and reed canary grass and encroaching shrubs. Present-day vegetation is detailed in Chapter 5. The watershed is highly urbanized, including commercial, industrial, institutional, park/open space, residential and undeveloped land.

There is very little stormwater infiltration within the watershed. Residential lawns, parks/open space and undeveloped land offer the only infiltration potential. The majority of the rainfall runs off impervious surfaces into storm sewers via curb gutters or concrete-lined drainage ditches, prompting the usage of the term "sewershed" interchangeably with "watershed." The storm sewers discharge runoff into small surface water channels that lead directly to Ponds 3 and 4 in Southeast Marsh (Figures 3.2, 3.3).

The storm sewers were designed to limit flooding in the residential watershed. The system moves stormwater through the sewers rapidly, resulting in high discharge rates into Ponds 3 and 4 during storm events. Due to the failure of both stormwater ponds (see Section 3.2), stormwater routinely inundates the marsh. Scoured channels now lead from both stormwater ponds to the culvert on the northern edge of the marsh.

Groundwater inputs to the marsh are considered to be minimal, i.e., less than 10% of the overall volume of water exiting Southeast Marsh (Ken Potter, personal communication, 2007). It is probable that groundwater enters the marsh near the fen that is east of Pond 3.

Pond-3 watershed, including the Arbor Hills Neighborhood and Greenway • Pond 3 is located at the southwestern boundary of Southeast Marsh and drains a 234-acre (94.7-hectare) watershed. Currently the Pond 3 watershed yields approximately 99 acre-ft (122,144 m^3) of runoff annually to the marsh, the majority of which comes from the Arbor Hills Neighborhood (UW–Arboretum 2006). Runoff that enters the pond from the urbanized watershed tends to be "flashy"—coming in bursts with high velocity. Despite the recent reconstruction of the riprap surface water channel immediately upstream (south) of Pond 3, it has eroded severely due to high runoff velocity and volume, once again impairing the pond's ability to retain and filter inflows (Chapter 8).

Due to the significance of the impact from upstream stormwater, it is relevant to note the conditions in the upstream neighborhood that may prove important for reducing the large volumes of stormwater. In-depth descriptions of infiltration options for the Arbor Hills Neighborhood, the Greenway and the Leopold Elementary School are in Chapter 7 and Chapter 15.

The Arbor Hills Neighborhood could increase infiltration to reduce the negative impacts associated with large volumes of stormwater (UW–Arboretum 2006). Arbor Hills is a medium-density residential neighborhood located south of the West Beltline Highway (Figure 3.4). The neighborhood is 232 acres (94 hectares) in size and is the primary source of stormwater draining into Pond 3. The neighborhood is predominantly within the City of

Figure 3.2: Surface channel leading to Pond 3 in Southeast Marsh.

Figure 3.3: Inlet to Pond 3.

Figure 3.4: Aerial view of Arbor Hills Neighborhood in the Pond 3 Watershed.

Figure 3.5: Aerial view of the Arbor Hills Greenway.

Madison; a small portion in the northwest corner falls within the Town of Madison. The neighborhood's southern boundary abuts the northern boundary of the City of Fitchburg.

The most promising site for improved infiltration is within the Arbor Hills Greenway. Owned by the Madison Stormwater Utility, it is located at the lowest elevation within the neighborhood boundaries (Figure 3.5). Preliminary estimates are that the Arbor Hills Greenway, in the same neighborhood, could be managed to reduce runoff to Pond 3 by 50% of a two-year storm event (UW–Arboretum 2006). Currently, the Pond-3 watershed contributes 35 acre-ft (43,172 m^3) of runoff in a two-year storm event (ibid.). Given these preliminary estimates and existing partnerships, we focus on efforts to improve infiltration in the Pond-3 watershed.

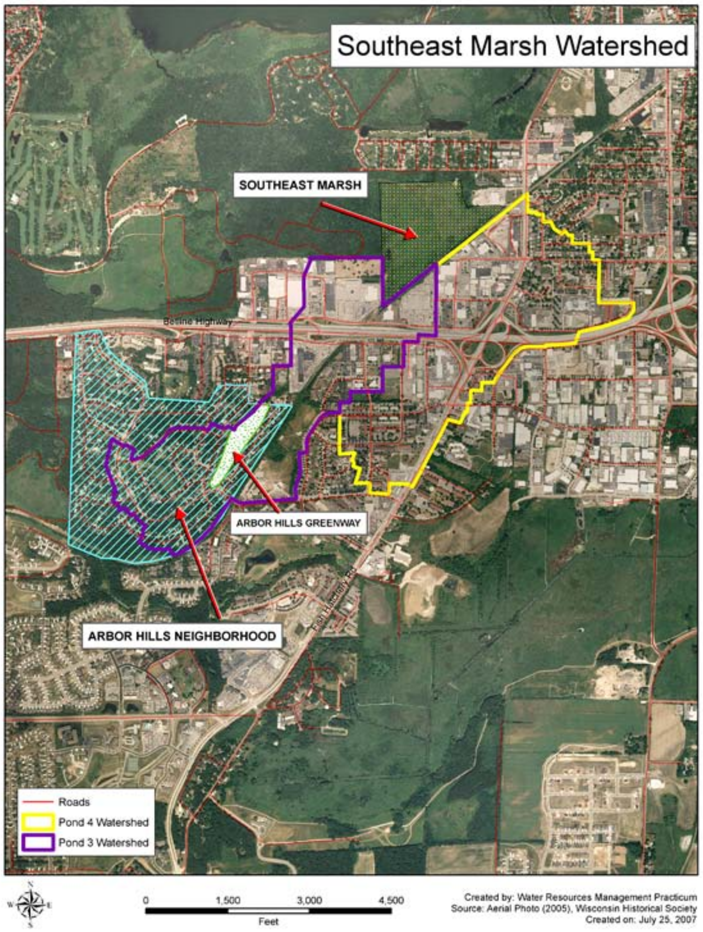


Figure 3.6: Watershed of Southeast Marsh.

The Greenway serves as a recreational area; it has a grass soccer field and a paved basketball court, as well as an engineered drainage corridor. It is long and narrow and totals approximately 11 acres (4.45 ha). It is adjacent to residential backyards on its east and west boundaries. The area slopes from the southern high point at Post Road to the north where it meets Greenway View Road. A storm sewer outfall is located at the southern point at Post Road. A concrete-lined drainage ditch starts at this outfall and directs stormwater through the Greenway before it re-enters the underground sewers at Greenway View Road. This channel does not follow the gradual slope of the Greenway. It was designed with several 3-ft (0.91 m) vertical drop structures between Post Road and Greenway View Road. The drop structures are intended to minimize erosion by reducing the slope and velocity of the runoff. Two additional inlets at the east and west edges of the Greenway have secondary concrete channels that merge with the main channel. Together these channels total approximately 1,958 ft (594 m) of concrete-lined drainage.

Runoff from Aldo Leopold Elementary School drains into the Pond 3 watershed; this site has great potential for a rain garden demonstration. The school is east of the North Western Railroad Line on Post Road. The school grounds cover approximately 14 acres (5.7 hectares). Roughly, one-third of the grounds are covered by the building and parking lot. The remaining grounds are grass and wooded areas. The main school building sits on the high point of the grounds, with the grass and wooded areas located at lower elevations. The grounds also contain a paved basketball court and dirt baseball field. The school could help educate faculty, staff and students about stormwater and the impact their neighborhood has on downstream waterways.

Pond-4 watershed • Pond 4 is on the southeast boundary of Southeast Marsh, just west of West Badger Road. It receives an estimated 136 acre-ft (16.77 hectare-meters) of stormwater annually. The Pond 4 watershed is 231 acres (93.4 ha) and encompasses the Lincoln neighborhood and a large part of the commercial and industrial region of the South Beltline Highway (UW–Arboretum 2006). The pond itself is approximately 2 acres (0.81 ha) (Donohue and Associates 1981) in area and was built in the mid-1980's (UW–Arboretum 2006) (Figure 3.6).

3.2 Failure of Ponds 3 and 4

Despite being purchased and subsequently modified to manage stormwater flows, Southeast Marsh and the two detention ponds currently do little to trap sediment and nutrients. Pond 3 is filled with sediment (Figures 3.7A, B), which reduces its storage capacity and limits its ability to retain sediment and associated nutrients such as phosphorus. The two outlet structures are clogged with debris and vegetation (Figure 3.8). As a result, stormwater is released unchecked into Southeast Marsh. A small channel has formed from Pond 3 as the water flows northeast toward the culvert at Martin Street.

Figure 3.7: Pond 3, with A, a 'delta' forming near the inlet; B, filling with sediment.

The berm surrounding Pond 4 breached in 1993 and runoff currently flows directly into Southeast Marsh (UW–Arboretum 2006). Stormwater flows from the Lincoln Neighborhood and the South Beltline Commercial Districts exceeded the capacity of Pond 4, causing the breach (ibid.). Sediment that had accumulated in Pond 4 is now being deposited directly into the wetland, entering through an approximate 9-ft (3 m) gap in the berm (Figure 3.9). The two outlet structures located to the south of the failed structure are currently intact, although they have no purpose due to the breach. There were three small channels exiting Pond 4 when it was previously functional. Now, a series of small, eroded channels exit Pond 4 and become one larger channel. This channel becomes smaller as it approaches the Martin Street culvert on the northern end of the wetland, until it joins with the channel draining Pond 4, becoming larger. During large storm events, stormwater likely moves across the marsh via several small channels, rather than one confined channel.

While Ponds 3 and 4 were projected to annually receive 53 and 27 tons of sediment, respectively (Donohue and Associates 1981), these estimates were based on land use in 1981, which has likely intensified in 27 years. The 1981 estimates were based on a 225-acre (91-ha) drainage area for Pond 3 and a 250-acre (100-ha) drainage area for Pond 4. Drainage area estimates (UW–Arboretum 2006) are less than the 1981 report, measuring 234 acres (94.7 ha) and 231 acres (93.48 ha) for Ponds 3 and 4, respectively. With Pond 4 effectively failed and Pond 3 in poor condition due in part to the heavy sedimentation, neither pond is trapping nor significantly slowing stormwater releases to the marshes. The implications of this are significant, as urban stormwater can contain high levels of nitrogen, phosphorus, sediment and invasive plant seeds, among other ecologically-harmful pollutants.

Figure 3.8: Outlet structure in Pond 3, clogged with debris.

Figure 3.9: Breached berm of Pond 4, looking west from pond.

3.3 Gardner Marsh

Gardner Marsh is approximately 175 acres (60.4 ha) of wildlife habitat surrounded by an urban center. Public access to the marsh is limited, as there are no public trails through the wetland and only during high-water situations is it accessible by boat. Nonetheless, significant research has been conducted in Gardner Marsh (Appendix C).

Understanding water flow has implications for restoration efforts. In Gardner Marsh, channel and lagoon dredging (Chapter 2) has made water flow through Gardner Marsh complicated. Currently the marsh receives "upstream" surface water from Southeast Marsh via a 30-in (76.2 cm) culvert running south to north under Carver and Martin streets. The largest outfall, located south of Schmidt Lagoon at Frazer and Carver Streets, carries the majority of the flow from Southeast Marsh. The majority of water entering Gardner Marsh comes from upstream; however, groundwater inputs have been located near the fen north of Schmidt Lagoon, as well as at the fish ponds on the eastern edge of the marsh (Figure 2.5), (Jones 1947; Michaud 1994). Additionally, water from Lake Wingra seeps into Gardner Marsh under the Arboretum Drive berm (Pennequin and Anderson 1983). These groundwater inputs are minimal relative to the marsh's overall water budget.

We did not quantify the sources of water to Gardner Marsh. Wingra Creek backs up into Gardner Marsh through the three outlets between the marsh and the creek. Wingra Creek water levels are determined by Lake Monona levels, which in turn are determined by the Lake Waubesa Dam at Babcock Park. Gardner Marsh may still receive inputs from its own watershed apart from Southeast Marsh, as several storm sewers from the Bay Creek neighborhood empty into Wingra Creek between the Wingra Dam and the Fish Hatchery Road bridge. The significance and extent to which downstream water from Wingra Creek contributes water to Gardner Marsh is unclear and needs further research.

From Schmidt Lagoon, water flows north through a dredged channel on the western edge of the marsh ("north-south channel") to Pond E-90. Historical and current maps and photos (Irwin 1973; Michaud 1994) suggest the north-south channel is a continuous waterway and that the large island running north-south in the western portion of Pond E-90 is actually surrounded by water. Dense stands of cattail prevent navigation around the southern end of the island (Figure 3.10). Since cattails do not grow in deep water, the area has likely filled in substantially with sediment and senesced vegetation, limiting conveyance of stormwater and potentially creating flooding issues for the Carver-Martin Street neighborhood. Although maps consistently show open water, the island might merge with the adjacent land during low water.

June and July 2007 were relative dry periods for precipitation, averaging 5 in (12.7 cm) and 2 in (5 cm), respectively. August 2007 brought a marked increase in precipitation levels, measuring near 16.37 in (41.58 cm) (NOAA 2007) (Figure 3.11).

Figure 3.10: Aerial view of Pond E-90 in Gardner Marsh. Notice the large island (middle left), not continuously surrounded by water, and the small island (middle of the wide part of the lagoon, on the left).

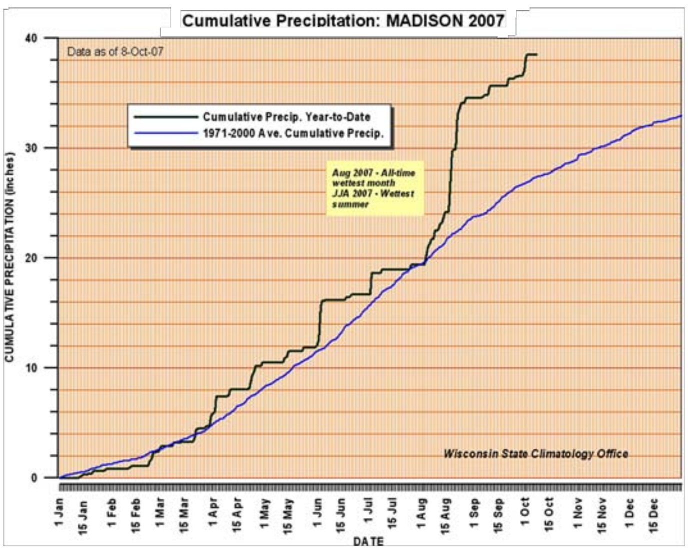


Figure 3.11: Graph of 2007 rainfall data for Madison, WI through October. Source: http://www.aos.wisc.edu/%7Esco/clim-history/stations/msn/msn-rts-2007.gif

Figure 3.12: Erosion of earthen berm supporting the CCC Dam control structure.

The CCC Dam fell into disrepair and was rebuilt in the 1980s. The dam is approximately 30 ft (9 m) berm with five 3-ft (0.91 m) diameter culverts, which separates the marsh from Wingra Creek. Slots on the culverts are for stop logs to regulate the outflow of water from the marsh; however, there is no evidence or record to suggest that managers have ever used stop logs. We observed that the berm around the five culverts is eroding, and the structural integrity of the structure is compromised, limiting its potential for water level manipulation (Figure 3.12).

From Gardner Marsh, water flows through one of three outlets into Wingra Creek and downstream to Lake Monona. The major artery of hydrologic exchange between Wingra Creek and Gardner Marsh is through Outlet 1 at the site of the CCC Dam (Figure 2.5). Outlet 2 is navigable by small watercraft during high water, but accumulated sediment hinders passage during low water. Water flows through the southernmost Outlet 3 only during high-water; however, the channel has filled with cattails and sediment that inhibit substantial exchange of water between the marsh and Wingra Creek.

The 0.5-ft (0.15 m) weir at Beld Street was removed in 2003 during reconstruction of the Beld Street Bridge (Draft Wingra Creek Master Plan 2003). An earlier report suggested that without the Beld Street weir on Wingra Creek, the marsh levels would drop to those of the lake and be subject to natural and human-manipulated fluctuations in the downstream lakes (Monthey 1974). However, we found no reports of unusually low marsh water levels since 2003.

Pond E-90 is too deep to support emergent vegetation, but shallow enough to allow light to penetrate to the bed of the lagoon. Along the northeast corner, deep channels have been scoured into the lagoon sediments several ft deeper than the average bottom depth.

As part of the failed Lost City development, two canals were dredged through central Gardner Marsh and spoils were discharged to form berms. Currently, the canals are filled with sediment and invasive cattail. Flow is minimal, although it may occur during high water. In the absence of adequate sediment control in Southeast Marsh, the lagoons and open channels of Gardner Marsh are vulnerable to continued filling.

Chapter 4: Soils of the Eastern Wetlands

4.1 Soil type

Geologically, the Arboretum is on the Southeast Wisconsin Till Plain (Albert 1995), and has a variety of glacial landforms such as drumlins and kettles. According to the Soil Survey of Dane County Wisconsin (USDA 1978), three soils historically dominated the Eastern Wetlands: Palms Muck, Wacousta Silty Clay Loam and Houghton Muck. The first two are found in Southeast Marsh (Figure 4.1A) and the Houghton Muck is present in Gardner Marsh (Figure 4.1B). The following descriptions are summarized from the soil survey text, for comparison with our own findings.

- **Palms Series/Palms Muck:** A soil characterized by deep, poorly drained organic soils in stream valleys. Partially decayed organic matter accumulation under sedge grasses, surface layer of black muck (~10 in), next layer is a black friable muck (~21 in), the underlying material in a mineral gray silt loam and fine sand. Palms soils have a higher water capacity, medium fertility, a moderately rapid permeability in its organic layer. Its seasonal high water table is above a depth of one in in spring.
- **Wacousta Series/Wacousta Silty Clay Loam:** Deep, poorly drained soils that occurs on low benches in old lake basins. Formed beneath sedges in silt with thin layers of very fine sand. Surface is black and dark gray silty clay loam (~12 in), its subsoil is silt loam, and its underlying material is olive gray silt loam. Its available water capacity is high while its permeability is moderately low. The seasonal high water table is one in or less.
- **Houghton Series/Houghton Muck:** Deep, very poorly drained, nearly level soils on low benches and bottoms. Formed beneath sedge grasses. Reeds and cattails grow in ponded areas. Mineral soil material is below the muck. Surface layer is black muck and the lower layer is very dark grayish-brown. These soils have medium fertility, high water capacity and moderately rapid permeability. Seasonal high water table is at or near the surface.

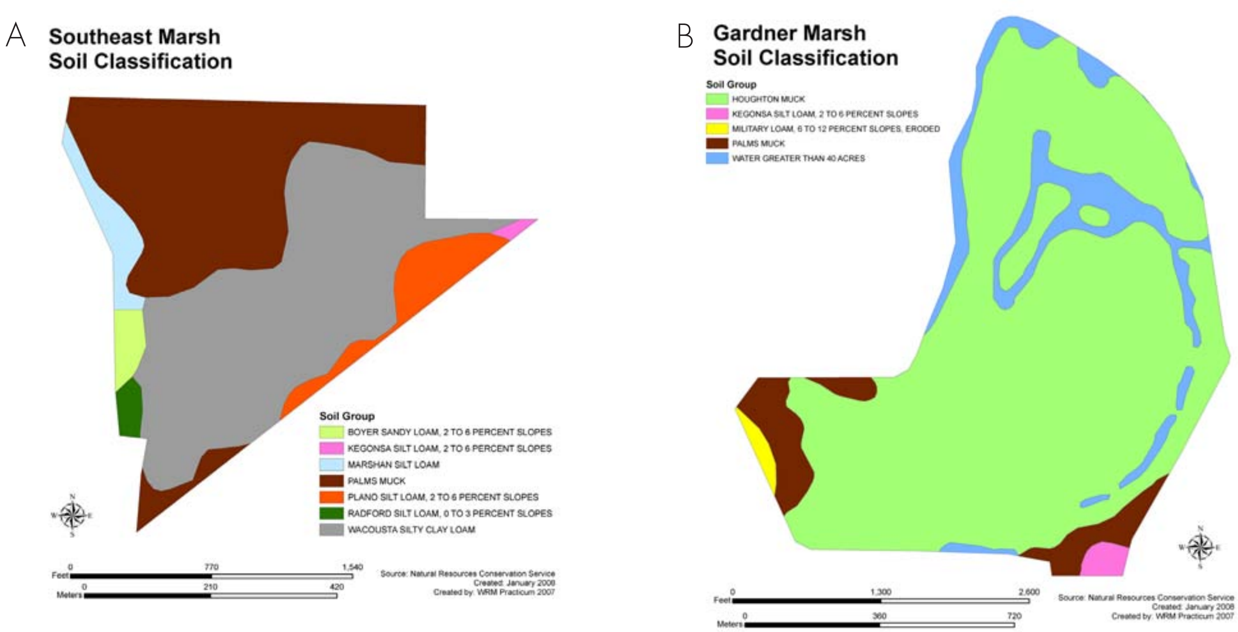


Figure 4.1: A. Soil map of Southeast Marsh. Two soil types, Palms Muck, and Wacousta Silty Clay Loam are most common in the Marsh. B. Soil map of Gardner Marsh. Houghton Muck dominates in Gardner Marsh..

4.2 Soil sampling and locations

Because these wetlands have been little studied, we gathered baseline soil data to help develop management recommendations. We sampled soil along transect lines that we oriented to capture unique features. We sampled along two transects in Southeast Marsh and two in Gardner Marsh, plus two outlier points (Figure 4.3 and 4.4). Soil cores were spaced approximately 50 meters apart. Each soil core was analyzed for nutrients and metals (Figures 4.5–4.10). In addition, we photographed each soil core (Figure 4.4). Details of soil sampling methods are in Appendix E.

The goal of soil sampling in Southeast Marsh was to determine whether stormwater entering this area may be depositing heavy metals and nutrients in the upper layers of sediment, due to failed or poorly functioning retention ponds or the presence of buried copper wires surrounding the WHA tower. We assumed direct stormwater flows from Ponds 3 and 4 to the outlet and positioned our transects accordingly (Figure 4.2). The most pronounced channelization occurs at the outlet of the marsh and at the outlets to both ponds. However, in the middle of the marsh there is more branching and overland flow. Accordingly, we asked if nutrients and metals formed a gradient, were localized, or were equally distributed within the marsh.

In Gardner Marsh, stormwater flows mostly through a channel along the western edge. Rather than following the channel, we maximized transect lengths to describe soil over a larger area (Figure 4.3).

4.3 Soil characteristics

Soil particle size • Particle size distributions for the top 30 cm of soil indicate that Gardner Marsh has slightly sandier soils than most of Southeast Marsh (Figure 4.5). Clay levels vary less in Gardner Marsh than in Southeast Marsh. These few observed trends could be due, in part, to the greater historical human disturbance in Southeast Marsh.

Soil pH • Although soil pH should be determined on wet soils samples, our soils samples were first dried and then ground. Oxidation upon drying can decrease pH, so our pH values may be lower than those in the field. The

Figure 4.2: Location of soil transects in Southeast Marsh.

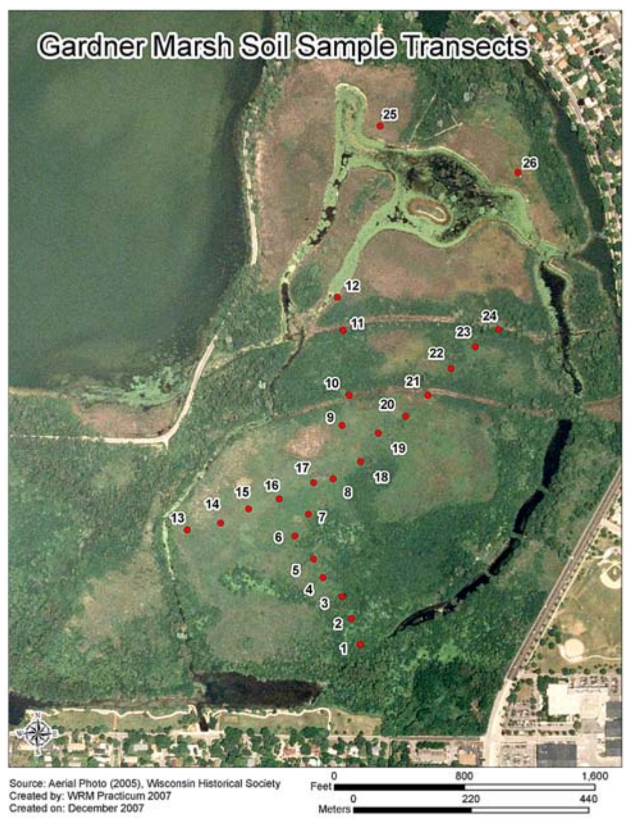


Figure 4.3: Location of soil transects in Gardner Marsh.

average soil pH was 7.3 in Gardner Marsh and 6.3 in Southeast Marsh (Figure 4.6). Higher calcium carbonate concentrations in Gardner Marsh could result in a greater buffering capacity to neutralize acidic conditions. The lowest pH values in Southeast Marsh occurred near the outlet to Martin St (Figure 4.3: points SE 1, 2, 3) and within the WHA antenna field (Figure 4.3: points SE 12, 13, 14).

Peat layer • Water flow in wetlands generally occurs across or close to the soil surface in the upper layer and root zone (Osmond et al. 1995). Accordingly, we sampled soil cores from surface sediments (Figure 4.7). Furthermore, "soil saturation and fiber content are important factors in determining the capacity of a wetland in retaining water. As the pore spaces in wetland soil and peat become saturated by water, they are able to hold less additional water and are also able to release the water more easily" (Osmond et al. 1995).

Figure 4.4: Example of a soil core taken along transects.

Soil cores G 1-G 7 were from the southeastern part of Gardner Marsh (Figure 4.3). These areas were higher in elevation and had dense tree and shrub cover. G7 was located where the trees and shrubs grade into sedge meadow. SE 8 and SE 8.8 in Southeast Marsh were the last points along the first transect which rise in elevation toward Pond 3. This area was dominated by a shrub-meadow mix, which probably does not experience saturation in times of average rainfall. Soil cores SE 9-10 were taken within the remnant Pond 4. Since this area was formerly the bottom of a constructed retention pond, we did not expect to observe a peat layer.

Soil Nitrogen (N) • Nitrogen is often a limiting nutrient for plant growth, making it an important factor in plant and community establishment. Nearly every site sampled in the marsh was dry, due to an early summer drought during our field season. Points G25 and G26 were a monotypic cattail (Typha spp.) stand and a sedge meadow near the outlet, respectively. These two areas were wetter than other areas along the transects. Southeast Marsh contained higher levels of total N throughout the marsh (Figure 4.8). Levels were lowest in the drier core sites. At wetter sites, we observed higher total N values.

Soil Phosphorus (P) • Phosphorus concentrations averaged 1,394 ppm in Southeast and Gardner Marshes (Figure 4.9). SE 2 had the highest phosphorus concentration at 5,158 ppm. Most of the phosphorous is absorbed onto to soil particles or incorporated into organic matter. A release of phosphorus may occur if wetland soils become saturated with phosphorus. In addition, such releases of phosphorus in a wetland system usually take

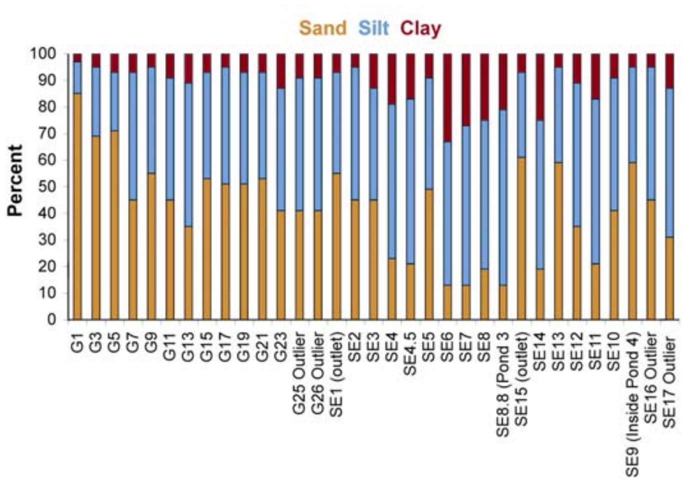


Figure 4.5: Particle size analysis results in Gardner (G) and Southeast (SE) marshes. Analysis performed by the Soil and Plant Analysis Laboratory.

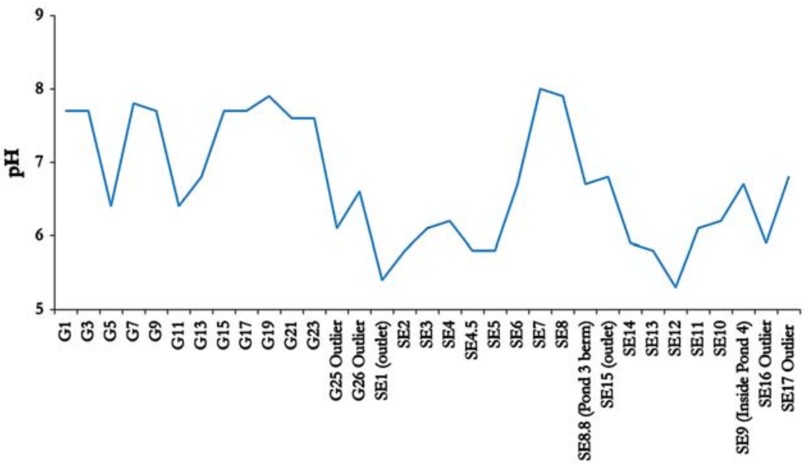


Figure 4.6: pH values in Gardner (G) and Southeast (SE) marshes.

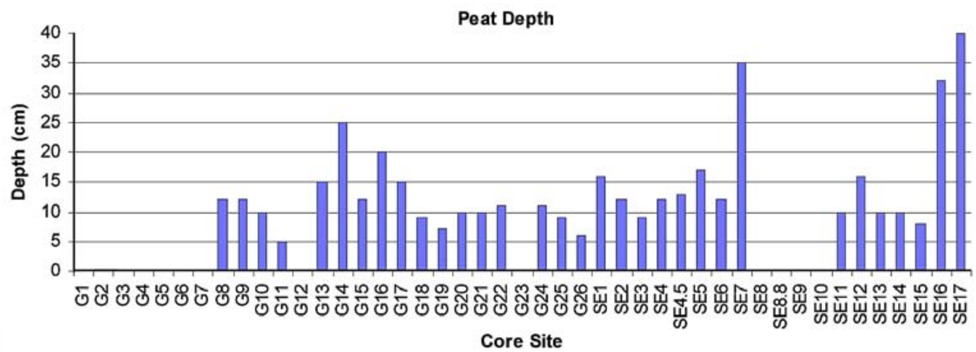


Figure 4.7: Depth of surface peat layer in both Gardner (G) and Southeast (SE) marshes.

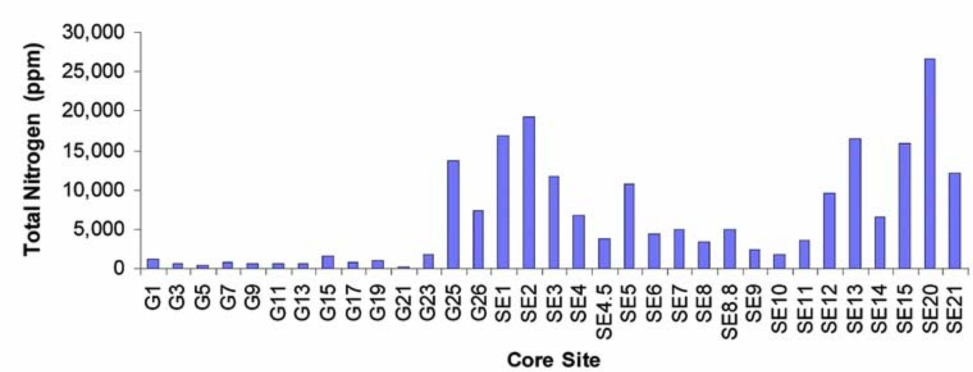


Figure 4.8: Total Nitrogen levels (ppm) in Gardner (G) and Southeast (SE) marshes..

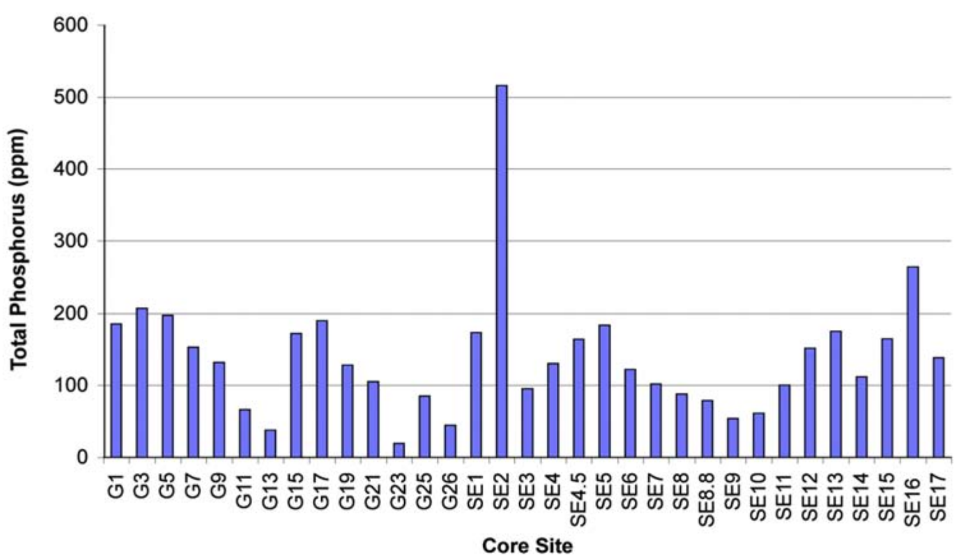


Figure 4.9: Total Phosphorus levels (ppm) in Gardner (G) and Southeast (SE) marshes.

place seasonally, particularly from late summer through the winter, coinciding with organic matter decomposition (Osmond et al. 1995).

Metals • Low concentrations of metals are present in most soils, however, levels high enough to create adverse human health and environmental impacts are usually a result of human activities. Ground and surface waters are the most common conduits through which metals enter wetlands. "As oxidized wetland soils are flooded and reduced, the pH converges toward neutral (6.5 to 7.5) whether the wetland soils were originally acidic or basic. A neutral pH increases metal immobilization in wetlands" (Osmond et al. 1995).

All metals except molybdenum averaged higher in Southeast Marsh than in Gardner Marsh (Figure 4.10). Levels of cadmium and lead were most similar between marshes, being only 1.3 and 1.7 times higher, respectively, in Southeast Marsh. Nickel was detected in two sites in Southeast Marsh, one sample (SE 3) was 26 times higher than the other (SE8). Lead, zinc, and lithium were between 1.7 and 3 times higher in Southeast Marsh. Average copper levels, of interest due to the buried copper wires present in the antenna field in Southeast Marsh, were 4.5 times higher than in Gardner Marsh.

Sample ID	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	Mn ppm	Mo ppm	Ni ppm	Pb ppm	Zn ppm	Li ppm
G1	0.8	1.6	5.6	4.2	8,107.6	132.2	<0.4	<0.3	33.9	40.8	2.5
G3	0.7	2.2	8.5	5.4	5,821.0	288.3	<0.4	<0.3	32.0	52.6	3.5
G5	0.6	2.5	9.4	2.8	10,295.9	275.2	<0.4	<0.3	19.4	40.1	6.2
G7	0.5	3.2	12.5	6.1	8,002.6	211.0	0.5	<0.3	33.3	75.2	6.0
G9	1.6	2.7	14.3	12.6	10,332.9	61.3	2.9	<0.3	98.7	121.1	5.8
G11	0.8	1.8	7.9	4.5	4,995.3	125.5	<0.4	<0.3	34.4	63.3	4.2
G13	0.6	1.0	4.1	<0.5	2,404.7	292.4	<0.4	<0.3	25.2	34.1	4.1
G15	1.2	3.5	12.1	14.0	10,580.0	71.5	2.1	<0.3	65.7	190.0	5.6
G17	1.2	4.3	11.8	12.2	9,656.4	120.3	1.3	<0.3	70.5	155.1	5.8
G19	1.1	2.9	12.1	6.1	9,171.5	141.7	<0.4	<0.3	47.7	74.9	5.5
G21	1.2	3.3	10.3	5.6	8,024.6	415.9	<0.4	<0.3	66.7	87.8	4.4
G23	<0.4	0.6	2.1	<0.5	1,674.0	239.9	<0.4	<0.3	15.2	15.8	3.1
G25	0.9	2.0	8.7	8.0	4,705.1	137.9	<0.4	<0.3	56.8	83.4	4.3
G26	0.8	1.0	6.2	1.5	2,629.1	306.3	<0.4	<0.3	50.3	53.5	3.8
SE1	1.3	5.5	33.0	32.0	15,945.7	333.2	<0.4	<0.3	112.2	270.9	11.3
SE2	0.9	17.0	27.5	32.5	42,195.9	1,387.8	<0.4	<0.3	98.8	403.9	8.0
SE3	1.4	5.1	54.8	35.2	13,305.7	136.1	0.8	7.8	143.9	162.6	10.2
SE4	0.5	8.9	39.4	23.9	20,221.2	634.4	<0.4	<0.3	50.1	176.6	14.6
SE 4.5	0.8	8.2	46.3	25.5	21,811.3	445.3	<0.4	<0.3	61.1	175.2	14.1
SE5	1.1	10.9	51.0	41.9	23,108.3	1,484.8	<0.4	<0.3	65.0	238.4	15.7
SE6	0.8	8.8	53.1	22.7	20,474.8	1,454.6	<0.4	<0.3	26.0	131.3	13.6
SE7	1.1	7.4	58.7	30.2	18,004.2	751.9	<0.4	<0.3	49.8	192.9	15.4
SE8	0.9	7.8	65.7	20.1	19,277.1	1,207.7	<0.4	0.3	48.0	176.6	13.4
SE8.8	0.5	9.4	38.5	13.3	18,335.0	1,637.2	<0.4	<0.3	36.2	153.7	13.0
SE9	0.6	5.4	51.9	45.0	11,486.3	382.1	<0.4	<0.3	44.7	318.0	6.0
SE10	1.3	6.6	57.9	53.4	12,803.0	355.0	<0.4	<0.3	78.2	399.7	7.7
SE11	1.0	9.0	53.6	21.9	18,183.9	1,325.7	<0.4	<0.3	120.1	233.5	12.8
SE12	3.0	8.4	52.3	52.2	18,653.2	717.2	0.4	<0.3	238.4	416.6	13.9
SE13	2.6	7.8	42.3	56.4	16,875.3	784.0	<0.4	<0.3	186.2	379.3	11.3
SE14	0.9	6.8	31.8	17.5	18,618.0	298.4	<0.4	<0.3	46.0	128.7	14.1
SE15	1.8	6.2	31.3	29.9	12,228.5	290.8	<0.4	<0.3	85.7	287.9	10.5
SE16	0.9	2.4	5.3	14.4	22,291.8	78.5	<0.4	<0.3	38.7	102.8	3.2
SE17	0.6	3.9	33.5	21.9	16,769.5	341.7	<0.4	<0.3	20.0	97.6	12.4

Figure 4.10 Metal Levels (ppm) in Gardner (G) and Southeast (SE) marshes.

Chapter 5: Vegetation

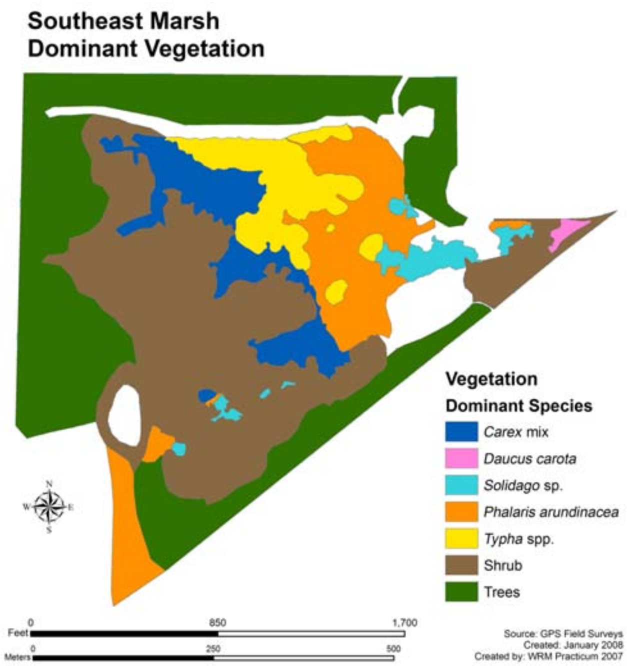
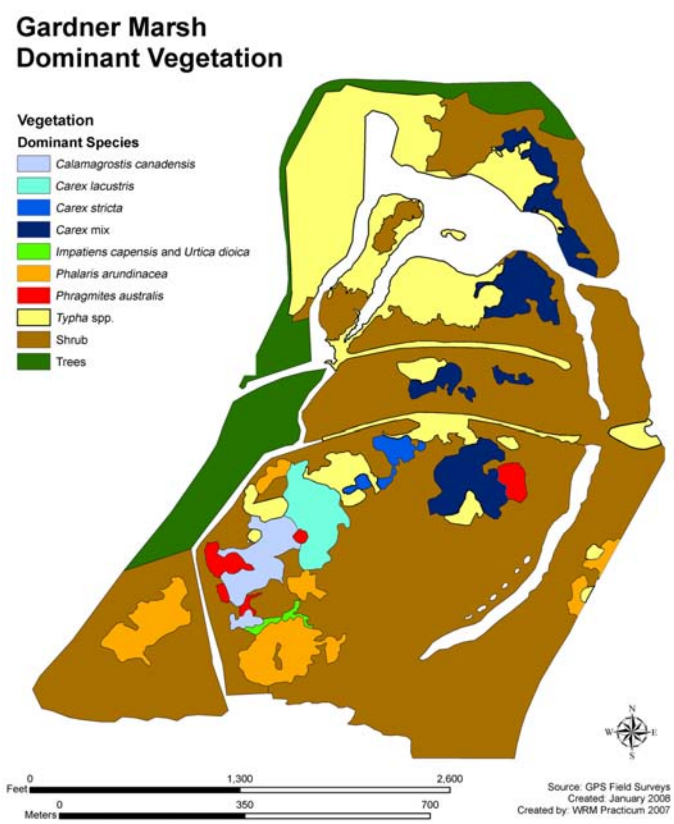


Figure 5.1: Vegetation map of Southeast Marsh.



Figures 5.2: Vegetation map of Gardner Marsh.

5.1 Goals and methods

Our goals in sampling vegetation were to develop a comprehensive list of plant species and to map plant communities based on dominant species (survey methods are in Appendix F). We then compared our map with recent aerial photos and past research to determine how vegetation has changed in recent years. Based on literature, aerial photos and our field data, we created comprehensive vegetation maps for Southeast Marsh (Figure 5.1) and Gardner Marsh (Figure 5.2).

We sampled vegetation along the four soil-sampling transects in Southeast and Gardner Marshes, collecting data at 50-m intervals. In each 1-m^2 plot, we recorded each plant species present and estimated their percent cover. From these data, we calculated species richness, species diversity and other relevant trends (Figures 5.6–5.10).

Using a high-precision Leica 530 GPS unit that measured elevation as well as location, we mapped distinct polygons by delineating the boundaries of dominant species. We considered a species dominant if it made up at least 50% of the total plant cover in an area. While the polygons represent dominants, they contain a mixture of plant species.

In September 2007, we surveyed aquatic macrophytes in Pond E-90 and surrounding area in a qualitative manner.

5.2 Southeast Marsh vegetation

Southeast Marsh has many plant species, although the central and eastern sides of the marsh contain predominantly invasive species in monotypic stands (Figure 5.1). The center of the marsh contains a large and substantial stand of *Phalaris arundinacea*, (hereafter "RCG"), extending from the WHA tower boardwalk on the north side to the edge of Pond 4 on the south side. Intermixed in this section are stands of cattail (*Typha* spp.), ranging in size and species. Small patches of goldenrod (*Solidago canadensis*), blue-joint grass (*Calamagrostis canadensis*), sedges (*Carex* spp.), jewelweed (*Impatiens capensis*) and a few other native species occur among the RCG and cattail. However, native plant species in this area are intermittent and isolated from other areas where native plants are dominant. In addition, many small patches of native species are found in the south-central area of the marsh, adjacent to the north side of Pond 4. These will likely be negatively impacted by the pending expansion of Pond 4 (UW–Arboretum 2006).

The far southeastern corner of the marsh, delineated by the railroad tracks to the south and a service road to the north, has a heterogeneous mixture of plant species. The area is dominated by goldenrod (*Solidago canadensis*) in the center and Queen Anne's lace (*Daucus carota*) at the eastern edge, but it also includes wild bergamot (*Monarda fistulosa*), big blue-stem (*Andropogon gerardii*), daisy fleabane (*Erigeron strigosus*), flowering spurge (*Euphorbia corollata*), riverbank grape (*Vitis riparia*), jewelweed (*Impatiens capensis*), and bull and Canadian thistles (*Cirsium vulgare* and *C. arvense*). Shrub species surround this area; they include buckthorn (*Rhamnus* spp.), honeysuckle (*Lonicera oblongifolia*) and red osier dogwood (*Cornus stolonifera*). In addition, seedlings of red osier dogwood occur throughout the area, indicating a threat of further shrub encroachment in this corner of the marsh.

The western side of Southeast Marsh is by far the most diverse and contains the only significant areas of sedge meadow, based on size and continuity. It is also higher in elevation than other areas of the marsh (the marsh spans an elevation range of 26 ft or 7.92 m). Patches of sedge meadow, blue-joint grass and goldenrod occur from the northern berm to Pond 3. Other species that appear to thrive in the western half of the marsh include: spotted joe-pye-weed (*Eupatorium maculatum*), swamp milkweed (*Asclepias incarnata*), wild bergamot, St. John's-wort (*Hypericum perforatum*), great water dock (*Rumex orbiculatus*), water-pepper or smartweed (*Polygonum hydropiper*), bittersweet nightshade (*Solanum dulcamara*), and bull, Canada and swamp thistles (the latter is *Cirsium muticum*), clearweed (*Pilea pumila*), wild and mountain mints (*Mentha arvensis* and *Pycnanthemum virginianum*), fern species (*Dryopteris* spp.), bedstraws (*Galium* spp.), bluegrasses (*Poa* spp.), blue sage (*Salvia azurea*), and others (Appendix G).

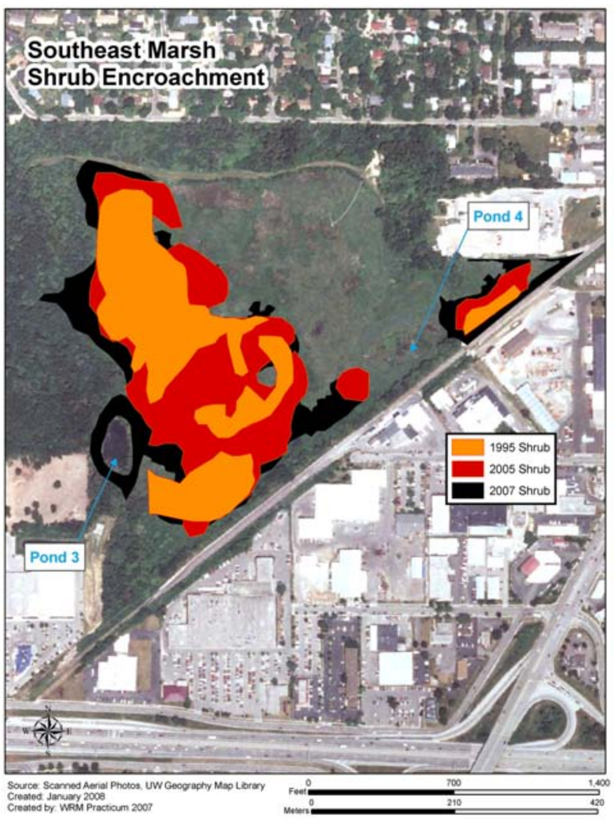


Figure 5.3: Shrub encroachment in Southeast Marsh.

The tree line that delineates the western boundary of the marsh does not appear to have advanced significantly in recent years. However, extensive shrub encroachment was indicated when we compared our plant community boundaries with past aerial photographs (Figure 5.3). The shrub mix on the western side of the marsh includes buckthorn, honeysuckle, red osier dogwood, and sandbar willow (*Salix exigua*). RCG and cattail are rare and minimal in the western side of the marsh, but areas of sedge meadow and other native plant species are being displaced by invasive shrubs. The boundary of the western shrub mix is moving eastward across the marsh.

5.3 Gardner Marsh vegetation

In areas where channels, lagoons, and canals were dredged, the resulting spoil piles were not intentionally revegetated, which created an opportunity for the establishment of non-native, invasive plant species. Currently, invasive species such as common and glossy buckthorns (*Rhamnus cathartica* and *R. frangula*), garlic mustard (*Alliaria petiolata*), and RCG are well established in almost all areas where human manipulation has occurred. While the current vegetation of many regions of Gardner Marsh (Figure 5.2) is a result of human interaction with the marsh, and largely composed of invasive or undesirable species, patches of native communities such as sedge meadows still exist throughout the marsh. The lettered descriptions of vegetation in the paragraphs below correspond to Gardner Marsh polygons in Figure 5.4.

Section A is characterized largely by black cottonwood (*Populus trichocarpa*) along the extent of the old Capitol Avenue remnant, as well as buckthorn and RCG in many other areas. Buckthorn does not allow the establishment of many native species, with perhaps the exception of jewelweed, which exists under the buckthorn canopy.

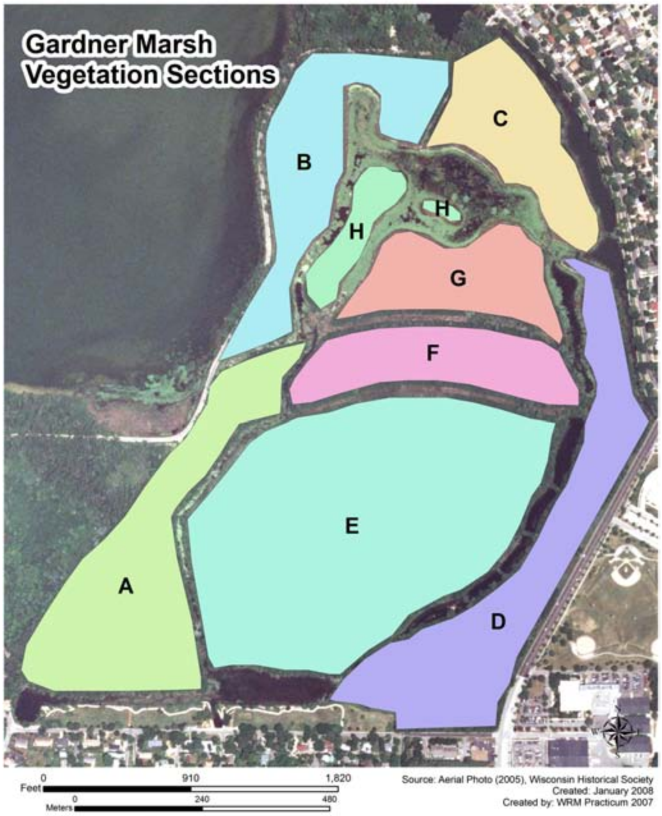


Figure 5.4: Gardner Marsh vegetation polygons. Gardner Marsh was divided into smaller polygons to make describing vegetation easier.

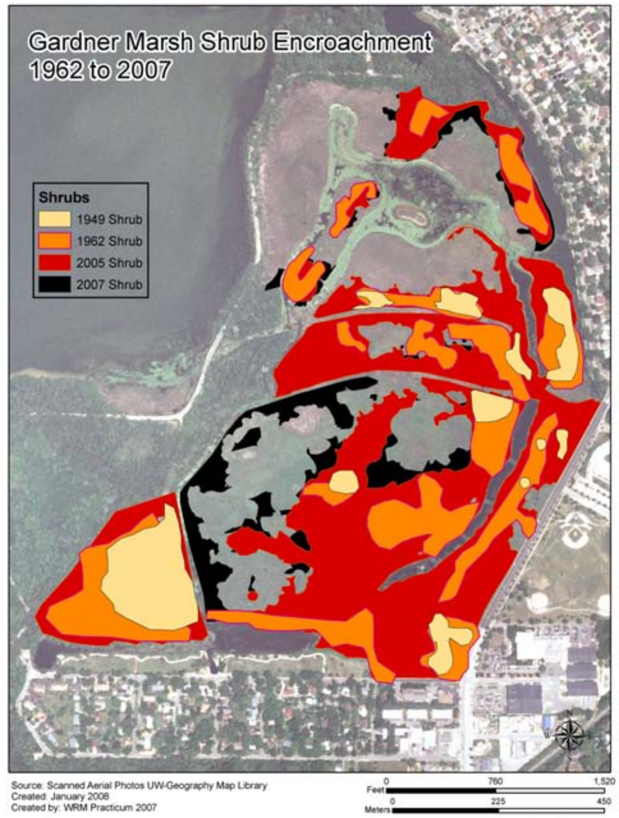


Figure 5.5: Shrub encroachment in Gardner Marsh.

Section B supports a black cottonwood and buckthorn buffer along Arboretum Drive. From the buffer to open water in Pond E-90, cattail species dominate, with broad-leaved cattail (*Tyhpa latifolia*) and narrow-leaved cattail (*T. angustifolia*) present in small numbers, and the hybrid *T.* × *glauca* most abundant. Small patches of willow exist near the northern 'thumb' of open water extending north. Small communities of bur reed (*Sparganium eurycarpum*) and sedge occur adjacent to Arboretum Drive, midway between Red Wing Marsh and the large bend as the drive turns east.

Section C has a medium-size sedge meadow bordering Pond E-90 to the south and the boardwalk to the west. The rest of the area is composed of cattail and a shrub-tree mix. The sedge meadow has several sedge species, including: common lake sedge (*Carex lacustris*), common yellow lake sedge (*C. utriculata*) and American woolly-fruit sedge (*C. lasiocarpa*). Other species observed in this section include rushes (*Juncus* sp.), soft-stem bulrush (*Schoenoplectus tabernaemontani*) and fox sedge (*C. vulpinoidea*). The sedge meadow in this section is threatened by cattail invasion around the periphery, but is otherwise of high quality. In addition, the area of cattail within Section C is where Steven Hall conducted his 2006–7 study of cattail expansion (Hall and Zedler in review).

Section D plant communities are dominated by invasive species. RCG, cattail, and other common roadside plants exist near Fish Hatchery Road. A buckthorn monotype has established on the spoil piles east of the fish ponds, formed as a result of the creation of the ponds. Large eastern cottonwoods (*Populus deltoides*) have also established on the spoil piles surrounding the fish ponds. Although tamarack (*Larix laricina*) was planted in this area in the past, we found no living individuals; only snags remain.

Section E is perhaps the least altered by humans. Consequently, it has healthy populations of a variety of native plant species. However, water levels in the marsh have been significantly lowered since pre-settlement times, resulting in peat subsidence and shrub invasion. Red osier dogwood and buckthorn have heavily encroached upon sedge meadows in some areas.

The southeast portion of Section E has a shrub mixture, predominantly buckthorn, but also box elder (*Acer negundo*), red osier dogwood, and willow. Jewelweed is frequently the dominant ground cover. Following the eastern shrub boundary northward, common reed (*Phragmites australis*) has established. The northeastern and northwestern parts, as well as intermittent pockets in the central and north-central parts of Section E are characterized by large, healthy sedge meadows communities composed of blue-joint grass (*Calamagrostis canadensis*), lake sedge (*Carex lacustris*) and other sedge species. This area is marked by the high diversity of herbs and forbs common to sedge meadows.

The northwest portion of Section E, bordered by the north-south channel on the west, has small, isolated patches of common reed bordered by blue-joint grass and some stinging nettle (*Urtica dioica*). The southwestern portion of Section E has a large meadow consisting of blue-joint grass and RCG surrounded by invasive shrub species. Jewelweed exists between the shrub mix and the meadow on the west and south sides of the meadow. The northeast portion of the meadow is adjacent to a mix of goldenrod species, stinging nettle, and jewelweed. Shrub species are present along the northern edge of the Schmidt Lagoon and continue eastward.

Section F is located between the north and south canals in the central portion of the marsh. Two isolated but large areas of sedge meadow exist between the canals, predominantly composed of lake sedge. Tussock sedge (*C. stricta*) exists in the northwestern portion of the western sedge meadow. Both meadows are surrounded by cattail, which give way to encroaching buckthorn. Beyond the fringe of the buckthorn encroachment is a well-established buckthorn community that makes up the majority of the vegetation between the two canals (Figure 5.5).

Section G is marked by a shrub mix of red osier dogwood, willow, and buckthorn on the southern edge, which borders the northern canal. Cattails have established on the western two-thirds of this portion. The eastern one-third portion consists of a large sedge meadow consisting of lake sedge, fox sedge, wooly-fruit sedge, wire sedge, and bulrush. Shrub species are establishing on the eastern border with Pond E-90.

Section H is composed of the two islands located in Pond E-90. The larger, more western of the two islands is largely inhabited by shrub species on higher ground and cattail and RCG at lower elevations. Box elder, black willow (*Salix nigra*), and buckthorn are relatively abundant on the island. A small portion on the northernmost part of the island has remains of the old Capitol Avenue. A small meadow of blue-joint grass is located directly over the concrete of the old road.

The smaller, more eastern of the two islands comprising Section H is being invaded by cattails from the west. Currently, cattails cover the western two-thirds of the island. A small stand of dogwood populates the very eastern tip of the island. In between these populations is a diverse mix of sedges, forbs and rushes, including Marsh bellflower (*Campanula aparinoides*), Great blue lobelia (*Lobelia siphilitica*), flat sedges (*Cyperus* spp.), spike-rushes (*Eleocharis* spp.) and willow-herbs (*Epilobium* spp.) (Appendix H).

5.4 Diversity comparison

Gardner Marsh was more diverse than Southeast Marsh, both in total species and average number of species per plot. Of interest is that the highest pH levels observed in Southeast Marsh coincided with the highest number of plant species present (Figures 5.6, 5.7). We found fewer plant species in areas dominated by invasive species in both marshes (Figures 5.6, 5.8, 5.9, 5.10). Also, in Southeast Marsh, invasive species tended to dominate the lower, poorly drained areas, while native plants tended to inhabit more well-drained areas. Such trends were not observed in Gardner Marsh.

5.5 Aquatic vegetation in Gardner Marsh

We recorded extensive areas of floating white water lily (*Nymphaea odorata*) on the surface in the main lagoon and in the entrance to Gardner Marsh where we could paddle our canoe, as well as along the shoreline of Wingra Creek. Duckweed (*Lemna* sp.) covered the entire surface of the channel on the east side of the larger island. We saw almost no aquatic vegetation underneath the floating vegetation, likely due to limited light penetration.

We estimated submerged vegetation in all other open areas as approximately 80% coontail (*Ceratophyllum demersum*), 15% milfoil (*Myriophyllum* sp.) and 5% sago pondweed (*Stuckenia pectinata*). Because our survey was done late in the season, we recommend further sampling in both early and late summer to record more species, since some may only be observed in early summer.

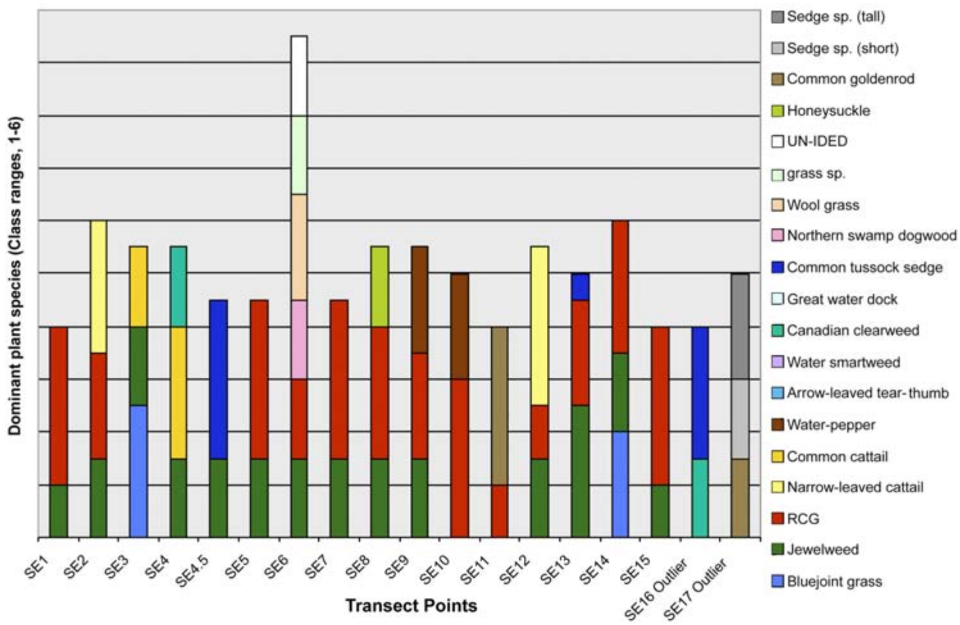


Figure 5.6: Dominant plant species along Southeast Marsh transects.

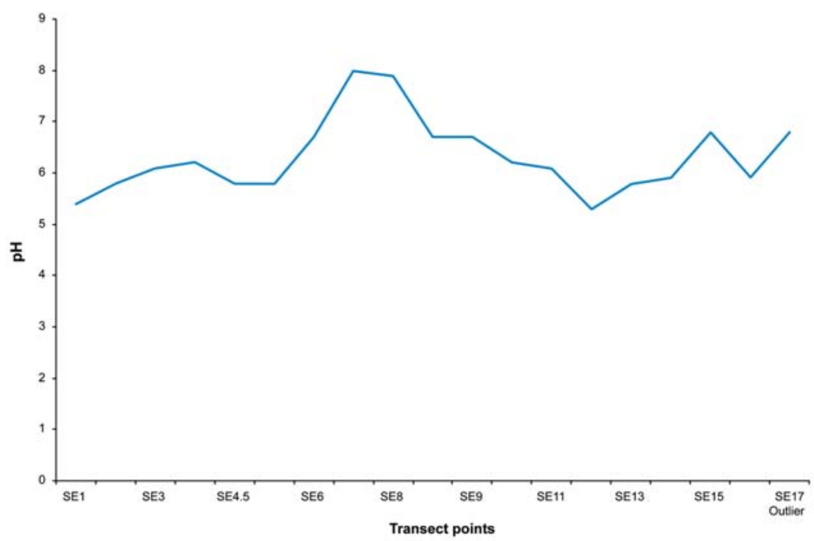


Figure 5.7: Soil pH along Southeast Marsh transects.

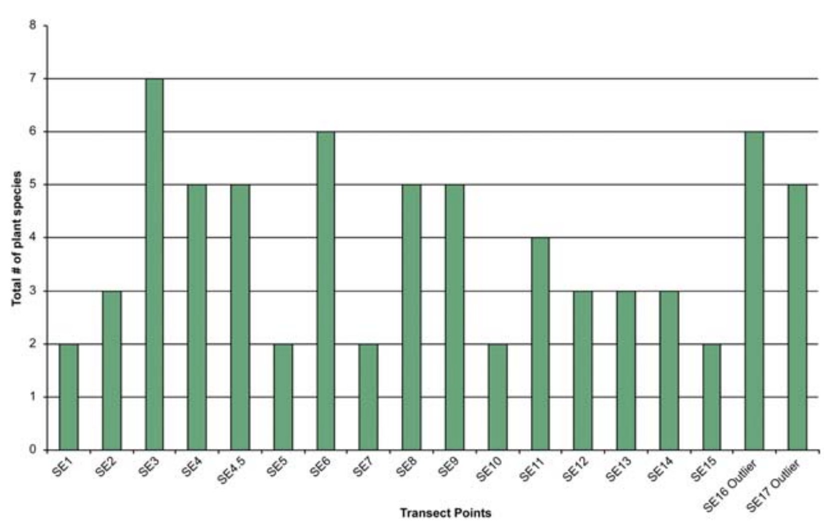


Figure 5.8: Species richness along Southeast Marsh transects.

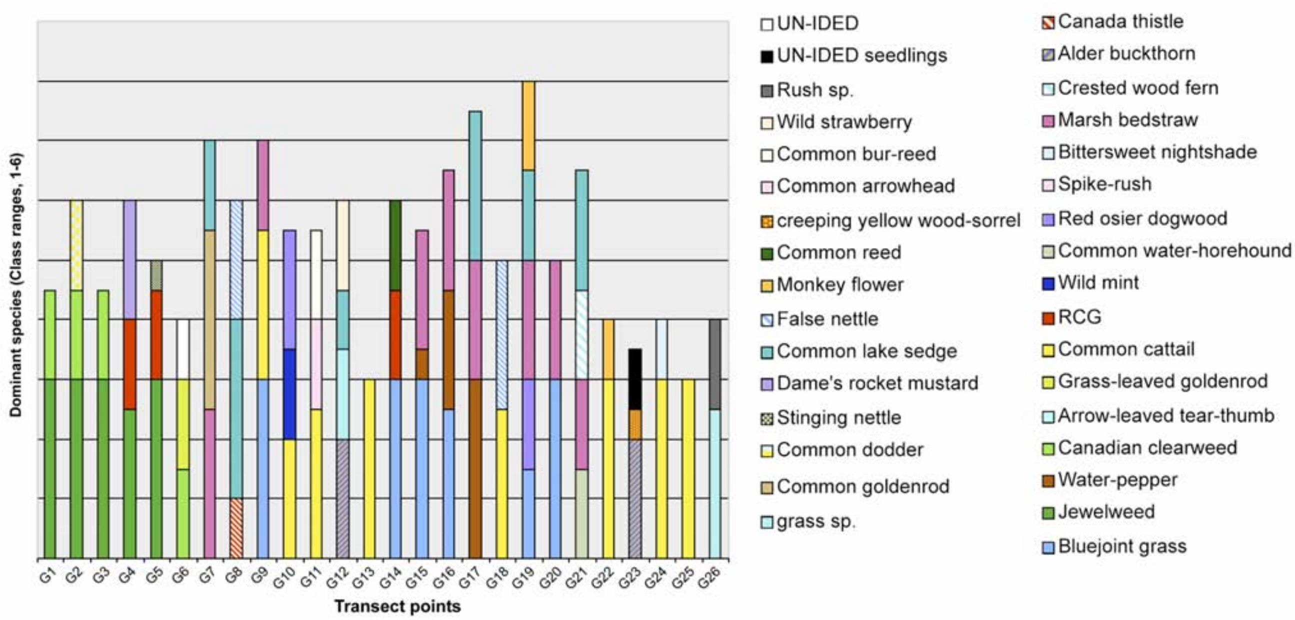


Figure 5.9: Dominant plant species along Gardner Marsh transects.

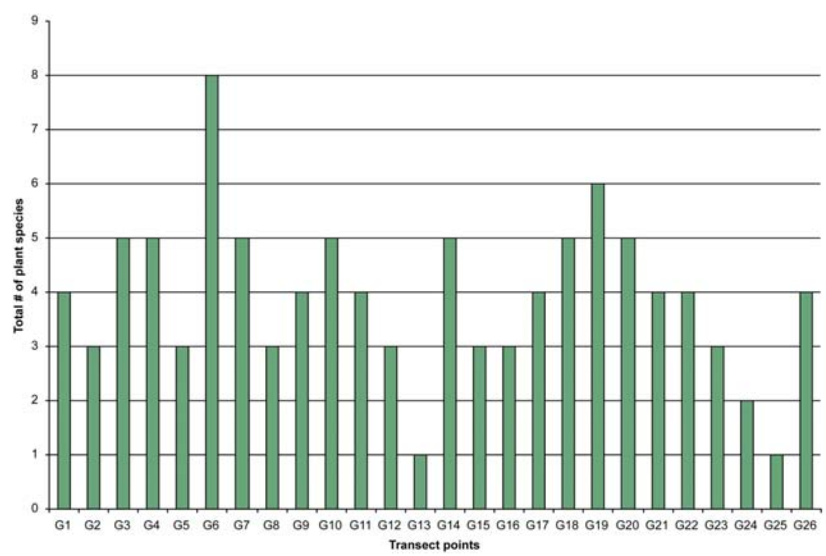


Figure 5.10: Species richness along Southeast Marsh transects.

Chapter 6: Water Quality

6.1 Water sampling

Stormwater of low quality and high volume has significant impacts on the vegetation and habitat of the Eastern Wetlands. Runoff from different areas of the watershed changes in quality as it picks up pollutants. Stormwater is generally thought to contain more pollutants during the "first flush" of a rainfall, especially if the pollutants are in the dissolved rather than particulate form (Lee et al. 2002). However, this effect can vary, depending on the mixing of runoff from upstream and downstream runoff.

We sampled water quality at a small number of key locations (Figures 6.1 and 6.2) and evaluated levels of nutrients, sediments and metals. First, we took samples from the upper reaches of the sewershed in the Arbor Hills Greenway. Then, we focused on stormwater entering Southeast Marsh at Ponds 3 and 4, where access was relatively easy and flows are concentrated in channels. We proceeded to the culvert entering Schmidt Lagoon, in the north-south channel in Gardner Marsh at Redwing Marsh, and finally, we sampled under the Wingra Creek bridge at Fish Hatchery Road where water leaves the Arboretum.

We sampled non-rain conditions to obtain baseline numbers for comparison with samples during storm events. We found high variability in stormwater samples, perhaps due to the length of time between rain events, the stage of the storm we sampled, and because we used a single-point grab sample. Results should be useful in comparing data once Ponds 3 and 4 are fully functional.

Over the summer 2007, we monitored three storm events and three non-storm events. We measured temperature, nitrogen, phosphorus, transparency, total suspended solids and pH in the field (Appendix I). Samples were taken to the State Laboratory of Hygiene for metals and additional nutrient analysis. Storm event sampling occurred at the beginning of a rain event once runoff entered Southeast Marsh in an attempt to capture the initial pulse of metals, nutrients and sediments coming into the system.

Figure 6.1: Stormwater sampling locations during storm events.

Figure 6.2: Stormwater sampling locations during nonstorm events.

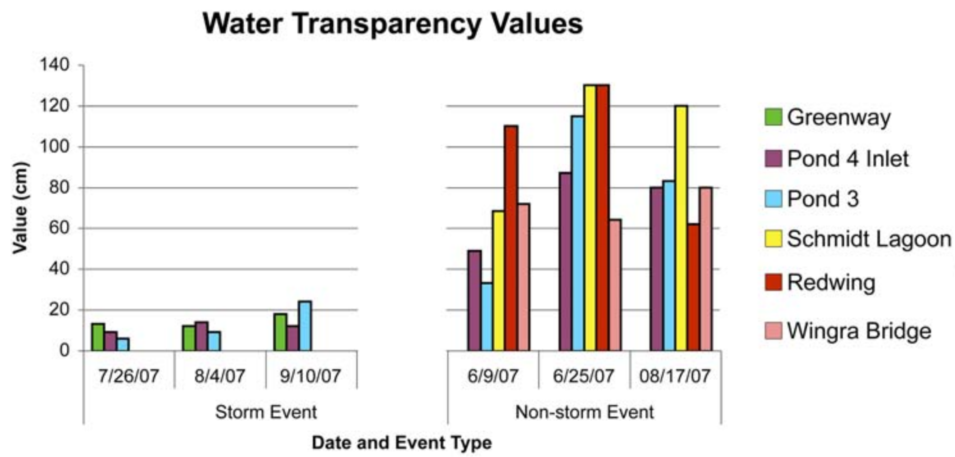


Figure 6.3: Water transparency (clarity) (cm).

6.2: Water quality during non-storm and storm events

Transparency ✦ We measured water clarity using a transparent tube 4 ft (120 cm) long and 3 in (8 cm) in diameter with a secchi disk at the bottom. Transparency is generally high during non-storm events because turbidity is low. On 6/9/2007 values were lower in the pond locations due to visible algal blooms in these areas (Figure 6.3).

Average summer transparency values for non-storm events were 77 cm at Pond 3, 72 cm at Pond 4, 106 cm at Schmidt Lagoon, 72 cm at the Wingra Bridge and 100 cm at Redwing Marsh. Average transparency values during storm events were 13 cm at Pond 3, 11.6 cm at Pond 4 and 14 cm at the Greenway. At the same locations in ponds 3 and 4 transparency was 6 times higher during non-storm conditions than storm events.

Total suspended solids (TSS) ✦ Vegetation slows the flow of the stormwater, settles suspended solids and reduces pollutants in the water column (Johnston 1991). Because little water moves during non-storm sampling, sediments and other particulates had time to settle out of the water column, and our TSS values were low.

TSS values during non-storm sampling were influenced by algae. Average summer TSS values for non-storm events were 9.7 mg/l at Pond 3, 9 mg/l at Pond 4, 5.3 mg/l at Schmidt Lagoon, 9.3 mg/l at the Wingra Bridge and 7.7 mg/l at the Redwing Marsh sampling site. Average values for TSS during storm events were 67 mg/l at Pond 3, 53 mg/l at Pond 4 and 19 mg/l at the Greenway (Figure 6.3). In Pond 3 and 4, TSS values during storm events were 6-7 times higher at the same locations than non-storm events. These higher values indicate that rain transports large quantities of sediment and other small particles in stormwater (Figure 6.4).

Figure 6.4: After a storm in 2007, Josh Brown collected a water sample at the Martin St. culvert, which drains Southeast Marsh. The water was dark due to a high sediment load.

The sample on July 26, 2007 was taken after nearly one month without any rain. As we arrived at Pond 3, the inlet was dry. After 5 minutes, the first pulse arrived and we captured it, as evidenced as the very high TSS values of 146 mg/l (Figure 6.5).

pH • The pH values were very close to neutral most of the time during non-storm events. On average, values lowered to pH 6 during storm events meaning the water became more acidic. We did not have access to a pH probe, which would have given more precise values. Future sampling would benefit from more precise measurements.

Nitrate • During storm events, nitrate averaged 4 times higher in Pond 3 and 7 times higher in Pond 4 than during non-storm conditions. The highest nitrate values were during the first stormwater event, measuring 10.5 mg/l at Pond 3, 10 mg/l at Pond 4 and 8.7 mg/l at the Greenway. Non-storm values were less than 2 mg/l at all sites (Figure 6.6).

Phosphorus • Soluble reactive phosphorus (SRP) dissolves in water and is readily available for plant growth. Concentrations vary widely in most waters over short periods of time as plants absorb and release it. SRP values during storm events averaged 1.7 times higher in Pond 3 and Pond 4 than during non-storm conditions. The highest SRP values were during the first stormwater sampling event, measuring 1.89 mg/l at Pond 3, 1.34 mg/l at Pond 4 and 1.6 mg/l at the Greenway. Non-storm event values were typically much lower than 1.0 mg/l at all sites (Figure 6.7).

Lake water is considered eutrophic when total phosphorus water concentration exceeds 0.025 mg/l (Lillie et al. 1983). All of our samples greatly exceeded this level, with average values 18 times greater in Pond 3, 19 times

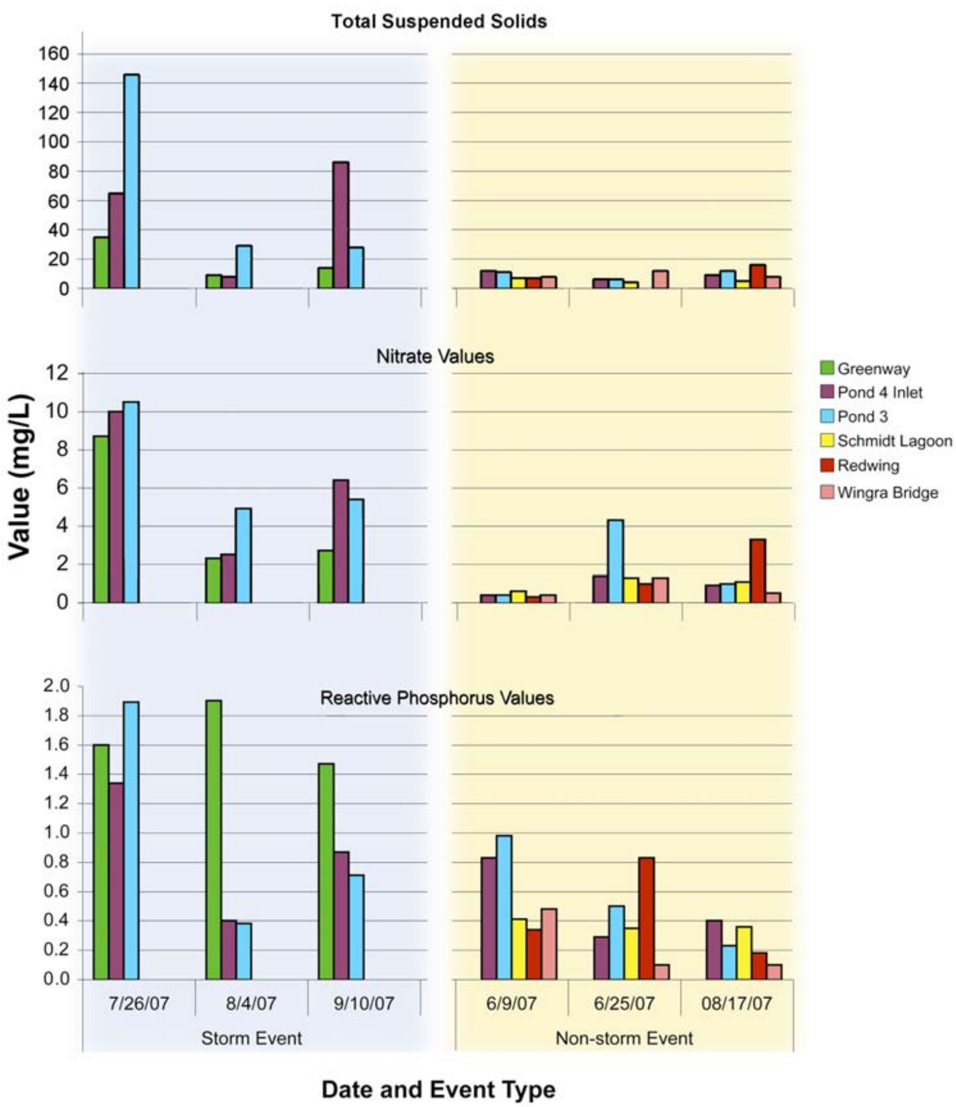


Figure 6.5:
Total suspended solids (mg/l).

Figure 6.6:
Nitrate levels (mg/l).

Figure 6.7:
Soluble reactive
phosphorous levels (mg/l).

Date	7/26/07			8/4/07			9/7/07			Average Of 7/26, 8/4, 9/7 Values		
Site	Pond 3	Pond 4	Greenway	Pond 3	Pond 4	Greenway	Pond 3	Pond 4	Greenway	Pond 3	Pond 4	Greenway
Total P (mg/L)	0.835	1.03	0.99	0.284	0.131	0.496	0.262	0.249	0.531	0.5	0.5	0.7
Aluminum (ug/L)	8930	1480	572	1600	904	80	1180	936	179	3903.3	1106.7	277.0
Cadmium (ug/L)	0.3	0.42	0.34	ND	0.24	ND	0.11	0.11	0.13	0.1	0.3	0.2
Chromium (ug/L)	18	13	5	4	7	1	2	4	1	8.0	8.0	2.3
Copper (ug/L)	59	91	19	9	28	4	16	20	8	28.0	46.3	10.3
Iron (mg/L)	10.3	2.6	1.3	2.1	2.1	0.1	1.3	1.5	0.3	4.6	2.1	0.6
Lead (ug/L)	8.9	17	5.8	1.8	11.8	ND	1.8	10	ND	4.2	12.9	1.9
Zinc (ug/L)	113	396	148	22	165	10	34	116	37	56.3	225.7	65.0
P/.025 (eutrophic levels)	33.4	41.2	39.6	11.36	5.24	19.84	10.48	9.96	21.24			
Average P	38.066			12.147			13.893					

Figure 6.8: Metals and total phosphorous levels during storm events.

greater in Pond 4 and 27 times greater in the Greenway. Except for the first flush of runoff at Pond 3 on 7/26/2007, stormwater had already passed at other sites and on other sampling dates before taking our samples. A future study should describe rain events more thoroughly.

Our water samples were analyzed for aluminum, cadmium, chromium, copper, iron, lead and zinc (Figure 6.8). Some of these metals were likely from human sources, due to high amount of impervious surfaces surrounding this watershed. For example, copper is released with metal corrosion, brake-pad wear on cars, industrial paint, and electroplating waste (Burton and Pitt 2002). Principal sources of lead within the watershed include peeling and chipping leaded paint, contaminated soils, vehicle wear, and batteries. "Zinc is a ubiquitous urban Stormwater contaminant; prominent sources include tire wear, galvanized steel, metal corrosion, road salt, and rubber" (Burton and Pitt 2002).

We recommend continued monitoring throughout the year. Remaining nitrate and reactive phosphorus standards for the Hach Kit would support monthly sampling for at least one to two years.

Chapter 7: Improving Stormwater Quality in the Arbor Hills Greenway

7.1 An opportunity to improve stormwater quality in the watershed

Stormwater runoff from the Arbor Hills Neighborhood converges at its Greenway, which is a continuous tract of green space within a highly impervious watershed. These characteristics make the Greenway a priority location for increasing infiltration within the Southeast Marsh watershed. Earlier, the Arboretum recognized the potential infiltration opportunity in the Greenway and asked students in the Biological Systems Engineering (BSE) Senior Design Class (supervised by Drs. Anita Thompson and John Panuska) to draft plans to re-design the area with the goal of increasing infiltration. One component of the BSE project was to analyze the existing hydrology of the Greenway and design a system to minimize stormwater volume. The BSE project included engineering analysis, field-testing, safety consideration and economic analyses.

Since the Greenway is owned by the City of Madison, a key to advancing city participation and implementation is to gain residential support for a re-design is crucial. In partnership with the BSE students, we gathered residential opinions through a mail survey regarding current use and future options for the Greenway re-design (Figure 7.1).

Figure 7.1: Existing conveyance channel in the Arbor Hills Greenway. Visible are large amounts of sediment and particles transferred from the upstream watershed to the Eastern Marshes.

7.2 Survey methods

Based on conversations with Drs. Anita Thompson and John Panuska, we identified key topics to survey opinions of residents, namely, the existing concrete channel, the recreational use in the greenway, potential standing water or retention ponds, and addition of native vegetation. Before we distributed the survey, it was reviewed and approved by Arboretum staff and the UW Institutional Review Board for compliance with human subjects research policy.

We developed and distributed the survey in cooperation with the Arbor Hills Neighborhood Association. Sheri Carter, President of the Arbor Hills Neighborhood Association, reviewed and endorsed the survey at their monthly meeting. She provided residents with background information on the potential re-design project and encouraged residents to share their opinions by completing the survey. The cover letter and survey (Appendix K) incorporated four sections: demographics and current use, background knowledge of stormwater and the Greenway, current opinions of stormwater and the Greenway, and additional comments. The cover letter stated our background and involvement in the potential re-design of the Greenway. The letter also briefly described the path of stormwater from Arbor Hills to Monona Bay and explained the concept of infiltration. This helped define some of the technical aspects of the project and strengthened the residents' understanding of the topic. Household demographics were included to relate Greenway activities with age and location of the resident. Uses of the Greenway were collected based on specific activity and the frequency at which they participate in such activities. Additionally, we asked for specific reasons why residents do not use the Greenway. This section was meant to frame the residents' opinions in the next section by determining their background knowledge. This section also assesses the need for neighborhood education. Responses were requested on a formatted scale ranging from 'strongly disagree' to 'strongly agree.' The purpose of the scaled answers was to provide neutral ground for each question. The survey asked for opinions relevant to the planting of native grasses, standing water, attracting wildlife, safety concerns, and future uses of the Greenway. It was intended to provide direct feedback to potential re-design options (i.e., retaining standing water). Lastly, the survey provided the opportunity for respondents to indicate concerns beyond our perspective.

7.3 Opinion survey results

Of 578 surveys mailed out, 137 residents responded (26%). The majority (57.7%) of respondents did not currently use the Greenway. Such respondents did not use the Greenway mainly because of safety (14.28%), location (32.14%), or other reasons (50.89%). Of the residents who did use the Greenway, the most popular uses included walking/running (88.9%), winter activities (22.2%), and pet activities (16.7%).

Of those who strongly disagreed with the current conditions of the Greenway, 62.22% strongly agreed that the Greenway would be more appealing if the concrete channel were replaced with native vegetation. Overall, the majority of all respondents (56.9%) moderately agreed or strongly agreed with this statement. Only 8.7% of people strongly agreed with the current conditions of the Greenway. Of all respondents, 59.1% strongly agreed or moderately agreed that it was good for stormwater to move through the Greenway without prolonged standing water. However, 65% of respondents also strongly or moderately agreed that it was important to increase infiltration to improve the quality of stormwater entering the Arboretum.

There was overwhelming support for an increase in native plants. Many additional comments were written supporting the installation of rain gardens in the Greenway, or just an increase in native plants throughout the Greenway. Additionally, 79.6% of respondents strongly or moderately agreed that native plants are attractive. These trends were discerned from both specific questions and additional comments. The residents support increasing native vegetation in the Greenway and removing the concrete channel. The majority of residents were against prolonged standing water in the Greenway. Finally there was collective opinion towards the importance of protecting the Eastern Arboretum Marshes from further stormwater degradation.

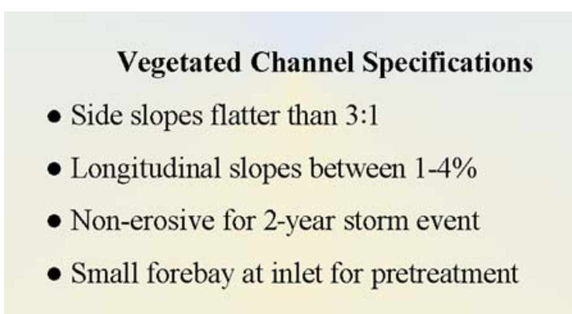


Figure 7.2 General design specifications for a vegetated channel (Caraco and Claytor 1997).

Figure 7.3 General schematic of a designed vegetated swale. Source: Center for Watershed Protection, Stormwater BMP Design Supplement for Cold Climates. http://www.cwp.org/cold-climates.htm

Results support the need to improve water quality by filtering out sand and nutrients before exiting the Greenway. This alone suggests support exists for a re-design. However, to gain strong support of specific designs, options should consider trends in residents' opinions. Residential support is a central component to implementing a design. Therefore, the BSE Senior Design class and the Arboretum should strongly consider the results of our survey when designing options. While strongly considering such opinions, designs also need to meet infiltration goals.

Residents appear to favor replacing the existing concrete channel, avoiding prolonged standing water, and increasing native vegetation. Both a vegetated channel and wet swale would be consistent with public opinion that prolonged standing water be avoided. The opinions expressed in the surveys do not support permanent detention ponds, or a temporary retention area in the Greenway which would result in standing water. However, detention ponds may maximize infiltration in the Greenway. Additionally, while many residents supported removing the concrete channel, using it in a re-design would limit the project costs. Such pros and cons are considered below for three options: vegetated channel, wet swale, and detention ponds.

Vegetated channel • In place of concrete, vegetation would increase hydraulic roughness of the bed with intentions to slow water movement and improve water quality through filtration and infiltration. Such engineered channels have a broad, mildly-sloped channel with thick vegetative cover. The design is based on a flow rate maintaining a minimum residence time of ten minutes for incoming water (Caraco and Claytor 1997). Densely planted native grasses should be tested for their ability to slow water flow, infiltrate water, and remove sediments, nutrients and contaminants.

The Arbor Hills Greenway has a moderate slope and therefore a vegetated channel should meander to meet slope recommendations. The meandering design acts like switchbacks to create a gentler slope for the path of water. By reducing the velocity through meandering, erosion potential is also reduced. A vegetated channel should be designed to be non-erosive for a two-year storm event (Caraco and Claytor 1997). This option would slightly increase infiltration by removing the impervious concrete channel and slowing the velocity of stormwater, but it is unclear how long it would take for the added benefit of infiltration to exceed the associated cost (Figures 7.2, 7.3).

Wet swale • A moderate slope can accommodate a swale with vegetation planted more densely than the native grasses recommended for a vegetated channel. The design is similar to the vegetated channel, but the slope is steeper. Check dams can also be used to maintain an appropriate slope (Caraco and Claytor 1997). The Greenway currently has drop structures installed to maintain a slope along the concrete channel. Removing the concrete channels but leaving the drop structures would greatly reduce

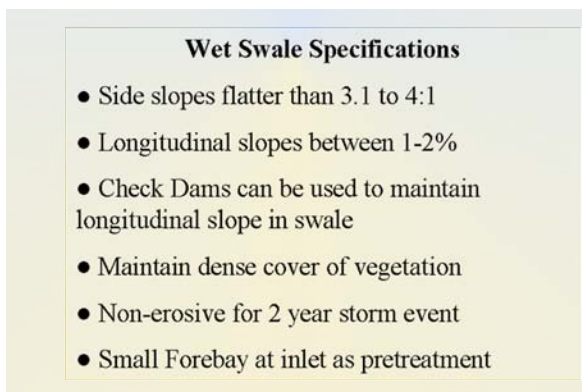
Figure 7.4 View of the Arbor Hills Greenway and the existing drop structures.

the associated costs (Figure 7.4). This option is less costly then a vegetated channel; it should increase both infiltration and filtration of stormwater.

This option is likely to be supported by neighborhood residents based on their desire to increase native plants and avoid prolonged standing water. Yet while public opinion may support this design, a wet swale might not sufficiently improve the quality of stormwater entering Southeast Marsh (Figure 7.5, 7.6)

Detention pond • A detention pond could maximize infiltration potential. Such ponds are used to capture and hold large amounts of stormwater, allowing water to infiltrate. In addition to infiltration they are often used for flood control in newly developed areas and groundwater recharge. While ideal for increased infiltration, the narrow shape of the Greenway limits some design options, and more than one pond might be necessary.

Pond construction has high costs, and this option is not supported by residents concerned with the dangers and nuisance of prolonged standing water. Detention ponds would need to be designed to limit the residence time of captured water. In addition, safety precautions would be needed, such as limiting the maximum depth and providing a shoreline shelf.



Wet Swale Specifications

- Side slopes flatter than 3.1 to 4:1
- Longitudinal slopes between 1-2%
- Check Dams can be used to maintain longitudinal slope in swale
- Maintain dense cover of vegetation
- Non-erosive for 2 year storm event
- Small Forebay at inlet as pretreatment

Figure 7.5 General design specifications for a wet swale (Caraco and Claytor 1997).

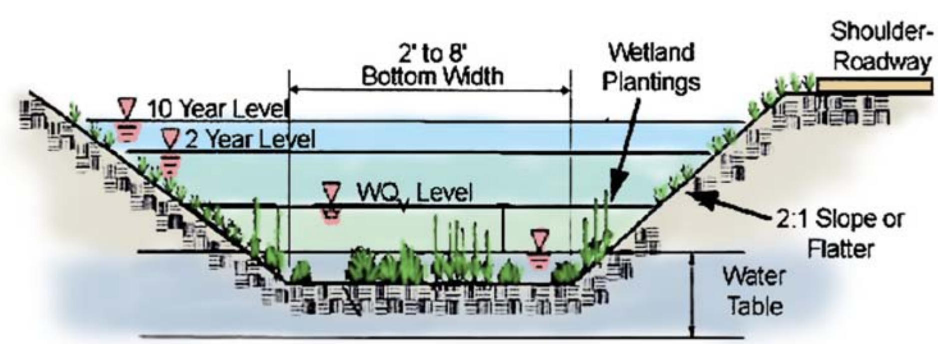


Figure 7.6 General schematic of a designed wet swale. Source: Center For Watershed Protection, Urban Stormwater Retrofit Practices. http://www.cwp.org/PublicationStore/USRM.htm#usrm3

Chapter 8: Improving Stormwater Quality in Southeast Marsh

8.1 Repairing Ponds 3 and 4

As natural low points in a landscape, wetlands receive inflows containing sediment, nutrients and pollutants as water moves down-gradient. While low-lying wetlands can be used to improve water quality, natural wetland ecosystems are not necessarily able to filter large volumes of urban stormwater. Even though Southeast Marsh was once considered a "stormwater detention basin," the opportunity exists to improve the quality of water exiting the marsh, while maintaining flood protection and creating habitat within Ponds 3 and 4. Thus, the highest priority is to repair the two wet detention basins, Ponds 3 and 4.

Nutrient removal is a primary goal of pond re-design, and phosphorus removal is often the focus for stormwater improvement. Phosphorus inflows to Wingra Creek and Lake Monona can cause summer algal blooms. Nitrogen loading is also a significant problem for downstream wetlands, where nitrogen can enhance growth of invasive plants, such as reed canary grass. Thus, the re-design of Ponds 3 and 4 should consider increasing the capacity for denitrification in addition to the standard design considerations of storage volume and sediment capture.

Pond re-design could also aim to enhance macrophyte species richness. Macrophytes can provide habitat for invertebrates, birds, fish, reptiles, and amphibians. In small experimental pools, Englehardt and Ritchie (2001) showed that a species-rich macrophyte assemblage removed more phosphorus than single species. Ponds 3 and 4 could provide areas to test the functioning of diverse vs. monocultures of native macrophytes.

Pond 3 • In its current state, Pond 3 does not function as a trap or filter; instead sediment, nutrients, pollutants, non-native plant propagules, and trash are dispersed into the marsh. Maintenance actions recommended for Pond 3 in the Arboretum Stormwater Management Plan include dredging, repair of outlet structures, re-design of the gabion stormwater channel leading into the basin, woody plant removal, revegetation of the pond perimeter with native plants, and routine maintenance.

1. ***Dredge.*** The pond should be dredged to its designed depth to accommodate stormwater flows and trap 60% of the total suspended solids. Its location in an upland area near an access point should minimize the impact of dredging equipment on healthy marsh areas. While machinery used for dredging will have environmental impacts on the upland areas surrounding the pond, much of the vegetation is invasive buckthorn and honeysuckle and in need of removal. Removal of invasive vegetation could be combined with dredging efforts to minimize costs and impacts on the marsh.
2. ***Repair failed outlet structure.*** Pond 3 features two corrugated metal pipe outlet structures, one on the north end and one on the northeast corner of the pond. The outlet structures are placed at a designed height, allowing sediment to settle and water to overflow into the marsh. The side of the northeast structure has rusted through, leaving a hole approximately 2 ft (0.6 m) from the top of the structure, and measuring approximately 1.5 ft (0.45 m) wide. Stormwater moves quickly through the pond, reducing the amount of sediment that can settle. This structure should be replaced and the other structure cleaned to work properly. The improved outlet structures should reduce stormwater dispersal and slow the degradation of Southeast Marsh.
3. ***Repair the gabion net upstream of Pond 3.*** In recent decades, stormwater flowed unimpeded into Southeast Marsh through a severely eroded channel (Steve Glass, personal communication, 2007). A large stormwater culvert draining the Arbor Hills neighborhood is located adjacent to the eastern edge of the Steinhafels parking lot immediately upstream from Pond 3. Flashy runoff flows north from the highly urbanized watershed through a rip-rapped channel, which was installed in August 2004 with a gabion net to catch debris and sediment.

   The gabion net is in disrepair. During a stormwater event in July 2007, we observed severe erosion, exacerbating sedimentation in the basin. It is not clear if the gabion net ever functioned properly or if any debris it caught was ever removed. The riprap channel should be repaired and the gabion net should be reevaluated and either repaired or removed.

4. ***Routine maintenance.*** Both Pond 3 outlet structures are choked with woody debris and vegetation, preventing the passage of stormwater. Furthermore, trash and litter blanket the area around the pond. The site needs to be visited regularly to check for proper functioning of outlet structures and roundup litter. Perhaps the administrative responsibility could be shared between the Arboretum and the cities of Madison and Fitchburg.
5. ***Woody vegetation removal and revegetation.*** The berm that surrounds Pond 3 and separates it from the marsh is heavily vegetated. The majority of the woody vegetation is staghorn sumac (*Rhus typhina*). As shrubs and trees mature, their roots deepen and threaten the structural integrity of the berm by creating "tunnels" where stormwater can leak and erode. Additionally, as trees grow taller, they are more likely to fall over during a storm event, potentially upending roots and damaging the berm. If a full breach occurs, the basin will fail and sediment, nutrients, pollutants, non-native plant propagules, and trash will flow down-gradient into valued water bodies.

   Woody vegetation should be removed from the eastern berm. As replacements, we suggest adaptive revegetation, testing plots of native herbaceous species on the upland areas and submergent vegetation along the pond edge. Replicate plots of different plant assemblages would create research opportunities to determine which native species best resist the invasion of exotic plants such as reed canary grass, invasive cattails, and others. Additional research could study inundation tolerance, denitrification capacity and nutrient uptake of plant species.

Pond 4 • Pond 4 requires a full reconstruction effort, as the basin drained when the western berm failed. An engineering firm is designing a new basin and planning to break ground in 2008 (David Liebl, personal communication, 2007). The primary objectives are to contain a ten-year storm event, safely pass a 100-year storm event, and to reduce 60% of total suspended solids(WDOA 2006). This is a significant upgrade from the previous basin, which was only designed to safely pass a 10-year event. The basin will also perform the standard wet detention basin functions of capturing coarse sediment, reducing downstream erosion and cycling nutrients such as nitrogen and phosphorus. To meet these objectives, the basin will be expanded from 2.5 acres (1.01 ha) to 6.5 acres (2.63 ha).

The new basin will offer opportunities to support biodiversity and treat stormwater. For many constructed wetlands, "the present-day focus is usually on nutrient dynamics or biodiversity, but both are seldom treated simultaneously;" though such ecosystems "would benefit from establishing communities with as high a diversity of plants as is ecologically realistic and logistically feasible—diverse communities will probably require minimal maintenance and monitoring because they are generally effective at excluding undesirable invaders" (Kennedy et al. 2002). These findings combined with the Arboretum's (2000) plan to "advance the discipline of restoration ecology and help to improve the practice of ecological restoration" suggest that the basin should be constructed in a manner that maximizes biodiversity.

Rather than a traditional pond design with uniform depth and slope around the fringes, we propose varying depths and slopes to support native macrophytes along the pond border. A diverse population of macrophytes will in turn provide habitat for microbial communities and invertebrates, which can increase the treatment capacity of the pond. We suggest "benches" measuring 6.56 ft (2 m) by 32.8 ft (10 m) placed at depths of 3 ft (0.91 m), 4 ft (1.22 m), and 5 ft (1.52 m). Ideally there would be 3 to 6 replicates of each depth within the pond, relatively interchangeable in location in the design phase. Spacing of depth treatments should take into account areas with different flow rates, with a experimental blocks in areas with high and low flow. If desired, slopes could be varied rather than depths, for example, treatments ranging from 3:1 slope to 5:1. Combinations of varying slopes and depths could also be created during pond construction. Topographic variability along the basin fringe should increase the potential to support diverse macrophytes, if species that prefer different depths are included in the plantings.

Retention basins should be more effective in filtering stormwater if they include a diversity of higher aquatic plants to slow and spread water flows. Diverse vegetation also provides varied substrates for biofilms (microbial communities associated with the living and dead plant tissues and detritus, including denitrifying bacteria), which mediate nutrient and pollutant retention (Kadlec and Knight 1996). Constructed wetlands that are managed to prolong contact between water and biofilms have the greatest water-treatment potential (Wetzel 2001). Furthermore, heterogeneous edges will increase surface area, potentially increasing denitrification (Hansson et al. 2005). Given plots with diverse assemblages, future researchers can determine how various species function in stormwater facilities.

Part of the Arboretum's (2000) vision is that its "collections of ecological communities and horticultural plantings illustrate exemplary land management practices and are a valuable resource for research, teaching, and outreach." We suggest that the Arboretum stormwater basins be capitalized upon by ensuring that they support native biota and that the amount and quality of habitat be assessed and reported (Figure 8.1). Furthermore, any threats to the health of wetland biota should be documented and reviewed (Knight et al. 2001). Considerable research can be done to determine how stormwater treatment basins can best provide habitat and support biodiversity.

Figure 8.1: A stormwater pond with diverse vegtation, showing that native species can grow along the edges of such created wetlands.
http://www.jfnew.com

Chapter 9: Restoration Options—Hydrologic Modification

In this chapter we consider the individual components of the hydrologic system and explore alternatives for each. Then, in Chapters 13 and 14, we consider these options and those from previous chapters to provide comprehensive restoration plans.

9.1 Southeast Marsh—Outlet

Outlet culvert modification • The culvert under the Martin Street berm is the only outlet from Southeast Marsh. Evapotranspiration is considered minimal in the marsh relative to the high volumes of water in the marsh after rain events; therefore, water released at the culvert essentially controls the depth of water in the marsh. Currently, the rate of flow is determined by the capacity of the culvert and the depth of the water in the marsh.

Modifying the outlet to include a variable control structure such as a stop-log dam would allow Arboretum managers to control the depth of water to benefit desired species or to continue experiments. Wetter soils should support native wetland vegetation and limit the encroachment of invasive shrubs (Chapter 10). A control structure would also allow managers to slow the pulses of water, increase water residence time, and potentially enhance denitrification rates in the marsh. It would also slow the release of stormwater to Gardner Marsh and Wingra Creek. Impounding water in Southeast Marsh could benefit downstream water bodies, but increased flooding could potentially expand the area of cattails in Southeast Marsh.

Overland flow in Southeast Marsh • The outlet structures from the repaired Ponds 3 and 4 (Chapter 8) should be designed to increase overland flow through the marsh and reduce channelization. Currently, water exits the stormwater ponds and flows into eroded channels that shuttle water through the marsh. During large storm events, water overflows the channels and inundates much of the marsh. But during smaller events, the channels convey the stormwater to the outlet culvert leaving large areas of the marsh dry, allowing shrubs to invade the marsh from the nearby uplands. Spreading the flow from Ponds 3 and 4 throughout the marsh should allow more removal of nitrates from the stormwater before it exits Southeast Marsh.

9.2 Gardner Marsh—Maintenance of appropriate depths in open water areas

To prevent flooding in the Carver-Martin Street neighborhood, channels must be able to handle precipitation events. The most straightforward solution is to maintain appropriate depths and outlets in Schmidt Lagoon, the north-south channel, Pond E-90 in Gardner Marsh and the outlets to Wingra Creek. The conveyance capacity of theses key areas is likely reduced by accumulation of sediment and organic matter. Future dredging may be needed to maintain proper conveyance.

The two canals in Gardner Marsh are dominated by invasive cattails, and they might lower marsh water levels by acting as drainage ditches (Friedman 1986). Allowing these canals to fill—or actively filling them—could benefit the marsh. Earlier plans suggest using the canals to convey water (Michaud 1994, Friedman 1986); however, we recommend other options (Chapter 13).

9.3 Gardner Marsh—Control structure at the CCC Dam

Water level control is often indicated as necessary to restore native plant communities within Gardner Marsh (Irwin 1973; Bedford, Zimmerman et al. 1974; Friedman 1987; Michaud 1994). With a system as complex as Gardner Marsh, the most viable control would be at the outlets to Wingra Creek. Thus, the CCC Dam and outlet structures would need to be repaired, and some form of control at Outlets 2 and 3 would be needed. Repairing the CCC Dam would allow managers to control and vary water levels within the marsh. Arboretum managers could then change water levels as desired to study the effect of depth on particular plant or animal communities. The height of the control structure would need to be managed so that water would not back up into the Carver-Martin Street neighborhood, and the maximum height of the control structure could be set to prevent such flooding.

Because dams and culverts require continual maintenance and eventual replacement, a rock riffle might be a suitable alternative in Gardner Marsh. It could be built to the specified height to control water levels within the marsh. A riffle structure does not allow the same ability to manipulate water levels in the marsh, but it would reduce the need for intensive management on the part of Arboretum staff. For either a riffle or the dam to work, the other two outlets between Gardner Marsh and Wingra Creek would need to be filled. Because the peat underlying the marsh could sink over time, especially with the addition of rocks, this option would require annual inspections of the structures and occasional addition of rocks to maintain the desired riffle height.

With any water control option, the crucial decision is the height of the structure. Freidman (1987) described an elevation of 845.96 ft (257.85 m) as providing an appropriate water depth to restore peat in the marsh. Similarly, Michaud (1994) recommended an elevation of 847 ft (258.2 m), but noted that such a height would flood the Carver-Martin Street neighborhood. The option described by Friedman (1987) allows for some improvement in water depth, while that of Michaud (1994) would require building a berm to separate the marsh from the neighborhood, with added expense, disturbance and maintenance.

9.4 Gardner Marsh—Reconnect to Lake Wingra

Arboretum staff and past researchers have suggested reestablishing the hydrological connection between Lake Wingra and Gardner Marsh (Bedford et al. 1974; Arboretum Adaptive Restoration Task Force, personal communication, July 2007). Such a connection would increase water levels in Gardner Marsh and benefit desired vegetation. It could also allow fish and wildlife movement between the two areas, making new habitat available (Chapter 11). Reconnection might, however, increase the number of carp in the marsh.

Reconnection could be accomplished with a series of culverts with slots for stop logs to control the water level or by converting sections of McCaffrey Drive to a raised boardwalk for a constant connection. Culverts with stop logs would require managers to monitor water levels and adjust the control structure to maintain desired conditions. The diversion could be temporary or continuous. In the boardwalk scenario, McCaffrey Drive would become a non-motorized path (no vehicular traffic). Closing a section of McCaffrey Drive would benefit animal passage over the road, as well as foot and bicycle traffic. Currently, bends in the road make it difficult to see animals and people.

In considering a connection, it is important to take into account the existing differences in water levels between Gardner Marsh and Lake Wingra and to determine how Lake Wingra water levels (now regulated by the Wingra Dam) would be affected by direct outflow to Gardner Marsh. Lake Wingra is heavily used for swimming, boating and fishing, and any significant change in water level could impact these uses. Increased water levels in the Carver-Martin Street neighborhood are also a consideration. Gardner Marsh water levels are lower than existing Lake Wingra levels. Gardner water levels are determined by Lake Monona levels, which in turn are determined by the Lake Waubesa Dam at Babcock Park.

The water control structure at the site of the CCC Dam would need to be repaired in order to gain control of in-marsh water levels and raise them higher than the adjacent Wingra Creek. If this were accomplished, and if in-marsh water levels were raised, the difference in water level elevation between Gardner Marsh and Lake Wingra would be minimal upon reconnection.

It would be opportune to coordinate reconnection of Lake Wingra and Gardner Marsh with road construction planned to move the lake's overflow point. Under current conditions, a 100-year flood event would cause Lake Wingra to overflow onto McCaffrey Drive at Red Wing Marsh (David Liebl, personal communication, 2007). When the City of Madison rebuilds Wingra Dam in 2009-2010, McCaffrey Drive will be elevated along Red Wing Marsh, and the dam will become the new 100-year flood event overflow point (ibid.).

9.5 Gardner Marsh—Hydrological restoration outlined by Michaud (1994)

Michaud (1994) developed a water budget for Gardner Marsh to determine options for using hydrology to restore the marsh. Following discussions with Arboretum staff, one goal was to restore an emergent marsh in the northern half of Gardner Marsh and to retain and expand the sedge meadow in the southern half. His recommendations were based on maintaining appropriate water levels during the growing season, i.e., keeping surface water levels higher in the northern half for the emergent marsh and saturated soils for the sedge meadow.

His "model hydroperiod" of higher water levels in the spring then decreasing levels in the summer would likely flood basements in the Carver-Martin Street neighborhood. Recognizing that as unacceptable, he suggested four alternatives to raise water levels within the marsh. The scenario preferred by the Arboretum involves separating Gardner Marsh from Wingra Creek and from Schmidt Lagoon by a large berm along the eastern edge. A new berm would allow managers to raise the water level in the marsh without flooding the homes in the Carver-Martin Street neighborhood.

A culvert under McCaffrey Drive would allow additional water into the marsh to compensate for water lost from diverting water from Southeast Marsh and Schmidt Lagoon. Michaud's plan also calls for repairing the CCC Dam, separating Wingra Creek from the marsh, and using stop logs to control marsh water levels. The additional two outlets between the marsh and Wingra Creek would be filled as the new berm was extended to control water levels. The plan as proposed by Michaud is highly invasive to the marsh, but the advantage is that water levels could be raised and controlled while still protecting the Carver-Martin Street neighborhood.

An obvious concern is that Lake Wingra water levels would decline. Based on Michaud's (1994) calculations for the marsh and lake water budget, the impact during dry periods would be a drop of 0.1 ft (0.03 m) over a month. During a normal wet time period, the effect would be less than 0.05 ft (0.015 m) over a month. The impact of water over the Wingra Creek Dam and on the creek itself would be a loss of less than a third of the creek's flow. Michaud estimated that some seepage would occur under the dike separating the marsh and Wingra Creek, allowing some water back into the creek. Overall the impact would be minimal, particularly in relation to the gain for the marsh.

9.6 Gardner Marsh—Fish ponds

Being relative similar in size, shape, location, soil type, and depth in some cases, the five fish ponds have served well as experimental replicates (Figure 9.1). There is no plan for future research use, so we suggest three alternatives. In one stormwater management scenario (Chapter 14), the ponds would be connected by removing the cinder dams that separate them. The resulting channel would then be used to reroute stormwater along the perimeter of the marsh, from Schmidt Lagoon to Wingra Creek. A second option is to re-grade the edges of the fish ponds, allowing experimentation with vegetation. The steep banks do not support emergent vegetation and the spoils are covered with buckthorn. A more gradual slope would allow planting of emergent vegetation. Third, the ponds could be filled and planted to native marsh or sedge meadow. This possibility might have low priority, as the ponds, while not particularly attractive, do limit human access to the marsh. Also, the cost of obtaining permits and filling the ponds might exceed the benefits.

Figure 9.1: One of five Arboretum fish ponds along the eastern edge of Gardner Marsh.

Chapter 10: Restoration Options—Invasive Species Control

In this chapter, we consider a wide range of control options for the three dominant invasive plants in the Eastern Wetlands: shrubs, RCG, and cattail. Each is very common and each is a major threat to biodiversity (Figures 10.1, 10.2). In all, the wetlands contain 121.7 acres (49.3 ha) of shrubs, 9.1 acres (3.7 ha) of RCG and 34.3 acres (13.9 ha) of cattail. Control options are not prioritized or critiqued; instead we list the most common methods. We then suggest minimal changes that could be implemented to control invasive species and protect the quality plant communities that remain in the marshes. These suggestions should be used if our preferred restoration plans (Chapters 13 and 14) cannot be implemented in a timely fashion.

10.1 Shrub control

An analysis of Gardner Marsh aerial photographs by Kogler (1979) showed that shrub cover increased steadily from 1940 to 1978. In many cases, areas of the marsh that were once high-quality wetland plant communities such as sedge meadow are now almost entirely dominated by shrubs. Our vegetation maps show that shrub encroachment has continued (Figures 5.1, 5.2). Buckthorn species appear to be the most rampant shrub invaders, but red-osier dogwood and honeysuckle also pose serious threats to the marsh (Figures 5.3, 5.5).

Buckthorn ✦ Both common buckthorn and glossy buckthorn are invasive in Wisconsin. Both originated in Europe and were cultivated as ornamentals. They are spread by berries dispersed by such native birds as robins and cedar waxwings (Moriarty 1998). As many as 75 seeds/ft^2 (0.09 m^2) of buckthorn seeds fall directly under the parent tree, allowing for high recruitment near mature trees. In addition, 85% of seeds can germinate (Archibold et al. 1997), so that recruitment can be very high. Where seedling densities are high, little else can grow. Given buckthorn's aggressive spread, a scientific strategy is critical to achieving efficient control.

Methods addressed in the literature include burning, grazing, mowing, biological controls and chemical controls (USGS 2006). Burning is only moderately effective, especially considering the effort required (ibid.). Efforts to eradicate buckthorn can focus on female trees that are large enough to produce berries (Moriarty 1998). Chemicals, such as glyphosate (Round-Up™), are then applied to the stump (NDDOA 2003). Herbicide application is most

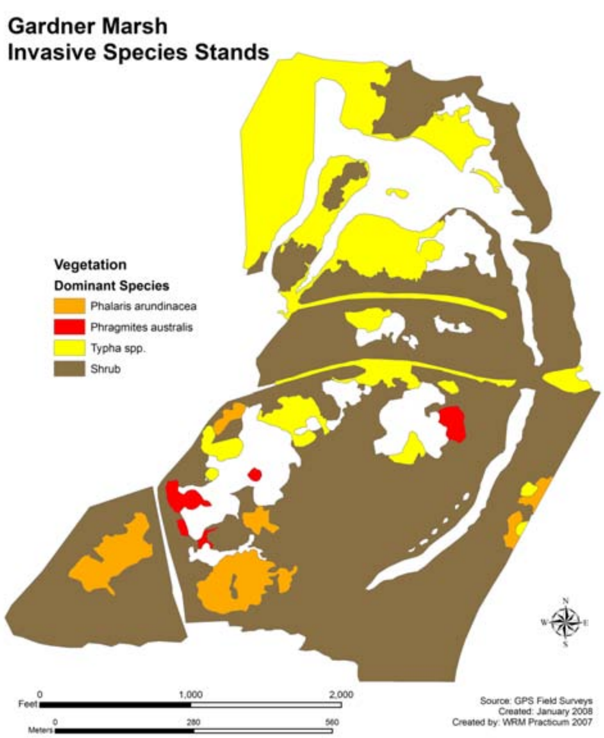


Figure 10.1: Common invasive species in Gardner Marsh.

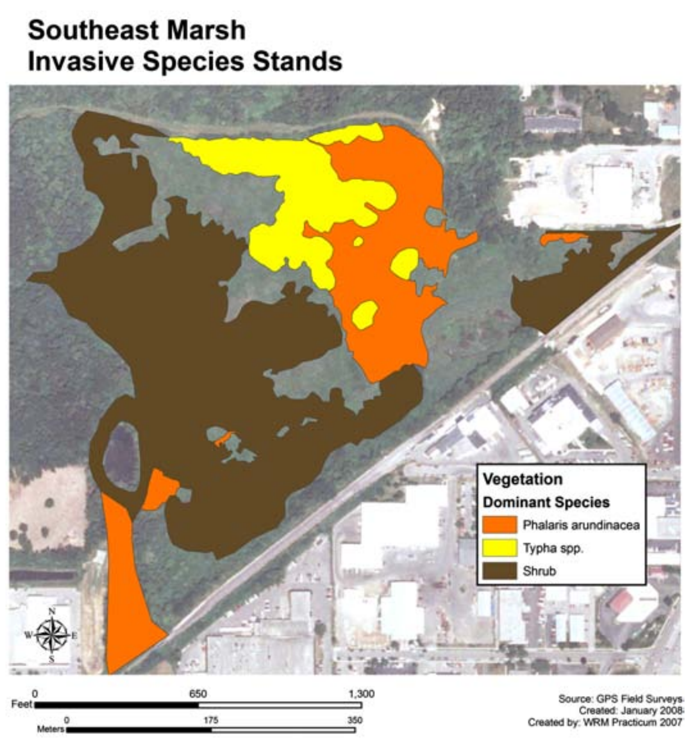


Figure 10.2: Common invasive species in Southeast Marsh.

effective when the tree's leaves are fully expanded and the temperature is above 32°F (0°C). Winter herbicide treatment is less effective than spring treatment according to Reinartz (1997). Smaller buckthorn can be pulled or leaves sprayed with a contact herbicide or basal sprayed with glyphosate. Because the removal of buckthorn creates an excess of brush, we suggest chipping it for use in carbon-addition experiments (see Chapter 13).

An efficient method of cutting large areas of shrub uses a "Geoboy" (Kleiman 2003). This machine can cut mature shrubs, leaving stumps ready for spraying. It also sits on wide rubber tires, so impact to the soil surface is relatively low. We highly recommend using this machine for efficient, large-scale clearing.

High water levels might inhibit buckthorn seed germination, based on laboratory experiments. Soaking buckthorn seeds for two months inhibited germination (Gourley 1985). Results might differ in the field, however.

Red-osier dogwood (*Cornus stolonifera*) • Red-osier dogwood is often recommended as a replacement for exotic species, such as buckthorn and honeysuckle. However, this native has become a problem species in both Southeast and Gardner Marshes. Dogwood, although native, is invasive (http://www.dnr.state.wi.us/invasives/fact/wetshrubs_red.htm). Its encroachment, along with other shrubs, reduces habitat available for other plant communities, such as sedge meadow. Like buckthorn, dense cover from red-osier dogwood could impede recruitment by herbaceous vegetation (Kogler 1979). Disturbances, including dredging, filling and trampling, have been shown to favor red-osier dogwood.

Cutting red osier dogwood increases its invasiveness when used independently of chemical treatment (Reinartz 1997). Reinartz found that applying a glyphosate herbicide to a cut stump yielded a 92–100% kill.

Fire appears to be relatively ineffective for removing red-osier dogwood, although it is suggested for removal of seedlings (Kogler 1979). Extensive research of burning in winter yielded the same conclusion; neither cover nor maximum height was significantly reduced. However, overall species richness increased and herbaceous species reappeared after being absent for decades (Middleton 2002).

Water level manipulation has proven to be the most effective way to manage established shrubs, red osier dogwood in particular. Red-osier dogwood can adapt to gradual water-level changes, but rapid, major water-level changes cause mortality. Twelve weeks of water levels several centimeters deep following snowmelt lowered red-osier dogwood germination rate to 3% in greenhouse experiments (Kogler 1979). Additional research demonstrated that an initial rapid increase in water levels followed by a rapid decrease in water levels may be more effective than maintaining high water levels for a period of many weeks. With an increase in water level, red-osier dogwood establishes near surface-level roots and its old roots die. Thus, rapid lowering of the water level at this time is an effective means of removal (Kogler 1979). Again, these results come from a series of laboratory experiments. The Eastern Wetlands could support the necessary field-test environments.

Reed canary grass (RCG; *Phalaris arundinacea*) • RCG is a perennial clonal grass of the upper Northern Hemisphere. It is a facultative wetland species that also occurs in riparian areas and uplands (Kilbride and Paveglio 1999). It was planted in the United States for erosion control, livestock forage, and wastewater treatment (Gelber 1995). It is considered indigenous to parts of North America, although European cultivars were introduced in the 1800s. Both native and exotic genotypes occur in North America (Galatowitsch and van der Valk 1996). RCG can flourish in flooded and drought conditions (Figiel, Collins et al. 1995; Miller and Zedler 2003) and in nutrient rich wetlands (Perry 2001), such as the Eastern Wetlands.

Tolerance of many conditions and its prolific seed production make RCG control difficult. Fire combined with herbicide treatments is one technique that has shown positive results. Two treatments of a spring burn followed by a fall herbicide reduced stem density in treatment plots to 0–1 stem/m^2 (Galatowitsch and van der Valk 1996; Reinartz 1997; Adams and Galatowitsch 2006). Spring burns and fall herbicide treatments were more effective than spring burns followed by a spring herbicide application (ibid.). Craig Annen (personal communication 2008) recommends spring burning, however. Michael Healy (personal communication, 2008) has tested sethoxydim in detail, including three years of experimentation in Curtis Prairie, but this herbicide only slows height growth; it does not kill RCG.

We do not recommend flooding to control RCG, as it survives in water depths of 80 cm, though growth was significantly reduced (Coops et al. 1996). This depth would be unrealistic for the Eastern Wetlands. Other methods that could reduce RCG biomass include mowing, carbon additions and biomass harvesting (Figures 10.3, 10.4).

Cattail • Three species of cattail occur in Gardner Marsh (Hall and Zedler in prep. 2007). *Typha latifolia* (broad-leaved cattail) is not usually invasive, and it does not necessarily displace other native species (ibid.). *Typha angustifolia* (narrow-leaved cattail) is native to Europe. A hybrid of these two species, *Typha* × *glauca*, is

Treatment	Effect	Should use	Could use	Should not use	Comments
Burning	• Removes biomass and litter; may kill seeds on soil • Reduces available nitrogen over multiple burns • Releases seed bank of desirable/undesirable species • Stimulates dormant buds of RCG, rhizomes re-sprout • Can jumpstart growing season by warming soil	• To reduce RCG in late spring after RCG is active but before natives break dormancy • To force RCG to re-sprout and use reserves from rhizomes • Use in combination with other practices	• To remove thatch prior to a planting/seeding of desirable natives • To remove thatch and prompt early spring sprouting of RCG, which can then be treated with glyphosate or sethoxydim	• In fall to control RCG in short term; RCG benefits from high light conditions after fire • In early spring in mixed vegetation sites; RCG growth is encouraged by increased light, unless you plan to combine with another treatment • On organic sites if very dry	• Jumpstart occurs if burn done in fall or spring • No research on critical density of RCG that can be controlled by burning alone • Early burns will stimulate RCG; timing and frequency critical
Excavation	• Removes rhizomes and seed bank • Removes sediment and nutrients • Alters hydrology	• Where material can be pushed to fill drainage ditches or where it can be moved off site; where deeper water is desired • During winter, to reduce soil compaction • During summer when wet sites are dry	• To remove alluvium over native wetland soils	• If there is no soil disposal site. • If compaction is an issue • If you don't want a deep-water marsh. • If there is a high-quality remnant plant community in area	• May cause soil compaction • RCG will rapidly re-colonize disposed soil; use caution when selecting a disposal site • Additional treatments will be necessary on drier sites • Seed with natives afterwards, except in the deepest water, or if a rich native seed bank exisits • May require special permits
Tree/shrub planting	• When woody species overtop RCG, shade slows its growth • May change plant community • Adds structure to habitat	• Where herbaceous vegetation cannot gain a competitive advantage	• Where landscape is receiving RCG seed inputs • Where inflows can't be diverted • To connect existing woody patches	• Where management goal is to maintain grassland habitat	• Apply herbicide/mulch around newly planted trees/shrubs • Conifers may be the most effective at shading RCG • Need to control RCG for 3-5 years to allow trees to establish
Grazing	• Reduces biomass in spring • Causes disturbance • Allows seedling establishment (good/bad) • Adds nutrients to system	• In highly disturbed sites to reduce RCG biomass • In fall, after a prescribed burn (RCG regrowth more palatable)	• To reduce biomass and height before herbicide treatment • To reduce seed production • Lightly, to sustain diversity	• During wet conditions in spring where trampling and compaction can damage a site • If there is a high-quality remnant plant community in area	• Effective at suppression only • Use proper stocking rates to prevent overgrazing of desirable species
Mowing & harvesting (haying)	• Removes biomass and nutrients • Reduces RCG height • Similar to fire (promotes seed establishment, stimulates plant growth by increasing light)	• To reduce biomass before herbicide treatment • To remove P from site • Before RCG seed heads appear • To prepare for herbicide application	• As a substitute for fire (though not quite the same) • To change fire behavior by reducing fuel height	• Where tussocks and microtopography will be damaged • When grassland bird nesting habitat will be impacted. • If site is too wet for equipment	• On high quality sites, avoid use during growing season • Mow before RCG seed heads appear (boot to late boot stage)* to prevent seed production
Mowing without harvesting	• Reduces RCG height • Increases light—promotes competition • Depletes rhizome reserves • Creates dry biomass for fire	• To prepare for herbicide application • To stress RCG • When harvesting equipment is unavailable	• To change fire behavior by reducing fuel height	• Where tussocks and microtopography will be damaged • When grassland bird nesting habitat will be impacted. • If site is too wet for mower	• Mow before RCG seed heads appear (boot to late boot stage)* to prevent seed production • May impede establishment of natives, due to remaining mat of vegetation
Herbicide: broad spectrum (i.e. glyphosate, imazapyr)	• Reduces plant height • Increases light—promotes competition • Depletes rhizome reserves • Creates dry biomass for fire	• On sites without native plants prior to reseeding. • To dry out RCG in order to burn • In late summer for maximum translocation to roots	• For treating clones within areas of natives • As an initial herbicide treatment on monotypic stands of RCG • If RCG height precludes use of other herbicides • In early spring or late fall, when RCG is live, but other plants dormant • On wet sites, with a surfactant approved for aquatic use	• On sites with desirable native plants actively growing • Soon after mowing/burning • When amphibians are on site (unless using Rodeo + a surfactant approved for aquatic use, as Roundup formulation can have negative effects on amphibians)	• Should be part of a continued control strategy, where natives are later introduced • Multiple treatments may be necessary • May need a permit for application on wetlands • Rhizome translocation less effective if temperature >70°F • Other treatments may influence herbicide effectiveness • Add ammonium sulfate to tank mix if water is hard
Herbicide: grass-specific (i.e. sethoxydim or fluazifop)	• Suppresses growth of most grasses • Releases native plant community (except for grasses)	• On sites with desirable, native, non-grass species • When active growth resumes after burning/mowing, when RCG is 6-12″ tall	• Following other herbicide treatments to control residual or re-emerging RCG	• For immediate eradication • If standing water is present • On sites with desirable grasses • When RCG is >12″ tall	• Apply with surfactant/crop oil • > one treatment required • Effectiveness of sethoxydim is reduced by UV light • Add a water conditioner or acidifier if water is hard
Tillage	• Exposes rhizomes to light; might activate dormant buds • Fragments rhizomes and may increase RCG density • Can contribute to erosion	• In combination with herbicide treatment (makes dormant rhizome buds respond to chemical control) • On monotypic, damaged sites to prepare for crop production	• To prepare a seedbed • To reduce RCG seed bank	• Where microtopography must be maintained. • Where RCG is mixed with desirable natives • On wet sites, where soil could become compacted, or equipment can get stuck • If offsite impacts are possible (sedimentation/erosion)	• For most effective control, combine with another treatment • Depth should be 4-6″ to target RCG rhizomes • Till in spring or early summer • Repeated tillage can be effective if conducted every four weeks.
Altering hydrology	• Prolongs/increases water levels • Prevents RCG seed germination • Kills RCG rhizomes	• If new water depth is > 12″ • If high water can be maintained through the growing season.	• To promote the growth of emergent plants such as native cattail, burr-reed and bulrush species	• If new water depth is < 12″ or site seasonally dries out • If other invasives are nearby (*Typha* x glauca, *Phragmites*)	• High water can promote growth of other invasives (*Typha* x glauca, *Phragmites*) if present in the area • May require special permits
Mulching / solarization with plastic or fabric	• Non-selective treatment; shades out all plants • Kills adult plants • Kills RCG rhizomes	• For small, isolated RCG clones • For 1-3 consecutive years • On patches with high edge:area ratio, to facilitate recolonization by soil fauna	• To facilitate seeding or planting of natives	• Where desirable natives are mixed with RCG • For abatement on large sites • If native species are present • In areas with microtopography	• Resurgence from seedbank may occur when tarping removed • May have adverse effects on soil microorganisms • May alter soil chemistry • Not always an effective treatment

RCG= Reed canarygrass * For a description of growth stages see the bulletin, *Growth and Staging of Wheat, Barley and Wild Oat* at http://plantsci.missouri.edu/cropsys/growth.html

Figure 10.3: RCG control options. Source: Wisconsin Reed Canarygrass Working Group 2006.

Reed Canarygrass Control Prescription Table

Amount of RCG present[1]	Site characteristics/vegetation (recent <25 years)	Hydrology[2]	Inputs[3]	Tree Planting	Burn*	Excavate[4*]	Graze	Mow[5]	Broad-Spectrum Herbicide[6]	Grass-specific Herbicide[7*]	Tillage/ Farming	Raise water levels[8]	Seeding[9]
RCG Monotypes	< 25 years since tillage/farming, uniform topography[a]	Normally wet	High/low	E	2	2			2	2		1	1
		Seasonally dry		1	1	1	1	1	1	2	1		1
	> 25 years since tillage/farming or no ag history, uneven topography[b]	Normally wet	High/low	E	2					2		1	2
		Seasonally dry	Low		1			2		2			2
			High	2	1		2	2		2			2
	Shrub or forest edge[c]	Normally wet	High/low	E	2			1	2	2			2
		Seasonally dry		1	2			1	2	2			1
RCG Mixtures	Mixed with non-native grasses and/or weedy forbs	Normally wet	High/low	E	2	2			2	2		1	1
		Seasonally dry		1	1	1	1	1	1	2	1		1
	Mixed with native grasses	Normally wet	High/low		2				spot-spray	spot-spray			2
		Seasonally dry			1			2	spot-spray	spot-spray			2
	Mixed with native sedges, rushes and forbs	Normally wet	High		2					2			2
			Low		2					2			2
		Seasonally dry	High/low		1			1		1			2
	Mixed with shrub or forest matrix[d]	Normally wet	High/low	E						2			2
		Seasonally dry		1						1			2
	Discreet linear strips or clumps of RCG within a desirable native plant community				1			1	spot-spray	spot-spray			1

KEY TO TABLE
1 = Suitable treatment
2 = May be a suitable treatment, site conditions need to dictate treatment(s) methods
E = Experimental treatment

Superscripts
1- Monotypic stands contain >75% RCG with few other (often ruderal) species.
2- Hydrology- Normally wet refers to saturation and inundation for all or most of the growing season.
Seasonally dry allows for access and treatment for a significant portion of the growing season.
3- Input refers to sediment, flooding, nutrient and stormwater inputs.
4- Excavated RCG sod and rhizomes should be placed on existing monotypic RCG stands, used in ditch filling or spread on cropland where it can be controlled.
Check for any required state and local permits before starting and follow with a native seed mix tailored to the site's hydrology
5- Mowing includes either harvesting and bailing or leaving clippings in place.
To avoid negative impacts of mowing on nesting birds, be sure to consult a grassland bird specialist before selecting a mowing date.
6- Broad spectrum herbicides that have been experimentally tested or are currently being tested for RCG control include glyphosate, imazapyr, and amitrole.
7- Grass specific herbicide should not be applied to open water or areas where standing water is present. Consult herbicide label for application instructions.
8- To be effective, water levels should be raised > than 1 foot above RCG crown buds for more than 3 months of the growing season for more than one growing season.
9- Seeding- Reference the seed list and seeding should typically be used with other treatments.
a- Sites with uniform topography lack microtopographic features.
b- Sites with uneven topography possess microtopographic features (springs, seeps, boulders, tussocks, internal drainage channels, snags, downed logs, etc.)
and may harbor suppressed native plant communities or remnant native seed banks.
c- Shrub or forest edge refers to the RCG population existing on the edge of the shrub or forest wetland
d- Shrub or forest matrix refers to the RCG population existing within the shrub or wetland wetland with a patchy distribution
* refers to the potential need for local, state and/or federal permitting

NOTE - Optimal results will be obtained by using two or more treatments in combination over a period of years, combined with active reseeding of native species.
Site conditions should dictate the treatment(s) methods. Always read the herbicide label before application.

Figure 10.4: RCG prescription table. These methods should be implemented based on the density of RCG on the site. Source: Wisconsin Reed Canarygrass Working Group 2006.

an aggressive invader that reduces diversity (Smith 1967; Boers et al. 2007). The hybrid thrives in nutrient rich wetlands (Woo and Zedler 2002) and in areas with stabilized water levels (Boers et al. 2007). Because of difficulty in identification, we refer to all three as "cattails" unless otherwise noted.

Common herbicides for cattail control are glyphosate and imazapyr. Glyphosate can cause high cattail mortality (Hall and Zedler in prep. 2007), but native species that receive spray will also be killed (ibid.). Rates between 5.6 and 10 kg active ingredient/hectare were effective in killing cattail in one study, and the higher application rates sustained control in later years (Beule 1979).

Systemic herbicides, such as glyphosate, could be most effective late in the growing season when cattails are translocating carbohydrates to rhizomes for the winter. Systemic herbicide applied earlier in the growing season could reduce above-ground biomass initially, but allow the ramet to recover by resprouting from its rhizome. Contact herbicides can be applied throughout the growing season.

Burning can temporarily remove aboveground cattail biomass, but it will only kill the plants if fire reaches the rhizomes (Beule 1979). Also, burning releases nutrients previously tied up in cattail biomass, and cattails thrive in nutrient rich environments (Woo and Zedler 2002).

Figure 10.5: Red-osier dogwood encroaching remnant sedge meadow in Gardner Marsh. Shrub encroachment threatens all sedge meadow communities in the eastern marshes. Late summer flooding in 2007 caused leaf mortality.

The combination of burning or cutting followed by flooding may be the most effective cattail control. Flooding "suffocates" cattail rhizomes by preventing oxygen diffusion into the rhizomes after their "snorkels" have been removed. After cutting ramets, inundation by 8–80 cm of water reduced cattail cover (Nelson and Dietz 1966; Shekhov 1974; Beule 1979; Murkin 1980). Hall and Zedler (in prep. 2007) found that cutting cattail four times without flooding reduced cattail the same amount as cutting once followed by a flood.

10.2 Vegetation management options: Southeast Marsh

Preserve remnant native plant communities • Two areas of significant native wetland vegetation in Southeast Marsh could be targeted for preservation and potential expansion as part of a minimal, low-cost restoration plan. These areas are the entire western side (west of Pond 4 at the southern end and west of the outlet at the northern end) and the far southeastern corner (east of Pond 4 and bordered by the railroad tracks at the eastern boundary). As described in Chapter 5, the western side of Southeast Marsh is dominated by small to large patches of sedge meadow, blue-joint grass and goldenrod, interspersed with many other native plant species. The major threat to this area of the marsh is shrub encroachment, particularly red-osier dogwood, buckthorn and honeysuckle. The far southeastern corner of the marsh has characterized a similar mix of native plants, encroaching shrubs and higher elevation. We recommend removing invasive shrubs to promote the expansion and re-establishment of native wetland plant communities, particularly sedge meadow and blue-joint grass.

Removal of existing invasive plant species • The central section of Southeast Marsh, from the WHA tower and boardwalk on the north to Pond 4 on the south, is almost entirely RCG and cattails. This section of the marsh is lowest in elevation and frequently experiences flash flooding. A rain event of 0.5–1 in (1.2–2.5 cm) can raise the water level from 0 ft (dry condition) to as much as 2–3 ft (0.6–1 m) of water over the course of a couple days, and water levels can drop just as quickly.

The RCG and cattails in this section of the marsh are extensive enough for field tests of burning, flooding, and herbicide applications. The risk of their re-establishment is high, however. Desired native plants would need to be seeded or planted. Field plots could compare the ability of various native species to establish and persist in this environment. Because the WHA tower occupies a large area, management would have to be compatible with the existing infrastructure.

Surveillance to spot new invasive plants + At present, a few invasive species occupy large sections of Southeast Marsh. Other potentially invasive species have been observed along the berm and nearby uplands; these include charlock mustard (*Sinapis arvensis*), white snakeroot (*Eupatorium rugosum*) and chicory (*Cichorium intybus*). In addition, purple loosestrife (*Lythrum salicaria*) remains a constant threat, although it has not yet been observed in Southeast Marsh. Annual or biennial surveys would alert Arboretum staff to remove new patches while they are still small. In addition, surveyors could also document the presence of desired native species.

10.3 Vegetation management options: Gardner Marsh

Preserve remnant native plant communities + Gardner and Southeast Marshes have 18.5 acres (7.5 ha) of remnant sedge meadow. If full-scale restoration of Gardner and Southeast Marshes is not feasible for logistical or financial reasons, at a minimum, the sedge meadow remnants should still be protected. Sedge meadow is a rare and declining habitat (Zedler and Potter 2007, in press) with potential for supporting high species diversity. We urge stronger control of invasive species around these areas, especially since the restored Ponds 3 and 4 will improve water quality. Several areas, especially in Gardner Marsh, could be preserved and improved by selectively eliminating invasive species and planting plugs of sedge meadow species.

Every patch of native plants is bordered by an invasive community on at least one side (Figure 5.3, 10.5). We prioritize protection of plant communities with a large area and high species diversity. The northernmost large sedge meadow is located in the northeast corner of Gardner Marsh (Figure 5.3). Here *Carex lasiocarpa* dominates among *Calamagrostis canadensis* and *Schoenoplectus tabernaemontani*. The major threat to this community is from the northwest. Cattail is advancing from the west (Hall and Zedler in prep. 2007). Hall recommends 3-m-wide swaths in fall or winter, allowing spring melt water to flood and kill cattail. Sedges can then expand vegetatively of a rate of about 1 m per 2 years (ibid.).

Unlike the sedge meadow north of Pond E90, the remnant directly to the south has less area of invasive species and higher potential for restoration. The meadow is dominated by *Carex lasiocarpa, C. lacustris, C. vulpinoidea* and *Calamagrostis canadensis*, bordered by dogwood and sporadic buckthorn. We suggest removing all shrubs in the core of the meadow and on the northern edge along the pond to eliminate the immediate seed source. A significant patch of buckthorn would remain to the south.

The largest sedge meadow occurs in south-central Gardner Marsh, occupying 6.8 acres (2.8 ha). This large meadow should be of greatest concern to the Arboretum. The west half of the meadow is dominated by blue-joint grass and the east by *Carex lacustris*. First, two small patches of *Phragmites australis*, on the west side of the meadow (Figure 5.3) should be removed. The patches are small, so eradication should be quick and effective. Even if they are not the invasive strain, their removal would prevent expansion and provide additional area for sedge meadow. To remove *Phragmites*, we suggest using the aquatically-approved glyphosate herbicide mixed as recommended for RCG control.

Moving east, a smaller, but still quality sedge meadow is dominated by *Carex lasiocarpa*. A third and final patch of *Phragmites australis* needs to be removed in this meadow; it borders the meadow to the east, next to heavy buckthorn (Figure 5.3). Small shrubs in the middle of the meadow should be removed in a similar fashion as the E90 meadow to eliminate shrub encroachment in the meadow core.

Surveys for purple loosestrife should take place yearly. One area in particular, near the middle fish pond in Gardner Marsh is of great concern. Here, we pulled two *Lythrum* sp. plants in the summer of 2007 as a precautionary measure. We believe these were the native, *Lythrum alatum*, but specimens were not verified at the UW–Herbarium. We strongly suggest monitoring the area for the non-native purple loosestrife.

While burning is commonly recommended to control shrubs in sedge meadows, new information indicates that tussocks are mostly organic (only 8% of tussock dry weight was inorganic in 5 samples taken from Southeast Marsh; Lawrence and Zedler, in prep.). Organic tussocks would be highly flammable when dry, so burning could incinerate these important diversity-support structures.

Chapter 11: Wildlife

The Arboretum lands have unique status as a wildlife sanctuary located within an urban center. Many species of birds, mammals, reptiles, amphibians, fishes and invertebrates rely on the Arboretum's wetlands. Historical records indicate the Eastern Wetlands and adjacent areas were important to a great many species of wildlife. This is likely attributable to the relatively open and treeless sedge meadows. Observations from the late 19th century report large flocks of prairie chickens (*Tympanuchus* sp.) in the area of modern-day Gardner Marsh (Sachse 1965). American woodcock (*Scolopax minor*), ring-necked pheasant (*Phasianus colchicus*), alder flycatcher (*Empidonax alnorum*), red-winged blackbird (*Agelaius phoeniceus*) and common grackle (*Quiscalus quiscula*) were also present (Irwin 1973; Bedford et al. 1974).

In 1936, the marsh was dredged to create wildlife habitat (Sachse 1965), but Bedford et al. (1974) contend that the dredging "almost eliminated the deep water-shallow water gradation with its large number of niches for plant and animal species." The dike between Lake Wingra and Gardner Marsh, constructed to support Arboretum Drive, separated the lake from its littoral zone, and various water level manipulations lowered the marsh's water by 0.98 ft (0.3 m; Sachse 1965). The resulting drier habitat allowed shrub encroachment of areas where macrophytes were native (Kogler 1979) and negatively affected wildlife.

Despite degradation, Southeast and Gardner Marshes continue to provide habitat for wildlife (Bedford et al. 1974). We did not conduct formal wildlife surveys, although several species were observed, including white-tailed deer (*Odocoileus virginianus*), common musk or "stinkpot" turtle (*Sternotherus odoratus*) (Figure 11.1), and northern leopard frog (*Rana papiens*) (Figure 11.2). We saw various Lepidoptera (Figure 11.3) and regularly found crayfish "chimneys" (Figure 11.4) near the east-west sloughs and bivalve shells near the Gardner Marsh fish ponds. Frogs (in mature and tadpole form, Figure 11.5) were common in and around the detention ponds in Southeast Marsh as well as in the eroded stormwater channels draining the ponds.

A restoration plan for the Eastern Wetlands should include both "target" wildlife species, for which habitat should be created or promoted, and "undesirable" species, for which habitat should be limited. We advocate restoring habitat for threatened species such as the osprey (*Pandion haliaetus*) and Blanding's turtles (*Emydoidea blandingii*). Habitat should also be restored for northern pike (*Esox lucius*) or the non-native muskellunge (*Esox masquinongy*), depending on management priorities. While we do not have data on the local economic impact of sportfishing for muskie in Lake Wingra, it is a well-known destination for muskie fishermen. Crowds gather at Wingra dam each spring to catch a glimpse of muskie attempting to clear the dam. The introduced common carp (*Cyprinus carpio*) is an "undesirable" exotic species to be limited through management and carefully considered in restoration planning.

11.1 Birds

The Eastern Wetlands historically supported a wide range of bird species. Gardner Marsh historically supported "sandpipers, rails, herons, bitterns, marsh hawks, short-eared owls," as well as various ducks (Cahn 1915). Several birds of interest nested in or adjacent to the marshes during summer 2007. These were red-tailed hawk (*Buteo jamaicensis*), great blue heron (*Ardea herodias*), and great horned owl (*Bubo virginianus*). In addition, osprey (*Pandion haliaetus*) nested on a cell phone tower east of Wright Middle School off of Fish Hatchery Road (Matthew Krueger, personal observation, 2007). We frequently observed sandhill cranes (*Grus canadensis*) near the small island in Pond E-90. Species of concern include the osprey, on the State of Wisconsin Threatened Species List since 1989, and the great egret (*Casmerodius albus*), also on the State Threatened Species List since 1989 (WDNR 2006).

From April through August 2007, we recorded 54 bird species in or adjacent to the marshes, observed by sight or by sound (Appendix J). These were ancillary observations during periods of other research, so concerted bird-surveying efforts should add more species to our list.

11.2 Northern pike

The northern pike (*Esox lucius*) is important in the 'top-down' predatory regulation of the fish community (Casselman and Lewis 1996). Pike were abundant in Lake Wingra "as far back as records go" (Noland 1951), with reported catches of specimens up to 19.75 pounds (8.96 kg) (Sachse 1965). In 1918 pike were the most abundant

Figure 11.1: Musk ("stinkpot") turtle (*Sternotherus odoratus*) in Gardner Marsh.

Figure 11.2: Northern leopard frog (*Rana papiens*) in Southeast Marsh.

Figure 11.3: Red Admiral butterfly (*Vanessa atalanta*) in Gardner Marsh.

Figure 11.4: A crayfish "chimney" in Gardner Marsh.

Figure 11.5: Tadpoles (the dark "spots" between the rocks) in a polluted stormwater channel leading into Southeast Marsh.

predator in the lake (Pearse and Achtenberg 1918 cited in Baumann et al. 1974). Only one individual was reported by the DNR in the last seven years (Kurt Welke, personal communication, 2007).

Despite being native, pike were stocked in Lake Wingra throughout the first half of the 20th century to supplement a declining population. In 1922, 300,000 pike fry were stocked (Noland 1951); subsequent stockings occurred in 1940–1942, but ended in 1957 (Baumann et al. 1974). Seining in 1936 documented that the once abundant pike population was in decline (Noland 1951), likely attributable to the introduction of carp, which decimated gamefish populations (Sachse 1965). According to Baumann et al. (1974), the decline was likely due to the introduction of a food competitor, walleye (*Stizostedion vitreum*), the elimination of viable spawning habitat, and the decrease of yellow perch (*Perca flavescens*) a preferred food species.

11.3 Muskellunge

The "muskie" is a large piscivore and prized sport fish, commonly growing past 40 in (1.05 m) and sometimes to 50 in (1.27 m). Muskie abound in Lake Wingra today due to an intensive stocking program conducted by the Wisconsin Department of Natural Resources (DNR). Pike-muskie hybrids (*Esox masquinongy* × *E. lucius*) were first stocked in Wingra in 1940 (Noland 1951). Hybrids were stocked again in 1948 (Baumann et al. 1974), but it was in 1979 when pure strains of muskie were stocked (Jaeger 1985). From 1979 to 1984, muskie and pike-muskie hybrids were stocked in the lake (Klingbiel and Brynildson 1984 cited in Jaeger 1985). Stocking continued through 2000, with up to 350 individuals added in some years (Kurt Welke, personal communication, 2007), although it is unclear if the stocked fish were pure-strain muskie or hybrids. The result was a population density of approximately four adult fish per acre, and the overcrowding stunted growth of adult specimens (ibid.). Since then, a less intensive stocking program has been implemented with up to 145 muskie stocked per year, resulting in a density of approximately 1.2 adult fish per acre and larger adult fish (ibid.).

Muskie display courtship behavior and lay eggs in the lake, but there is no evidence of natural reproduction, potentially because of paucity of spawning habitat (Kurt Welke, personal communication, 2007). The requirements for spawning habitat include organically rich sediments, woody debris, deadfall trees and seasonal fluctuations of water levels, including spring flooding of shoreline areas, which provides access to organically-rich spawning habitat (Rust et al. 2002).

Based on these criteria, Lake Wingra could support natural muskie reproduction due to being relatively undeveloped and its abundant marshy "fringe." However, the limiting factor could be land use in the watershed. Rust et al. (2002) found that lakes with self-sustaining populations were primarily surrounded by forest; those that required stocking were surrounded by human development. A further limiting factor could be the overabundance of carp, which can feed on muskie eggs.

11.4 Common carp

A high priority for Lake Wingra is to remove the common carp. Carp were introduced to the Yahara lakes between 1885 and 1897. They were "present in Lake Wingra by the late 1890's, common by 1915 and dominant by 1930" (Bedford et al. 1974). From 1936–1955, intensive seining operations were implemented to remove carp from the lake (ibid.). As noted above, carp have a detrimental effect on northern pike in Lake Wingra. Carp significantly increase turbidity and total phosphorus, decrease macrophyte cover, and suppress zooplankton and macroinvertebrate abundance (Parkos et al. 2006).

In 2006, community stakeholders, including UW–Madison, Friends of Lake Wingra, the Wisconsin DNR, Dane County, and City of Madison, initiated a comprehensive carp study in Lake Wingra. During spring (late May) carp move into the shallow, warmer water of Vilas Lagoon to spawn; in late fall and winter, they move into the deeper middle part of the lake (David Liebl, personal communication, 2007; Lathrop 2007). At these times of concentration, the carp might be vulnerable to removal.

Carp are abundant in Gardner Marsh, especially in the north-south channel and Pond E-90 (Figure 2.5). It is unclear if they use the fish ponds, but they have a significant presence in the larger marsh area. Carp can travel from Gardner Marsh to Wingra Creek via the culverts at the CCC Dam and second outlet (Figure 2.5). Because carp prefer warm, shallow water, Gardner Marsh currently provides "ideal spawning habitat" (Kurt Welke, personal communication, 2007).

11.5 Blanding's turtle

Records dating back to 1915 indicate that Gardner Marsh provided habitat for Blanding's turtle, as well as snapping turtle (*Chelydra serpentina*), painted turtle (*Chrysemys picta belli*) and the softshell turtle (*Amyda* sp.) (Noland 1951). Blanding's turtles have been on the State of Wisconsin Threatened Species List since 1979, largely due to habitat loss and fragmentation following the draining of wetlands (WDNR 2006). Although we did not sample for Blanding's turtles, it is likely that habitat alterations have reduced the local population. In particular, roads that divide essential habitats are hazardous for turtles. While we do not have data on turtle mortality due to roadways, it is clear that much of the potential upland habitat for turtles must be accessed from wetlands by crossing a roadway—Arboretum Drive, Carver Street, or Martin Street.

Blanding's turtles are considered "semi-aquatic" because they use permanent and seasonal pools and forest swamps, as well as upland habitat (Joyal et al. 2001). Important wetland characteristics include emergent and submergent vegetation, "edge" habitat between emergent vegetation and open water, basking areas with logs and woody debris and deep muck substrates greater than 27.56 in (70 cm) (Hartwig and Kiviat 2007). They use uplands for basking, nesting and travel between wetlands. Nesting sites have been reported as far as 1345 ft (410 m) from wetland areas by Hartwig and Kiviat (2007), and up to 1.5 mi (2.41 km) by WDNR (2006).

Joyal et al. (2001) found that most Blanding's turtles overwinter in small seasonal or permanent pools; however, Dinkelacker et al. (2004) found that hatchling turtles may also overwinter in terrestrial habitats that offer "moist and friable soils where they can burrow, maintain water balance and avoid severe cold." In spring and summer months, the turtles use open-water habitats with available cover at the fringe.

In New York, Hartwig and Kiviat (2007) found a particularly high association between Blanding's turtles and buttonbush (*Cephalanthus occidentalis*), a shrub with a late leaf-out that provides basking habitat in spring and shelter and shade in the summer. Buttonbush grows in wet habitats and can survive long periods of time with roots and stems submerged. Open-water habitats with concentrations of filamentous algae were also preferred by turtles, as it provided cover, food and a warm microclimate (Hartwig and Kiviat 2007). Patches of filamentous algae in the vicinity of buttonbush were especially preferred.

11.6 Restoring wildlife

Birds ✦ Restoration Plan 2 (Chapter 14) advocates water control structures to return a more natural water regime to the marshes; this would help restore native wetland vegetation and support viable populations of wetland birds. While Gardner Marsh is still an excellent area for observing waterfowl, restored wetland habitat might attract more snowy egrets and great-blue herons, as well as provide foraging habitat for nesting osprey. Osprey could also be enhanced by constructing nesting platforms. While we do not know if osprey feed on carp, it would be useful to know if an active hunting pair could help reduce carp populations.

Interspecific competition among pike and muskie ✦ Muskie and northern pike are congeners, and they potentially compete for food and spawning habitat (Inskip and Magnuson 1983). Young-of-the-year muskie were suspected to be vulnerable to predation by young-of-the-year pike, as they hatch in similar habitats, yet pike hatch earlier in the spring and are cannibalistic at a small size (ibid.). While they tend not to co-occur, other research indicates that pike and muskie do not always negatively interact (Rust et al. 2002).

If efforts are undertaken to restore Lake Wingra to its presettlement ecosystem, we suggest that northern pike be given priority over muskie, since the latter appears to require annual stocking. If the stocking regimen were shifted to pike, a healthy population of a native species might be restored. Whether or not such a priority could garner the necessary political strength to dismantle the widely popular muskie fishery is doubtful, however. Regardless of preferences for a muskie versus pike fishery, we suggest that reconnecting the lake to Gardner Marsh would suit either species, due to their similar habitat requirements. A reconnection coupled with the water level controls (Chapter 14) should create spawning habitat for either or both species.

The preferred spawning substrate of northern pike is flooded grasses and sedges in shallow, sheltered areas such as marshes (Casselman and Lewis 1996). Similarly, pike require high water levels in the spring to provide increased nutrient concentrations, increased amounts of available prey for larval fish, expanded cover, and reduced potential for predation and cannibalism (ibid.). Nursery habitat is also essential for restoring northern pike (Minns et al. 1996). Reestablishment of macrophyte cover is more important to the restoration of pike stocks than the reestablishment of suitable spawning habitat. Vegetative cover of 40% to 90% would protect juvenile pike from predators and provide cover for their "wait and ambush" hunting methods (ibid.). Given that sedge meadow and blue-joint grass meadows are preferred spawning and nursery habitat, we suggest targeting these habitats and species for the reestablishment of northern pike.

Installing a weir at Red Wing Marsh and a biological connection between Lake Wingra and Gardner Marsh would provide habitat for spawning fish and also critical midsummer "nursery habitat." Juvenile fish are a key and often neglected life history stage in restoring pike populations. Water level fluctuations are critical to the restoration of spawning and nursery habitat. According to Casselman and Lewis (1996), water levels for northern pike should be "gradually increasing prior to spawning, and stable until fry start to move from spawning grounds (6–8 weeks), then gradually decreasing." Restoration planning would need to include water level control, using stop-logs at the reconstructed CCC Dam.

For muskie, Zorn et al. (1998) found that most mortality occurs before the fry reach nursery habitat, highlighting the need for spawning habitat with fallen logs, stumps and marshy vegetation. The lowest egg mortality was on organic substrates, such as silt and wood, likely because these substrates provided the physical separation of eggs, which limits fungal infestations (ibid.). Muskie nursery habitat is shallow water, between 9.84 in (25 cm) and 19.69 in (50 cm) deep, within the proximity of spawning sites and submerged marshy vegetation (ibid.). Preferred macrophyte species include hardstem bulrush (*Schoenoplectus acutus*), sedges (*Carex* spp.), yellow water lilies (*Nuphar* sp.) and pondweeds (*Potamogeton* spp.), among others (ibid.). While some of these species occur in Gardner Marsh, others could be introduced during restoration. Muskie reproduce in habitats where water levels are drawn down in winter, a process that aerates substrates and desiccates and consolidates organic materials (ibid.). If Lake Wingra continues to be managed for muskie, water levels in Gardner Marsh could be controlled to encourage muskie reproduction, perhaps at the same time as the marsh is managed to eliminate carp.

Whether muskie or northern pike can reproduce in Lake Wingra and/or a restored Gardner Marsh is uncertain, but restoration would increase the probability. Both muskie and pike deposit eggs that can fall to the bottom where carp feed. Thus, reproduction of either species would be hindered if carp remain abundant in Gardner Marsh (Kurt Welke, personal communication, 2007). Additional challenges are the impacts that carp have on macrophytes and water clarity. Carp "rooting" increases water turbidity, reduces light penetration, inhibits macrophyte growth, and impairs feeding activity (Casselman and Lewis 1996). Periodic stormwater pulses likely combine with carp activities to the detriment of muskie and pike. Carp need to be removed from areas intended for either muskie or pike spawning.

Common carp • An adaptive approach to carp management using combinations of the following actions could potentially bring the "carp problem" under control. We suggest Gardner Marsh be used to test the more promising management actions.

1. **Electroshocking/seining.** The restored connection between Lake Wingra and Gardner Marsh (Chapter 14) should expand spawning habitat for carp, but it could also provide new opportunities to "trap" carp. Once reconnected to Lake Wingra, carp would likely move into Gardner Marsh in early spring. Once carp are concentrated in Gardner Marsh, several management techniques could be implemented. The most labor-intensive but most ecologically-sensitive technique would combine seining and electroshocking. While several people would be required, this technique would allow for selective harvest, removing the undesirable carp while releasing other captured species.
2. **Water level draw-down.** The reconstructed CCC Dam could be used to draw down water levels in the marsh. At Horicon Marsh, a complex system of dams allows managers, to draw down water levels in the fall to promote winter kill of yearling carp (Wendy Woyzcik, personal communication, 2007). If the draw-down is not sufficient, rotenone can be applied in the spring to kill the winter survivors (ibid.). In Horicon Marsh, 98% of fish are carp. Because Gardner Marsh efforts would need to protect desirable fish species prior to and during a drawdown, seining operations during the drawdown would require many people, but it would spare desirable species.
3. **Exclosures.** According to Wendy Woyczik (2007), biologists at Horicon Marsh have made some progress using carp exclosures—metal brackets with 1.5-in gaps attached

to stop-log dams—to restrict the passage of larger carp, while allowing smaller fish to pass. Excluding migrating carp could reduce stocks but is unlikely to extirpate them. An exclosure could be used at the reconnected passageway from Lake Wingra to Gardner Marsh, but it would require constant surveillance to make sure the exclosures are free of debris and functional.

4. **Plastic mesh substrates.** Plastic mesh pinned to benthic substrates has promoted native fish in carp-rich aquatic systems (Anderson 1996). Des Plaines River Wetland Demonstration Project used mesh fencing material with openings of 2.5 cm, 5 cm and 7.5 cm to attempt to prevent carp from disturbing the streambed (ibid.). Macroinvertebrates were found in higher abundance in the 2.5-cm treatment. Fish were nearly 10 times denser in the treated than untreated reaches of the river, with the 2.5-cm treatment harboring the highest densities (ibid.). Researchers noted a potential improvement in the benthic conditions, as indicated by the presence of bottom-dwelling fish in test plots. Six of nine fish species found in test plots were classified as bottom-dwellers, possibly due to the increased availability of food in the form of benthic invertebrates. It should be noted that carp abundance was greater in the test plot area than in the control area of the river, but this may have been due to the increased availability of food mentioned above. While Anderson (1996) initially hypothesized that mesh could be used to manage carp, a year later he found that the mesh actually increased the number of carp present from pre-to-post treatment samples (ibid.). However, it also increased the number of other species of fish present and decreased the percentage of carp in the total fish population and overall carp density. Mussels and benthic invertebrates also increased in density and diversity. Parkos (2006) replicated the plastic mesh experiments and cautioned found that "the mesh treatment did not show great promise in reducing the effects of common carp on aquatic ecosystem structure." Mesh might inhibit mussel movement and become covered by silt; still, more macrophytes established. Future experiments could combine larger treatment areas and plantings of aquatic macrophytes.
5. **The Williams cage.** In Australia, researchers installed a trap for invasive carp on fishways in the Murray River. They found that trapped carp tend to jump out of the water, unlike most native fish species; thus, they develop a trap that could separate carp from native fish at fishways (Stuart et al. 2006). They used a galvanized steel structure that features two compartments separated by an adjustable-height "jumping baffle." Carp jumped over the baffle into the second compartment, while native Australian fishes were captured in the first compartment and eventually released via a "false floor" activated by a mechanical counter-weight (ibid.). Between November 2002 and April 2005, 88% of adult carp passing through the fishway were captured (ibid.). If native Wisconsin fish lack the jumping behavior, the Williams cage could be a low-cost carp management technique. The cage costs about $5,000. The researchers recommend the cage for narrow passages, such as wetland entrances, irrigation channels and below weirs. Additionally, it can be adapted for young-of-the-year fish by adjusting the mesh size and jumping baffle height. In Gardner Marsh, a floating jumping baffle would be needed to accommodate seasonal water level changes in the marsh.
6. **Rotenone.** Rotenone kills native fishes and other aquatic biota such as zooplankton and macroinvertebrates, so it must be carefully considered and we suggest it be used only as a last resort.

Blanding's turtles • Because of the extensive distances that Blanding's turtles range, it is imperative to maintain existing habitat in the Eastern Wetlands and to reduce the hazards posed by roads that separate wetland and upland habitats. Conservation of wetlands alone is unlikely to protect fauna from anthropogenic habitat modifications (Roe et al. 2006). To link Lake Wingra and Gardner Marsh (Chapter 14) for purposes of turtle conservation, a terrestrial corridor would be needed in addition to culverts for water flow. Although the population of Blanding's turtles might increase by providing preferred marsh habitat and creating terrestrial corridors between wetlands and uplands, it might take decades for the population to increase noticeably (Klemens 2000). And if juvenile recruitment is impaired, populations may not increase, as in other urban wetlands (Rubin et al. 2004).

We recommend monitoring mortality of Blanding's turtles and other terrestrial fauna on Arboretum roads to address threats to Arboretum wildlife. Also, because Blanding's turtles associate with buttonbush, either this native shrub or a similar one could be used to increase habitat. While native to Wisconsin, we did not find buttonbush in Gardner Marsh. We suggest planting test plots with buttonbush and one or more native shrubs with similar characteristics.

Clam shell along Gardner Marsh

Chapter 12: Restoration: No-Action Alternative

The Eastern Wetlands have been neglected for several decades, with unintended degradation of ecosystem services. Biodiversity support, water quality improvement, and flood abatement functions provided by these marshes will continue to degrade if no comprehensive management plan is implemented. We have identified key areas that, if not addressed, could add irreparable damages to these wetlands. If the minimum action of installing a new and larger Pond 4 is all that is accomplished, most ecosystem services will continue to decline due to increased storm water volume, decreased water quality and increased sedimentation from other point sources in these marshes. Here we summarize the likely future if no action is taken in the marshes.

12.1 Water quality will continue to decline

Water sampling during storm events documented high levels of suspended solids flowing into Southeast Marsh due to the failure of Ponds 3 and 4. Vegetation surveys showed that woody vegetation weakens berm stability, and a windfall could uproot shrubs and trees, causing catastrophic sedimentation. If no action is taken, the open water areas of Gardner Marsh will continue to fill in. Slower backwater areas (the two east-west drainage ditches, Figure 2.5) will likely fill first (David Leibl and Ken Potter, personal communication, July 2007). During high flow events, re-suspended sediment and associated contaminants will be carried downstream, ultimately to Lake Monona. The no-action alternative will encourage further degradation of water resources for both people and natural ecosystems.

12.2 The threat of flooding will increase

The infilling of water bodies will increase the potential for flooding. Schmidt Lagoon and the north-south channel in Gardner Marsh have accumulated sediment such that many places are only a few ft deep. If allowed to continue filling, their capacity to retain stormwater will be significantly diminished, reducing the ability to convey stormwater away from the Carver-Martin Street neighborhood. The five fish ponds could eventually fill as well. While they do not receive stormwater directly, these ponds could eventually fill due to erosion, debris deposition, and peat accumulation.

12.3 Biodiversity will continue to decline

Invasive species are rapidly encroaching upon these wetlands, decreasing biodiversity and native species. Vegetation is steadily shifting from predominantly sedge meadow and native cattail to RCG, invasive cattails, and invasive shrubs. In recent years, the cattails near the boardwalk overlook have expanded 0.8 meters per year into the tiny remnant of native sedge meadow (Hall in prep. 2007). As they expanded, the native seed bank was depleted, making restoration much more difficult (ibid.). While there are still high-quality areas of native sedge meadow vegetation in both marshes, these areas total a mere 18.5 acres (7.5 ha; Chapter 10). Such native plant communities are being lost at a significant rate. If no action is taken, sedge meadow will be lost altogether.

Based on our work and earlier studies from Kline (1992), Werner and Zedler (2002) and the Botany 670 class (Zedler 2005) we suggest planning for:

- The protection of remnant native communities;
- The restoration of native vegetation where it no longer exists;
- Optimizing biological and habitat diversity; and
- Using an adaptive restoration framework to "learn while restoring."

The most obvious reasons for not undertaking immediate restoration are cost and additional maintenance. Yet, if nothing is done, the problems of encroachment, pond failure and decreased biodiversity will be exacerbated, adding cost and effort requirements to future maintenance.

12.4 WHA Tower construction will have negative impacts

Of considerable impact to Southeast Marsh is the WHA Radio communication tower on the northern border of the marsh (Figure 2.9). This tower has been in the marsh for more than 30 years and its contract has been recently renewed and expanded. It is located directly in the path of stormwater flow. During high water periods it can remain under >1 ft (>0.3 m) of water for extended periods. Key concerns are potential contamination from copper released by both the old and new buried copper-wire antennas; the potential interaction of heavy metals and inflowing street salt; the heavy construction equipment that will install the new tower and; and the effect of the tower and guy wires on birds and bats.

More than 6 miles (nearly 10 km) of copper wires (a receiving antenna) have been buried in the ground for more than 30 years. Corrosion and heavy metal contamination is possible, and copper levels are elevated in the buried-antenna area (Dr. Cynthia Stiles, personal communication, fall 2007). Winter runoff containing road salt from the Beltline flows into Southeast Marsh. This salt has corrosive properties. The potential for salt corrosion of the buried copper wires is unknown. Initial soil testing by Dr. Cynthia Stiles (formerly UW–Madison Soils Department, now USDA, Lincoln, Nebraska) and Ed Dunkinson (Arboretum volunteer soil monitor) suggests that heavy metals can be liberated by the interaction of salts and metals within the antenna field. Additional water sampling will occur in spring 2008.

Because the wires are buried just below the soil surface, their presence hampers restoration efforts. Any disturbance to the wires could interrupt the operation of the radio tower. Thus, soil remediation is not possible as long as the wires remain in the ground. Machines cannot be used to manipulate vegetation. Hand-pulling requires far more time than mowing, spraying, or cultivating by machine. Restoration efforts in this area will require critical attention to detail, if such efforts are even possible. If the invasive species within the antenna field cannot be controlled, they will remain as a seed source and continued threat for expansion into any adjacent areas that are restored.

The construction of a new tower, new guy wire anchors, and addition of more copper wires is scheduled for spring 2008. If the ground is not deeply frozen, heavy construction equipment will compact the organic soil, cause ponding, and increase habitat for invasive cattails.

The effect of the tower and guy wires on birds and bats is unknown but should be further studied. At night, birds and bats can potentially collide into these structures. No formal study has been done around this tower.

Chapter 13: Restoration Plan 1—Restore Selected Functions with Minimal Hydrologic Change

13.1 Objectives

Restoration Plan 1 (Figure 13.1) is an initial wetland restoration effort in the Eastern Wetlands. The objectives are to improve water quality and increase habitat for native vegetation and wildlife. We highlight areas of remnant native vegetation and suggest mechanisms for preserving and enhancing them with an adaptive restoration approach. With higher quality native vegetation, wildlife habitat will also increase. Because invasive species are well-established in the marshes, restoration and maintenance efforts must be continuous.

Plan 1
Restoration with Limited Hydrologic Changes, Summary of Restoration Plan

WATERSHED STORMWATER IMPROVEMENT

Redesign Arborhills Greenway with infiltration ponds in accordance with BSE student recommendations.
Work with Leopold School students to design education programs around improved stormwater practices.
Work with businesses to implement stormwater best management practices following CBSM techniques as recommended (Chapter 15).
Work with residents to implement stormwater best management practices following CBSM techniques as recommended.

SOUTHEAST MARSH

Pond 3
Dredge Pond 3 to design depths
Repair or replace two outlet structures
Remove vegetation along berm
Remove invasive vegetation adjacent to pond
Repair upstream riprap channel

Pond 4
Rebuild pond entirely to new 6-acre size
Create habitat "benches" along inside of berm for adaptive experiments

Southeast Marsh Culvert
Rebuild or retrofit culvert to allow for water level manipulation with stop log structure
Raise berm elevation if necessary to maintain higher water levels

BOTH MARSHES
Vegetation Management
Implement adaptive experiments for invasive control and native community establishment:

Figure 13.1: Summary of Restoration Plan 1.

13.2 Minimal hydrological changes

Greenway • Based on the neighborhood survey and the goal to increase infiltration in the Greenway, we made preliminary recommendations to the BSE Senior Design students (contact BSE department for the Senior Design report). They considered the neighborhood survey results, modeled infiltration, and conducted a cost/benefit assessment. Both a vegetated channel and wet swale were modeled, but neither met infiltration goals or was cost effective.

The students then designed a series of detention ponds that would utilize the existing concrete channel and drop structures. Their final recommendation has three detention ponds connected by the existing concrete channel. This alternative would increase infiltration potential the greatest and eliminate costs of removing existing infrastructure. The design uses the existing soccer field as one of the three detention areas.

The BSE recommendation would protect the Eastern Wetlands, but it does not follow residential opinion, because it requires standing water, it retains the concrete channel, and it does not add native vegetation. Because a re-design of the Greenway will need public support for the City of Madison to fund the project, we recommend that neighborhood concerns be addressed in a final design. Incorporating opinions beyond those associated with stormwater may increase public support for detention ponds.

A landscape and recreation plan could be added to the BSE design. The majority of survey respondents (88.9%) used the Greenway for walking or running, and many provided additional comments desiring a walking path or track. Some respondents indicated the desire to attract more birds through an increase in native vegetation. Those who use the soccer field commented on the poor condition of the field and nets.

We suggest incorporating public opinion by modeling the feasibility and cost of planting native vegetation throughout the site and installing a walking path around the Greenway. When modeling the path, pervious surfaces should be considered, such as wood chips. Because the Greenway drains an urban neighborhood with winter salt application, landscaping plants need to be tolerant of saline runoff.

Ponds 3 and 4 • Repairs to Ponds 3 and 4 are essential to slow water flow, reduce water and settle out sediments. Details for repair and redesign are in the Stormwater Management Plan (Arboretum 2006); the work will help restore the marshes without significantly changing the direction of flows into either Southeast or Gardner Marsh. Pond repair will also create potential for adaptive restoration using experimental approaches. Pond 3 would be dredged and shrubs and trees removed to prevent their roots from weakening the berm. The outlet structures would be cleared of debris and the outfall channels relined with rock to prevent scour on the downstream end of the culvert. Pond 4 work will more extensive, as the berm and outlet have both failed.

Pond 4 is set to be rebuilt in spring 2008 (David Liebl, personal communication, 2007) to meet conditions in the State of Wisconsin Administrative Code NR 151. Its area will increase from about 2 acres (0.8 ha) to 6 acres (2.43 ha). The new pond is designed to safely pass a 100-year flood event and remove 60% of the total suspended solids (WDOA 2006).

In the long term, both ponds need continual maintenance. Accumulated sediment should be dredged as needed. The berms should be vegetated with native plants, but kept free of shrubs and trees in order to maintain their structural integrity.

13.3 Phase A: Invasive species removal and seed bank analysis

Once Ponds 3 and 4 are repaired, nutrient inflows should decrease, thereby reducing the susceptibility of remnant native vegetation to invasion (Aerts and Berendse 1988). We know from an experiment in Gardner Marsh that *Typha* × *glauca* with added N and P nearly doubled its biomass (Woo and Zedler 2002). Major restoration should start after Ponds 3 and 4 are functional, making possible a broader adaptive restoration plan than the minimal restoration actions proposed in Chapter 10. This larger plan would allow managers and scientists to "learn while restoring" by experimentally testing restoration alternatives.

Why adaptive restoration? • Adaptive restoration is "the design and implementation of a restoration project as a series of experiments, using knowledge from early experiments to revise subsequent experiments and improve subsequent restoration efforts" (Zedler and Callaway 2003). Restoration activities are often based on anecdotal information or trial and error (Adams and Galatowitsch 2006), but these approaches do not test cause-effect mechanisms. Alternatively, the site can be designed to support experiments, and as managers learn which techniques work best and why, they can apply the information to larger efforts. This method helps identify cause-effect relationships while simultaneously restoring the site (Zedler 2005).

The Eastern Wetlands are amenable to an adaptive approach for several reasons. The marshes cover a large area (246 acres; 99.55 ha), so the work should employ methods that have been tested on site. An adaptive approach is needed because there are many unknowns, such as how best to remove invasive species in an urban setting where traditional methods might not prove effective. Because research is a priority at the Arboretum, and because the staff includes expertise in horticulture, ecology, land management, and restoration, an efficient way to proceed is to test alternative methods at the small scale and expand the use of those that prove most effective.

We identified five topics with significant unknowns, each of which can be addressed in field experiments:

- Invasive species control, removal, and maintenance
- The existing seed bank
- Plant/seed mixes
- Planting techniques
- Ideal water level manipulations in the marshes

We suggest two phases for the adaptive restoration process, (A) removing invasive plants and testing the seed bank, then (B) re-establishing native vegetation. Phase A experiments will test methods of removing invasive species. After the most effective methods for invasive removal have been determined, the most effective method will be applied to appropriate areas. Then, Phase B experiments will test native plant establishment, varying seed mixes, seeding timing, and plant type. Once the most effective methods for establishing native plants are known, those techniques will be applied to larger areas of the site, as in Phase A. Finally, the restoration will be monitored and maintained as needed.

RCG, cattails, and shrubs each require different approaches for removal. We consider 'shrubs' to be any woody species including the two buckthorn species, honeysuckle, and red-osier dogwood.

Invasive species control, removal, and maintenance ✦ Water level manipulation would probably not be effective in removing RCG, because it tolerates a variety of hydroperiods (Miller and Zedler 2003; Wilcox et al. 2007). Kercher and Zedler (2004) found that RCG flourishes at a constant depth of approximately 15 cm of water, but one study found that RCG cover was reduced in water depths greater than 35 cm (Coops et al. 1996); thus, total inundation could kill RCG (considered in Plan 2, Chapter 14).

Burning and glyphosate treatments, carbon additions, and biomass harvesting can be used to reduce growth of RCG. Various combinations have been shown to reduce RCG cover initially (Reinhardt-Adams and Galatowitsch 2006, Wilcox et al. 2007). We suggest adding to this knowledge, further tests of sethoxydim, a grass-specific, contact herbicide that is not approved for use over water. Also, we propose tests of cover crops and methods of establishing a sedge meadow community. Phase A should span at least three growing seasons, repeating the methods suggested below. Invasive species removal will take several years, so planning for long-term allocation of human resources is imperative.

Experiment 1

Herbicide timing (compare spring, late summer, fall, and control treatments) ✦ A spring burn and fall herbicide application provide short-term control of RCG, (Apfelbaum 1987; Kilbride and Paveglio 1999; Reinhardt-Adams and Galatowitsch 2006), Fall has been considered the optimal time to apply a systemic herbicide such as glyphosate, because plants translocate energy from the leaves to the rhizomes for winter storage, carrying the herbicide to the rhizomes and increasing chances of killing the plant. One herbicide treatment in the fall was found to reduce reed canary grass the same amount as two mid-May treatments (Reinhardt-Adams and Galatowitsch 2006). While a spring burn does not reduce RCG stem biomass, Reinhardt-Adams and Galatowitsch (2006) found that the RCG seed bank in unburned plots contained twice as many seeds as burned plots (175 vs. 75 seeds/m^2 after two burns). This could be very important where RCG seeds are abundant.

A key unknown is when glyphosate should be applied. We propose comparing two herbicide treatments approximately one month apart, plus a control (no treatment). Recent work by Craig Annen (personal communication, 2008) suggests that spring application should also be compared. All plots should be burned at the same time in the spring, with variation in the time of the herbicide treatment. Several locations could support this experiment (Figure 13.2). All RCG experiments in Phase A could be conducted wherever RCG is abundant, but we

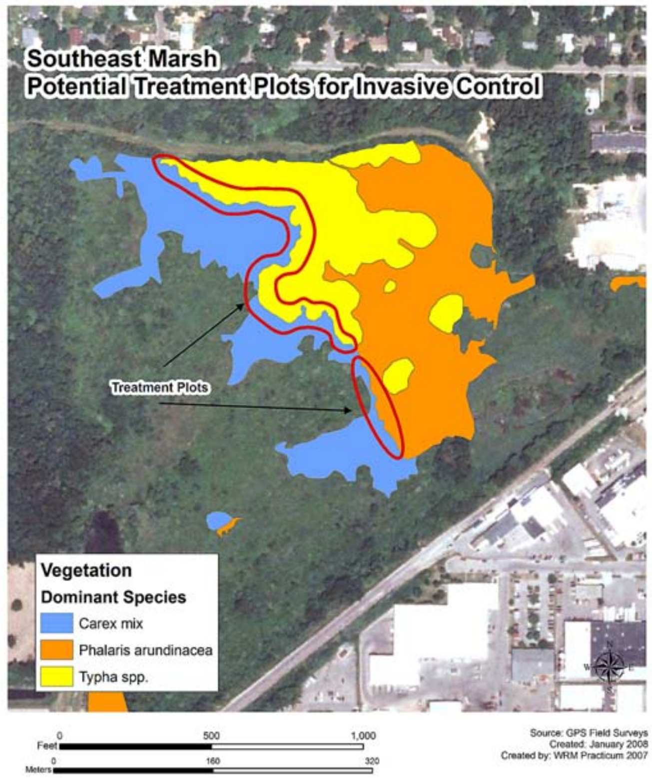


Figure 13.2: Potential RCG treatment areas that occur in an ecotone between RCG and sedge meadow, where RCG density could be lower than in other areas.

recommend placing control plots in ecotones between RCG stands and sedge meadow.

Experiment 2

RCG control (evaluate sethoxydim, compare cover crop species and time of seeding) ◆ The RCG seed bank can be reduced by burning (Reinhardt-Adams and Galatowitsch 2006), and seedling emergence can be reduced by low light quality and low light availability (Lindig-Cisneros and Zedler 2001). In the latter study, RCG seeds exposed to 14 hours of red and white light had 40 to 50% more germination than those exposed to far-red light, as occurs under canopies. Thus, a closed canopy should be less susceptible to invasion than an open canopy (Maurer et al. 2003).

After year 2, we suggest experimenting with sethoxydim and planting forb cover crops, as Healy (in prep.) has done in Curtis Prairie. The forbs we suggest all have broad leaves, which could reduce light penetration and inhibit RCG growth. In shade, RCG seedlings grow and spread slowly (Lindig-Cisneros and Zedler 2001). A cover crop that grows tall rapidly might outcompete RCG. We recommend an experiment to test cover crop species and time of seeding.

The RCG group convened by Art Kitchen (USFWS, Madison) recently developed a list of native plant species expected to compete well with RCG. Here, we suggest testing annual plants, fast-growing perennials, and species that resist disturbance, and species that occur in a variety of habitats, i.e., those with a low coefficient of conservatism (C) (Swink and Wilhelm 1994). Cover crops should also be obligate or facultative species (those most likely to occur in wetlands). Thus, we suggest testing a mixture of three forbs as cover crops: *Bidens frondosus* (C=1), *Impatiens capensis* (C=2), and *Polygnum punctatum* (C=5). This forb mix should be compared with a more common cover crop mix such as Canada wild rye. The seed mix should have equal parts of the three forb species, and no herbicide should be used.

After results from the earlier glyphosate experiment have been completed, the thatch should be removed by burning. The seed mix should be sown the following spring at a rate of 25–50 lbs/acre, or another similar rate typical for cover crops (Morgan 1997). For experimental comparisons, we suggest seeding the cover crop throughout and applying sethoxydim in half of the plots and not in the other half. Note that sethoxydim reduces grass height but does not kill RCG (Wilcox et al. 2007). Thus, it is best used where RCG has been reduced to small patches by glyphosate. A final treatment could combine cover crop species, e.g., two species that dominate different canopy levels. Because sethoxydim is not aquatically approved, we suggest herbiciding in fall when water levels are lower.

Experiment 3

Carbon enrichment (evaluate types, rates, and timing of carbon additions) ◆ The addition of carbon as sucrose or sawdust to the soil is a tool for short-term reduction of plant-available nitrogen, which can alter competitive interactions among species (Morghan and Seastedt 1999; Corbin and D'Antonio 2004; Perry et al. 2004). Enriching soil with carbon-rich media can also promote growth of desired native species (Zink and Allen 1998; Perry et al. 2004). Carbon rich amendments promote microbial activity, which immobilizes plant available nitrogen, nitrate, into a less-usable from, ammonium. In a greenhouse experiment, sawdust was added to soil at a soil to sawdust ratio of 2:1 by volume and 9:1 by weight (Perry et al. 2004). In a disturbed Colorado grassland, 650 g of sucrose were added monthly to 3 × 1.5 m plots to reduce diffuse knapweed levels (Morghan and Seastedt 1999). In the same study, 325 g of sawdust was added monthly to the same 3 × 1.5-m plots. A third study used pine bark and oat straw applied at 3-cm thickness on the ground surface to effectively promote the growth of a native shrub in California (Zink and Allen 1998). Later, Corbin

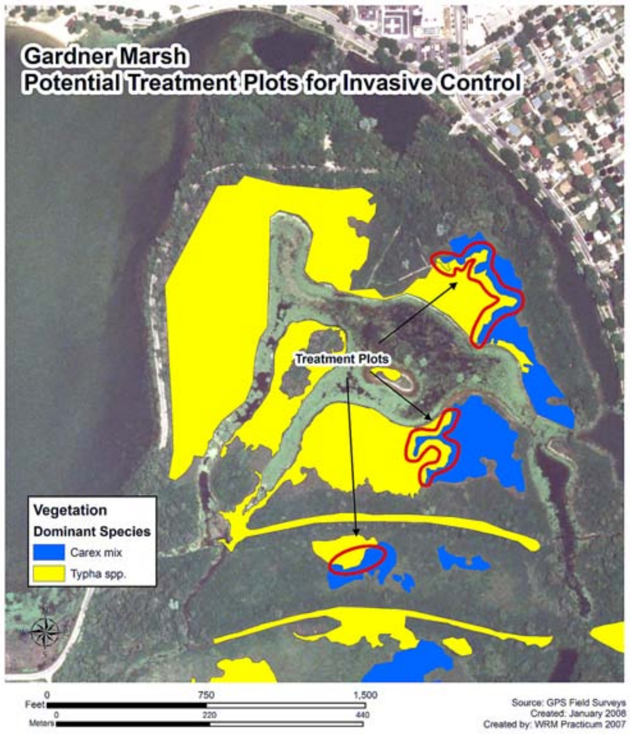


Figure 13.3: Potential cattail treatment areas that occur in an ecotone between cattail and sedge meadow, where cattail density could be lower than in other areas.

and D'Antonio (2004) used 1.2 kg/m of wood chips during a grassland restoration experiment.

We suggest testing carbon additions in plots with the most effective cover crop and sethoxydim regime. For the Eastern Wetlands we propose using wood chips at three application levels. Wood chips should not include buckthorn or honeysuckle berries. We recommend treatments with 1, 1.5, and 2 kg/m^2/month of wood chips in each respective plot. For a source of wood chips, we suggest using shrub biomass from control work that will be going on during this time. A controlled burn would help wood chips reach the soil.

Experiment 4

Harvesting RCG biomass ✦ Mowing and harvesting of plant biomass has been shown to reduce nitrogen and shift species composition to native vegetation (Maron 2001), often in a nutrient-rich, sewage treatment setting (Toet et al. 2005; Vymazal 2007). One experiment testing five harvests per year of the cover crop *Lolium perenne* (annual ryegrass) removed 515 g nitrogen as biomass from the soil (Perry et al. 2004). Next, they compared competitive interactions between RCG and *Carex hystericina* (porcupine sedge) and found that the sedge was better able to compete with RCG once soil nitrogen was reduced.

Because Gardner and Southeast marshes already have monotypic stands of RCG, we suggest harvesting monotypic stands of RCG, harvesting an annual grass cover crop in an area where RCG has been treated for multiple growing seasons with fire and glyphosate, and harvesting an annual grass cover crop where RCG has been burned and treated with herbicide for only one season.

Cattail Removal ✦ Because cutting and flooding reduced cattail cover in Gardner Marsh (Hall and Zedler, in prep.), we defer experimentation with water level control to Plan 2 (Chapter 14). Cattail also responded to herbicide treatments (ibid.), so we propose to test herbicide options. Since water level manipulation is not required, the experiments could occur anywhere in the Eastern Wetlands. Ideal plots would be located near ecotones where cattail densities are low and sedges are most threatened (Figure 13.3).

Experiment 1

Cutting and burning ✦ To avoid herbicides and surfactant side-effects, cutting and burning can be tested as a way to reduce cattail densities or eliminate patches (Botany 670 Class 2006). We suggest experimenting with cutting and burning at different frequencies conducted at different times of the year. Burning could, however, release nutrients and that might increase cattail resprouting and seedling establishment.

Experiment 2

Herbicide with cutting and burning ✦ For this experiment, treatments plots will be cut or burned, followed by an herbicide application. Once biomass has been reduced by cutting or burning, live shoots can be treated with herbicide whenever cattail shoots adequately resprout. Timing should be varied as well. Cattail should be burned or cut followed by three treatments (one of each per year): in mid May, late June, and late August.

Shrub removal ✦ Buckthorn, honeysuckle, and dogwood (hereafter shrubs) are all invasive, and treatment methods are similar enough that they can be combined into one prescription unless otherwise noted. To control shrubs, we suggest testing combinations of fire, herbicide, and water level manipulation. For large stands, we suggest a mechanical approach using the Geoboy, which can cut large shrubs and small trees. It has a cutting device on its front end, and it sits on 28-in rubber tracks that distributes its weight to reduce compaction. The Nature Conservancy has used it to remove shrubs at Nachusa Grasslands where it "in a minute accomplished what would take a crew of four all day to do" (Kleiman 2003).

Experiment 1

Herbicide timing • Herbicide treatments are effective in killing buckthorn (Reinartz 1997; Kline 1981; Boudreau and Wilson 1992), but the optimal application time is uncertain. Reinartz (1997) found mortality rates of 92–100% from winter and spring applications, but Solecki (1997) suggested that late fall or early winter treatment was most effective. We suggest comparing treatments in May, July, and September. We hypothesize that the September application will be the most effective, since the plants will be transporting energy and herbicide to belowground parts. A fourth treatment in October could be effective if plants senesce later. Shrub experiments could occur anywhere in the Eastern Wetlands, with ideal plots located near shrub-sedge meadow ecotones.

Experiment 2

Repeated burning • Burning is often used to suppress buckthorn and other woody plants (Kline 1981). Burning reduces shrub biomass, increases available light and encourages the growth of herbaceous species. Because the seed bank is most likely saturated with buckthorn seeds, repeated burning will probably be needed. In one study, the best time for burning was between late March and early May, when plants were weak due to low carbohydrate reserves (Dziuk 1998). We suggest experimenting with burn frequencies at different times of the year. Plots should be at least 100 m^2 in size. Treatment frequency should be yearly, every other year, and every four years. Time of burning could be spring and fall.

Experiment 3

Combined burning and herbicide • Once the effective herbicide and burning timing and frequency are established, the two methods could be combined. A spring burn and fall herbicide could yield greater mortality than either alone. The most effective herbicide time and the most effective burning time can be compared with previous data from single treatments. At least one single treatment should be repeated to control for interannual variation in treatment results.

Seed bank analysis • We suggest that seed bank analysis be expanded to more areas in Gardner Marsh and that Southeast Marsh be added. Hall and Zedler (in prep. 2007) found few native species where cattails had been established for several years. Due to the many disturbances in both marshes, the seed bank is no doubt significantly altered and mainly composed of invasive plants. Samples should be taken at representative elevations and under current vegetation types.

Where native seeds are still present in significant numbers, and, more importantly, where invasive species' seed supply is low, the seed bank could supplement efforts to reestablish native plants. We predict that both plugs and seeds will have to be planted. If this is the case, frequent burning (Reinhardt-Adams and Galatowitsch 2006) could be explored as a method of reducing the invader populations and their seed banks. We suggest not relying on the native seedbank to revegetate the restored wetlands, however. Invasive species control will likely need to be followed by sowing or planting of plugs. Where only the hydrological component of the system is restored, wetlands tend to support fewer native species, more exotic species, and lower plant cover than undisturbed wetlands (Seabloom and van der Valk 2003; Mulhouse and Galatowitsch 2003).

13.4 Phase B—Native vegetation re-establishment

Species and communities chosen for revegetation should be competitive and resilient. These traits will help natives establish and suppress invasive species. We suggest that the target plant community be the sedge meadow, because it was widespread in the Eastern Wetlands before recent disturbances (Bedford et al. 1974) and because this wetland type has been lost at a high rate (Potter and Zedler, in press). Also, sedge meadow has the potential to support many species (Peach and Zedler 2006),

Adequate tools and infrastructure are necessary for any large-scale restoration. We recommend building a full-size greenhouse at the Arboretum to determine which species can withstand the novel conditions of urban-influenced wetlands. We consider this just as important as repairing Ponds 3 and 4 and establishing water control structures.

We suggest testing the establishment of both individual species and assemblages. Species that are common in sedge meadows and in the Eastern Wetlands are *Carex utriculata, C. lasiocarpa, C. lacustris, Calamagrostis canadensis, Mimulus ringens, Juncus* spp., and *Alisma subcordata*. Each should be tested to find efficient establishment approaches, including seeding vs. the need to use plugs, number and type of species in seed mixes, and methods of evaluating resilience and competitiveness. Because elevation is similar across the Eastern Arboretum Marshes, especially

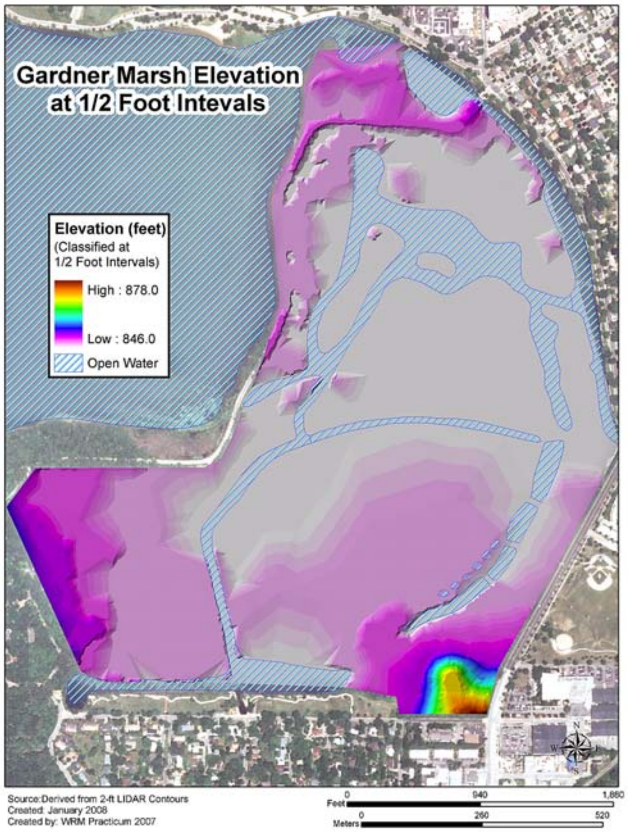


Figure 13.4: Gardner Marsh land elevation (ft).

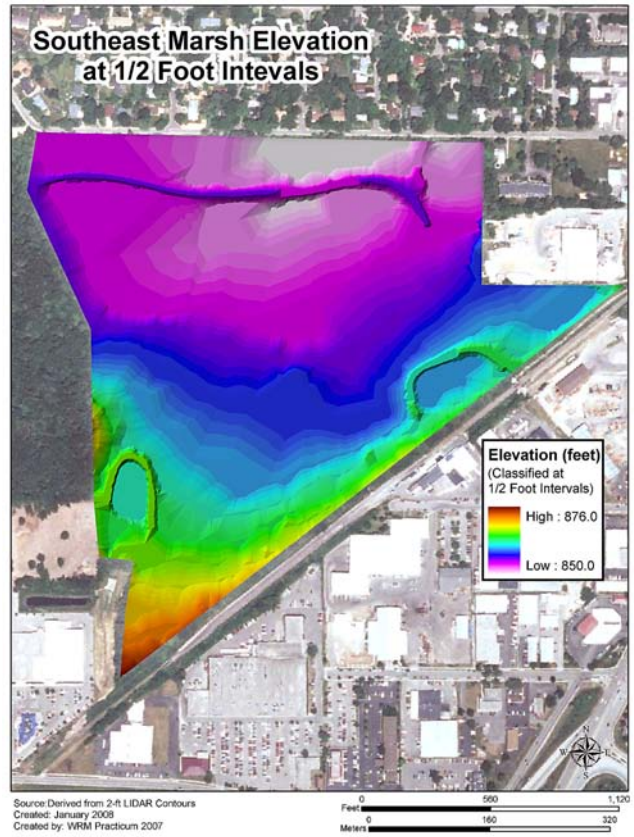


Figure 13.5: Southeast Marsh land elevation (ft).

Gardner Marsh (Figures 13.4, 13.5), the following plant experiments can occur wherever invasive species are dominant. All species and communities chosen are expected to establish rapidly and compete with invasive species.

Experiment 1

Number of species per assemblage ✦ Species richness has been correlated with ecosystem function (Tilman and Downing 1994). For example, resistance to invasion increased with the number of species present per test plot (Fargione and Tilman 2005). Others consider that functional diversity, not species diversity is the key to ecosystem function (Wright et al. 2006). A test of these ideas will have four treatments: 1, 5, 10, and 15 species (Figure 13.6).

For the 1-species treatment, we have chosen *Carex stricta,* which creates tussocks and acts as an ecological engineer (Crain and Bertness 1995; Peach and Zedler 2006). This species was common in the Eastern Wetlands in the early 20th century (Bedford et al. 1974) and it persists to date (Chapter 5). The other 14 species are drawn from a variety of sources (www.jfnew.com, Bedford et al. 1974, Botany 670 class 2007 and our 2007 survey). We selected species that were present in the Eastern Wetlands and predicted to compete with invasive plants (low C value; Figure 13.6). The mix is meant to create a complex, dense canopy to resist recruitment by invasive species. The 15 species consist of six graminoids, three grasses, and six forbs. Two of the forbs are annuals, *Bidens frondosa* and *Impatiens capensis*. This mix includes an ecological engineer, fast growing annuals, and long-lived forbs.

Seed should be of local genotype, whether purchased or collected at the Arboretum. Seeds should be sown in a greenhouse and seedlings measured to obtain similar size plugs. The same number of plugs per species should be planted in each plot, because equal starting conditions simplify interpretation of experimental outcomes. We suggest 9-m^2 plots with approximately 16 plugs per plot. In experiments 1 and 2, cover and height should be measured to assess establishment ability, and reinvasion rates should be assessed to compare as resistance to invasibility.

Experiment 2

Plant establishment by functional group ✦ Plants are often divided into taxonomic groups, which are expected to differ in function. Grasses, forbs, or graminoids could be compared to a combination of all three. The 15 species

Species	Observed In Marsh	C value	Functional Group	Wetland Occurrence
Carex stricta	Yes	7	Graminoid	OBL
Calamagrostis Canadensis	Yes	5	Grass	OBL
Schoenoplectus tabernaemontani	Yes	4	Forb	OBL
Impatiens capensis	Yes	2	Forb	FACW
Lobelia siphilitica	No	5	Forb	FACW+
Carex utriculata	Yes	7	Graminoid	OBL
Juncus effuses	No	4	Graminoid	OBL
Mimulus ringens	Yes	6	Forb	OBL
Polygnum hydropiper	Yes	4	Forb	OBL
Asclepias incarnate	Yes	5	Forb	OBL
Eleocharis obtusa	No	3	Graminoid	OBL
Spartina pectinata	No	5	Grass	FACW+
Glyceria striata	No	4	Grass	OBL
Bidens frondosus	Yes	1	Forb	FACW
Carex vulpinoidea	No	2	Graminoid	OBL

Figure 13.6: Suggested seed mix for Phase B, Experiment 1. The first five species are for the five-species treatment, those five and the next five for the ten species treatment, and all 15 species for the 15 species treatment. C values are from the Wisconsin State Herbarium, except Polygnum hydropiper, from http://nhic.mnr.gov.ca. Wetland occurrence designations are OBL=Obligate, FACW=Faculative wet.

Functional Group	***Species***
Graminoid	*Carex stricta*
	Carex vulpinoidea
	Schoenoplectus tabernaemontani
	Juncus effuses
	Eleochris obtuse
	Carex utriculata
Forb	*Impatiens capensis*
	Mimulus ringens
	Polygnum hydropiper
	Asclepias incarnate
	Lobelia siphilitica
	Bidens frondosus
Grass	*Glyceria striata*
	Spartina pectinata
	Panicum virgatum
	Andropogon gerardii
	Elymus virginicus
	Calamagrostis canadensis

Figure 13.7: Species List for Phase B Experiment 2.

from experiment 1 are listed above (Figure 13.7) with three grass species added. A field experiment could test each species for ease of establishment and ability to resist invasive species.

Experiment 3

Plant establishment using functional groups • We propose functional groups based on growth characteristics of species. In 2007, students ranked species in order of their potential to reduce erosion and promote infiltration, and accomplish these services in the presence of competition from other species (Botany 670 Class 2007). We suggest a similar experiment to identify functional groups drawn from species in Experiment 1. Each would need to be grown in a greenhouse under uniform conditions to test growth characteristics such as biomass and root:shoot ratios.

Experiment 4

Plant establishment with soil amendments • To aid plant establishment, carbon could be added to the soil of each of the above treatments. This experiment could focus on the most well-established groups. In either case, adding carbon could give the native species an advantage over invasive species. Note that species that performed well in experiments 1 and 2 might not grow as well with less available nitrogen.

Experiment 5

Planting plugs and seed. • By itself, seeding is most effective in revegetating sites for species that can form a dense cover crop. In Greene Prairie, only a few of the 30 species sown in a RCG-infested wetland exceeded 10% cover (Wilcox et al. 2007). The stresses imposed by RCG, altered hydrology, and nutrient enrichment reduce chances of establishing native vegetation from seed.

To find low-cost revegetation methods, we suggest comparing the plug mixtures that grew best in the previous experiment with the same species mixes sown as seed. Seed should be sown in fall at different rates. Timing could be compared, e.g., in spring versus fall, but Wilcox et al. (2007) found no difference due to season of seeding wetland species in Greene Prairie.

Experiment 6

Density of plugs • Plugs planted too far apart allow gaps where invaders can establish, while dense plantings increase cost and could increase intra-specific competition. In wetland restorations, 1-ft (30-cm) grids are common (Joshua Brown, personal observation 2004). We suggest testing 15-, 30- and 60-cm grids. Plugs of the same species at the same relative abundance should be planted in plots at different spacing. Cover, height and invasibility should be sampled. Cost of planting for each plot should be considered relative to the establishment per species in the treatments.

Chapter 14: Restoration Plan 2—Restoring a More Natural Hydrological Regime

14.1 Objectives

As detailed throughout this report, the Eastern Wetlands have been significantly altered from their natural state. Human manipulations have reduced in-marsh water levels and introduced numerous invasive species, fundamentally altering the natural marsh ecosystem. Due in large part to the lowered water table, the present-day marshes are characterized by shrub invasion and diminished native communities such as sedge meadow.

In order to halt the encroachment of invasive shrubs and recreate hydrological conditions favorable to native sedge meadows, in-marsh water levels must be restored. Plan 2 features large-scale hydrologic restoration, a concerted maintenance commitment, and significant financial investment (Figure 14.1). The intent of this plan is to restore the wetland ecosystem functions of improving water quality and promoting biodiversity by creating habitat for native biota.

It is important for the Arboretum to initiate a dialogue with residents of the Carver-Martin Street neighborhood, discussing restoration goals and actions, including the manipulation of water levels. Included in the discussion would be the risks of flooding and how scientific evaluation has allowed the Arboretum to determine and implement "safe" in-marsh water levels, but also evaluating what the "normal" (pre-installation of water level control structures) risk of flooding was, and how the installation of water level control structures would affect risk in rain events of great magnitude.

The scale and impact of Plan 2 is significant; however, we assert that significant efforts are necessary return the Eastern Wetlands to a more natural state. While Plan 2 is not a step-by-step blueprint, we sincerely believe that ideas we advance and actions we recommend are worth consideration and are in line with the Arboretum's mission.

14.2 Goals: Restore wetland functions of water quality and biodiversity support

Plan 2 takes an adaptive approach to the management of water levels. The overall goal is to restore wetland functions through the restoration of native vegetation communities, particularly sedge meadow. Specific goals are:

- Re-establish native communities including emergent aquatic marsh, sedge meadow, and wet prairie.
- Control invasive species.
- Treat inflowing stormwater to reduce peak flows and nutrient and sediment inputs
- Increase water quality through increased residence times

We propose to control water levels at strategic locations to allow managers to replicate seasonal inundation, water depths, and natural hydroperiods. The restored hydrological regime will slow the encroachment of woody plants such as dogwood and buckthorn; restore native plant communities such as sedge meadow; improve water quality (e.g. via denitrification); and reconnect the marshes to Lake Wingra to improve habitat for native fishes and waterfowl.

Wetlands are complex and difficult to manage, since one management practice can promote one desirable species while harming an equally-desirable species. Put another way, "wetlands do not just do one thing…optimizing for one is usually at the expense of the other" (Mitsch and Gosselink 2000). In urban ecosystems, restoration could require new management practices. Because outcomes are uncertain, we recommend an adaptive approach (Zedler 2003).

14.3 Southeast Marsh—Construct stop log dam at culvert

Reconstruction of stormwater Ponds 3 and 4 will improve overall water quality by capturing sediment and enhancing denitrification. Nonetheless, when pulses of stormwater exit the ponds they will carry phosphorus and nitrogen to the marsh. To increase downstream water quality, we propose installing a stop log structure at the culvert where water exits at the north end of Southeast Marsh (Figure 14.2). Increasing water residence time should enhance

Plan 2

Hydrologic Manipulation, Summary of Restoration Plan

WATERSHED STORMWATER IMPROVEMENT

Upstream Stormwater Improvement
Redesign Arbor Hills Greenway with infiltration ponds in accordance with BSE student recommendations.
Work with Leopold School students to design education programs around improved stormwater practices.
Work with businesses to implement stormwater best management practices following CBSM techniques as recommended (Chapter 15).
Work with residents to implement stormwater best management practices following CBSM techniques as recommended.

SOUTHEAST MARSH

Pond 3
Dredge Pond 3 to design depths
Repair or replace two outlet structures
Remove vegetation along berm
Remove invasive vegetation adjacent to pond
Repair upstream riprap channel

Pond 4
Rebuild pond entirely to new 6 acre size
Create habitat "benches" along inside of berm for adaptive experiments

Southeast Marsh Culvert
Rebuild or retrofit culvert to allow for water level manipulation with stop log structure
Raise berm elevation if necessary to maintain higher water levels

Vegetation Management
Implement adaptive experiments for invasive control and native community establishment

GARDNER MARSH

Connect Fish Ponds to create new stormwater channel
Remove cinder dams between fish ponds.
Create meandering channel to connect with Wingra Creek to the north.
Rebuild submergent banks of fish ponds to allow for improved habitat and submergent plants.
Install berm across the north-south channel to disconnect Schmidt Lagoon from the channel and Gardner Marsh.
Connect new channel to Schmidt Lagoon.

Rebuild CCC Dam
Repair or rebuild CCC Dam to allow for water level manipulation with a stop log system
Fill the second outlet to Wingra Creek by extending the berm
Block the connection between Gardner Marsh water and the newly created channel from the fish ponds.

Reconnect Red Wing Marsh
Open connection from Lake Wingra to Gardner Marsh under Arboretum Drive at Red Wing Marsh.
Install control structure for water flow between the marsh and the lake.

Vegetation Management
Implement adaptive experiments to control invasive species and establish native communities

Figure 14.1: Summary of Restoration Plan 2.

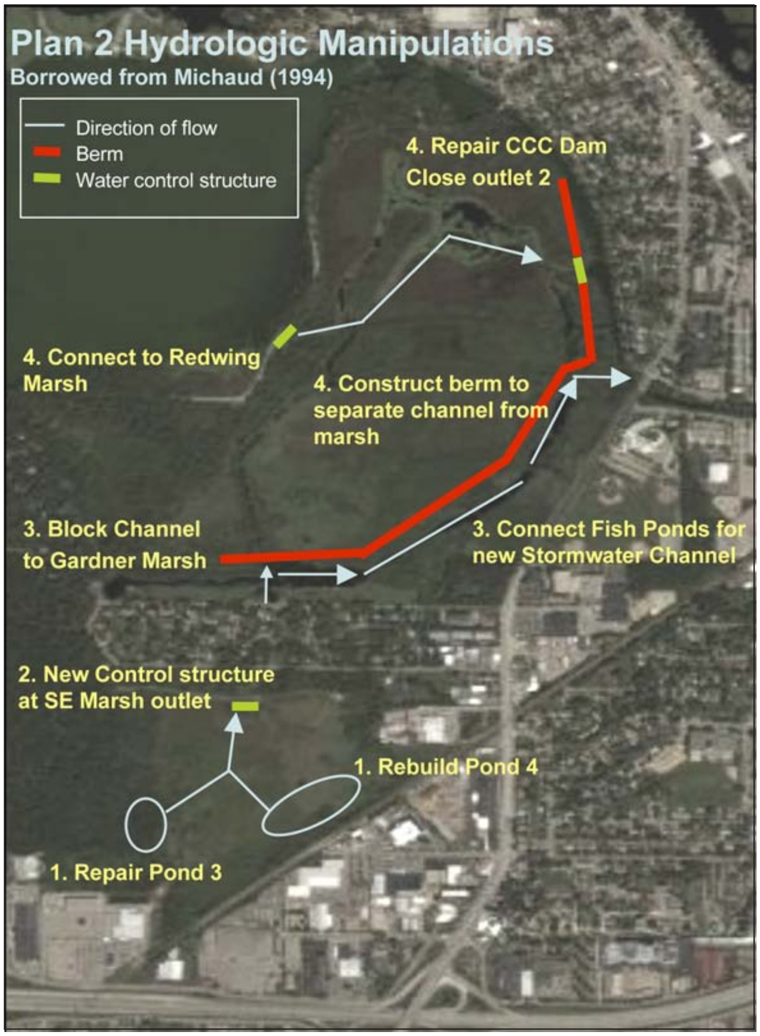


Figure 14.2: Summary of Plan 2 implementation.

denitrification in the marsh. Stormwater will contact macrophyte surfaces for longer time periods so the attached bacteria and periphyton can reduce nitrates to N_2 gas.

Stop logs will allow Arboretum managers to control water levels in the marsh. In times of drought or heavy rainfall, the stop logs in the dam could be used to reduce extremes. In the wet spring months, logs could be added for higher water levels, for amphibians, fish, birds, and native plant communities. During drought (as in 2007) the dam could be used to retain water throughout the marsh. Global climate change predicts that rainfall will decrease in frequency at the same time it increases in intensity. If true, stop logs could be used to achieve more even water levels or to mimic more natural hydroperiods with high spring water levels followed by a summer draw down. A dam with stop logs would also facilitate testing of invasive and native species to show how each performs under different hydroperiods. The re-designed outlet structure will allow managers to flood sections of the marsh to various depths.

The current outlet control is at an elevation of 850 ft (250.9 m) and the top of the berm averages 854 ft (260.3 m). Water level control could retain elevations of 851 ft (259.38 m), 852 ft (259.69 m), and 853 ft (259.99 m) (Figure 14.2). Even if water is held at 853 ft (259.99 m), the existing berm should prevent flooding in the neighborhood. During storm events, water will rise above the stop log elevation because the outlet constricts flow. Therefore, the discharge capacity of the culvert needs to be understood, so the structure and berm will serve managers' needs while still protecting the neighborhood. Until water approaches 854 ft (260.3 m), very little of the marsh is inundated (Figure 14.2). It may therefore be necessary to raise the height of the berm or limit water control experiments to areas of the marsh adjacent to the berm.

14.4 Gardner Marsh—Route stormwater from Schmidt Lagoon through fish ponds to Wingra Creek

Despite historical manipulations and periodic inundation with stormwater rich in phosphorus, nitrogen, suspended sediments, and other contaminants, Gardner Marsh still maintains healthy and diverse native plant communities, as well as provides habitat to birds and amphibians. It still shows promise for recovery through strategic and timely restoration efforts (Chapters 5 and 11). Because of this high restoration potential, we suggest limiting the input of stormwater.

We propose creating a stormwater channel to the east of the marsh, directing stormwater to avoid ecologically-sensitive areas of the marsh. The channel would lead from the northeast corner of Schmidt Lagoon to the south end of the southernmost fish pond (Figure 14.2). The cinder dams between the fish ponds would be removed and all ponds would be connected. A channel would then be dredged eastward from the northernmost fish pond to Wingra Creek (at the location of Outlet 3). Stormwater would then bypass the greater part of Gardner Marsh.

Given that the southeast corner of Gardner Marsh has the highest elevation (878 ft; 267.61 m), dredging may prove difficult, labor-intensive, and expensive. We recommend routing the channel to the northwest, through an area of lower elevation. A channel constructed directly from the northeast corner of Schmidt Lagoon to the south end of the southernmost fish pond would bisect the area at 850 ft (259.08 m) in elevation.

Because the five fish ponds already exist, dredging would be minimal if the channel were created by removing the cinder berms between the ponds. The original depths of the fish ponds, 8.2 ft (2.5 m) (Jones 1947), would be favorable for a channel; however, updated surveys of pond depths would be necessary prior to dredging. The channel would then continue east from the northeast corner of the northernmost fish pond, toward Outlet 3 and the Fish Hatchery Road Bridge. This is a direct route for stormwater to flow to Wingra Creek.

The channel from the southernmost fish pond to its confluence with Wingra Creek could follow the straight line of the fish ponds and convey stormwater quickly. Alternatively, a meandering channel would create a more natural system. A meandering stream buffered by native plants, shrubs, and trees would be aesthetically pleasing for viewing from Fish Hatchery Road. The stretch of Gardner Marsh adjacent to the Fish Hatchery Road corridor is likely the most frequently-seen area of the Arboretum. It has been called an "eyesore," and its restoration could enhance public perception of the Arboretum, as well as possibly providing an outreach opportunity to the students and teachers of Wright Middle School, located directly across Fish Hatchery Road. The area could also be used for research on native plants in stormwater-rich environments, or to gauge the effects of stormwater pulses on biota.

Our actions proposed for southeastern Gardner Marsh will have definite impacts on the marsh. Heavy machinery will be necessary to remove the cinder dams between the ponds so large-scale earth-moving operations should be undertaken during the winter months, when fragile marsh soils are less susceptible to compression. This is particularly important in areas with peaty soil. Damage would be minimal because the ponds and proposed channel are relatively accessible from Fish Hatchery Road, and because we did not identify any sensitive vegetation in that area.

The majority of plant species in the vicinity of the ponds are invasive, much of it a buckthorn monotype. While heavy equipment is onsite for channel construction, regrading, and cinder dam removal, shrub removal could occur simultaneously on the upland areas and along the edges of the pond. Large scale invasive removal in these areas would open an opportunity to revegetate the regraded area with native emergent and submergent vegetation.

14.5 Gardner Marsh—Rebuild CCC Dam with stop logs and fill key outlets

Water level control is key to restoring particular communities within Gardner Marsh (Monthey 1974; Friedman 1987; Michaud 1994). We advocate water control structures at strategic locations, namely the outlets to Wingra Creek, labeled Outlets 1, 2, and 3 (Figure 2.5). To control water levels, the CCC Dam (Outlet 1) would be rebuilt, Outlet 2 would be filled by a berm, and a new channel would route stormwater through the existing fish ponds, where it would exit the marsh at the current location of Outlet 3.

The CCC Dam located at Outlet 1 has been off-line for at least twenty years (and is thus relatively untested). Based on our observations, the CCC Dam is structurally insufficient (Figure 3.11) because the earthen berm supporting the four culverts is significantly eroded. If it were used to increase water level in Gardner Marsh, the structure could fail over the course of several years. The impaired state of the berm was likely exacerbated in August 2007, when Madison received a record rainfall of 15.18 in (38.56 cm; NOAA 2007). Water levels in Gardner Marsh and Wingra Creek nearly overtopped the northern berm. The likely result of this extensive inundation was further erosion of the berm that supports the dam.

While our assertions are speculative, the fact remains that reactivating or retrofitting the CCC Dam would necessitate a reconstruction effort, complete with reinforcement or replacement of the existing berm. The source of fill for the berm must be considered so as not to introduce soil types or new opportunities for invasion (as has happened historically in the marsh). Also, the new berm must be revegetated quickly to slow colonization of invasive species.

Repairing the CCC Dam in its current design as a stop log dam would allow managers to control water levels within the marsh. While the Arboretum could then change water levels to study the impact of depth, hydroperiod, and seasonal inundations on biota, the height of the dam would need to be maintained below the flood levels for the Carver-Martin Street neighborhood. The maximum height of the water must not flood the neighborhood.

As mentioned in Section 13.4, water levels in the marsh could be maintained to mimic a natural water regime or to mitigate seasonal extremes. This may include moderately increased water levels and related residence times during the spring growing season to benefit native vegetation and breeding wildlife, and reduced summer drawdowns. Between the months of March and May, Madison historically receives abundant precipitation, approximately 8.98 in (22.81 cm; NOAA/NWS 2007), but stormwater moves through the urbanized watershed and exits Southeast and Gardner Marshes relatively quickly.

The flashiness of the system is a concern. Both unnaturally-high flows and unnaturally-low flows (or no flows at all) stress native plants and promote the growth of invasive species. A longer residence time could benefit vegetation and wildlife. In light of this, we advise maintaining the reconstructed CCC Dam at a consistent water level. Regular releases of water to the marsh could benefit native submergent and emergent vegetation. A stop log would also maintain water levels in late summer, a time of year that has recently been prone to drought, as detailed (Section 14.7).

Once the CCC Dam is functional, the next critical step is to control water exchanges at Outlets 2 and 3. As Outlet 2 is filled with water from spring to fall, it is a significant artery of water exchange (second to the outlet at the CCC Dam) and would need to be blocked to prevent unregulated flows in and out of the marsh. Filling the outlet by creating an elevated berm would block the passage of water through the channel, allowing water levels to be controlled exclusively at the CCC Dam. We recommend using dredge spoils from the stormwater channel to fill the outlet so as not to further introduce soils that potentially contain seeds of additional invasive plants.

Dams and culverts have limited lifespans and require continual maintenance and eventual replacement. Maintenance of water levels to maximize restoration and minimize flooding to the Carver-Martin Street neighborhood would require substantial time. Water levels at this dam and at the dam proposed for Southeast Marsh will need to be maintained as one hydrologically-connected system. The water levels proposed for either dam must be evaluated to assess effects on the downstream and upstream structures and water bodies.

The new berms recommended in this plan would also need maintenance. It is realistic to expect that, over a period of years, the berms, dams, and other associated structures will actually "sink" into the marsh due to peat subsidence. We speculate that the soils underlying the current CCC Dam have already subsided.

14.6 Gardner Marsh—Reconnect with Lake Wingra at Red Wing Marsh

As detailed in Section 9.4, we propose eliminating the major stormwater inputs to Gardner Marsh, and connecting the marsh to Lake Wingra near Red Wing Marsh to make up for the water lost (Figure 14.2). As previously advocated (Bedford et al. 1974; Kline 1992; Michaud 1994), reconnecting Lake Wingra to its original littoral zone, Gardner Marsh, would enhance biodiversity. We found no species inventories conducted before Lake Wingra was severed by McCaffrey Drive (between 1914 and 1922). The road berm cut off valuable habitat for fishes, amphibians, and aquatic mammals, and likely had a detrimental effect on biodiversity (Irwin 1973; Baumann et al. 1974; Bedford et al 1974).

14.7 Increased water levels and a new berm

In order to achieve the desired invasive plant control due to insufficient water levels in Gardner Marsh, additional water level control is likely necessary. As described in Section 9.5, Michaud (1994) developed a scenario for raising water levels in Gardner Marsh. Similar to the recommendations described above, his earlier report details connecting the fish ponds and drawing water from Lake Wingra through the Red Wing Marsh connection, in addition to constructing an extensive berm along Wingra Creek and along the western side of the fish ponds (Figure 14.2). The berm will allow managers to raise and maintain the water level in the marsh at an elevation of 847 ft (258.17 m) without flooding the downstream Carver-Martin Street neighborhood (Michaud 1994).

Raising water levels in Gardner to this higher elevation (847 ft or 258.17 m) would offer managers the ability to flood areas of invasive cattail and shrubs. This option requires extensive construction and disturbance to areas of the marsh at a considerably increased cost. Before proceeding with this option, managers should test shrub and cattail control in areas of Southeast Marsh, where sufficiently high water levels are assured, to determine the effectiveness of flooding as a control method. Adaptive approaches for controlling invasive shrubs and cattails are detailed below.

If Arboretum managers determine that berm construction is necessary, additional factors should be considered prior to undertaking these large-scale restoration efforts. Soil borings along the proposed berm may be necessary to determine if the soil can support the weight of a new berm. Geo-textile fabric underneath the berm will help to limit compaction. Construction should occur during the winter on frozen soils to limit soil compaction.

14.8 Wildlife habitat considerations

Plan 2 uses water level control to restore vegetation and promote wildlife habitat, through a reconnection between Lake Wingra and its native littoral zone, Gardner Marsh. Management of Lake Wingra for non-native "muskie" versus native northern pike needs further review. Either fish species would have increased spawning habitat under this plan, as both species lay eggs over flooded vegetation (Section 11.6).

We propose using Gardner Marsh as a "carp trap" prior to reconnecting it to Lake Wingra. Since trapping carp in Gardner Marsh could require varying periods of flooding and drawdown, we suggest implementing carp control measure before Plan 2 begins. Once carp levels have been reduced, vegetative restoration could begin. An alternative would be to install all water control measures, including reconnecting Gardner Marsh with Lake Wingra, but restrict fish movement between the marsh and the lake. Then Plan 2 Phases A-B could be carried out as planned. Once sedge meadow communities have established, carp control could begin. *Carex* species tolerate a variety of hydroperiods once established (Budelsky and Galatowitsch 2004; Lawrence and Zedler unpub. data 2007). Concurrent efforts to use water level controls to manage carp populations and restore native sedges might not work if water level fluctuations do not mimic a natural hydroperiod and instead promote RCG reestablishment (Miller and Zedler 2002).

Year 1

Carp control in Gardner Marsh • First rebuild the berm supporting the CCC Dam and reconstruct CCC Dam; create berm across Outlets 2 and 3; and create berms across both west and east ends of drainage canals in Gardner. This will effectively prevent carp already present in Gardner Marsh from escaping, as all outlets will be blocked. Water levels can be manipulated using stop logs at the CCC Dam to manage vegetation. When water levels are seasonally reduced and drawn down, carp in the marsh will be exposed, and vulnerable to removal by netting/seining/electroshocking (Section 11.6).

During drawdown periods, other "desirable" native fish species will also be stranded in the marsh and they would need to be protected and salvaged to the extent possible. Additionally, if and when stop logs are removed from the reconstructed CCC Dam, and after carp are harvested, it is important to prevent carp from entering the marsh. A net or blockade should be temporarily installed on the culverts of the CCC Dam to prevent fish passage into Gardner Marsh from Wingra Creek.

The restored CCC Dam would prevent unregulated water exchanges between Gardner Marsh and Wingra Creek. Carp that enter the marsh during this period would have no escape, and would be vulnerable to removal. This effort, combined with seining operations in Lake Wingra that could be implemented when carp are relatively concentrated on the lake bottom during late fall and winter, could potentially reduce the carp.

Year 2

Carp control in Gardner Marsh • Actions detailed in Year 1 should be repeated, to remove any carp that were missed and survived the winter (or entered the marsh by other means) are caught. The precautions for native fish should also be repeated.

Year 3

Carp control in Gardner Marsh after reconnection with Lake Wingra • The delay in connecting Gardner Marsh and Lake Wingra allows for the capture of the majority of carp present in Gardner Marsh, and gives native vegetation a chance to establish.

Ideally, the carp harvesting in Lake Wingra (see Chapter 11) will have continued, and the population in the lake will be more manageable. However, some carp will survive, and a connection between the lake and the marsh in the spring would quickly attract carp to spawn in the marsh. Fish counts could be conducted at the passageway between the water bodies during this period. Once it is determined that an abundance of carp have entered the marsh, a drawdown cycle similar to Years 1 and 2 should be replicated, with precautions for native fishes.

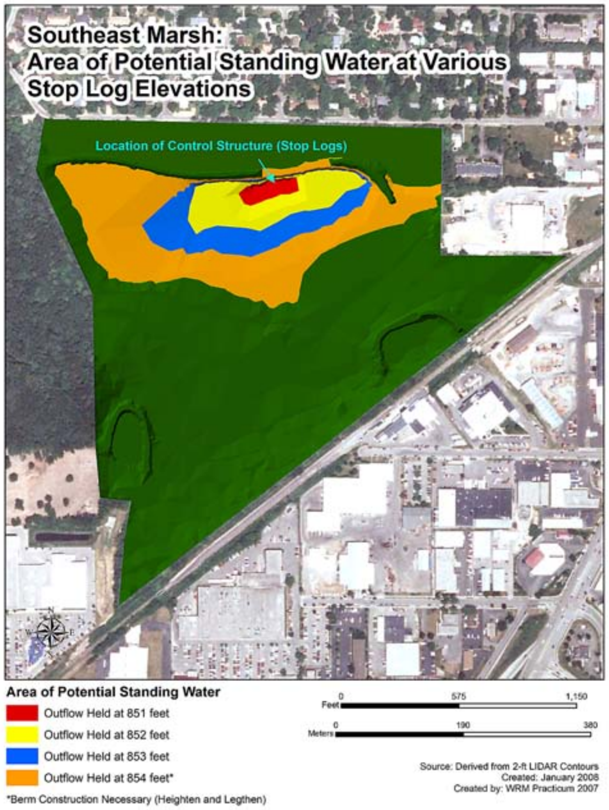


Figure 14.4: Invasive species communities in Southeast Marsh that would flood using Plan 2.

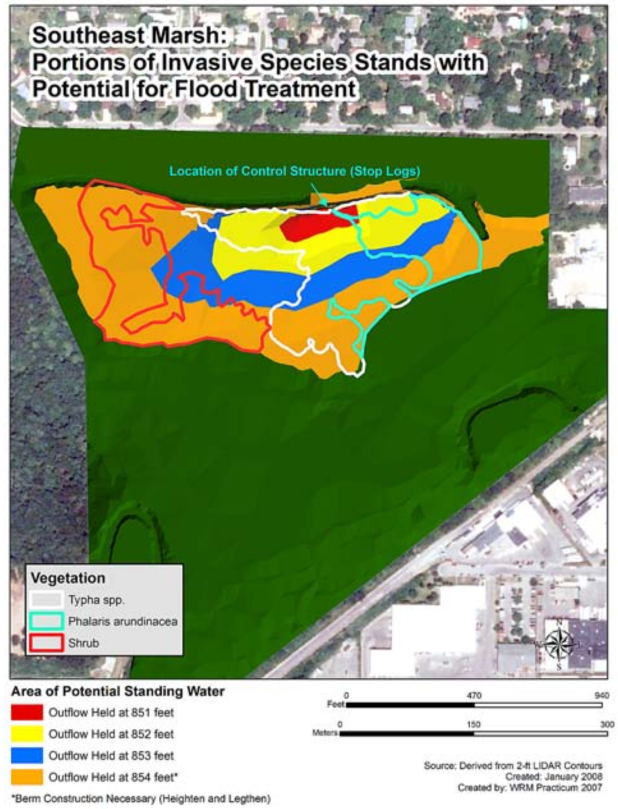


Figure 14.3: Possible water levels in Southeast Marsh with using weir.

Year 4

Carp control in Gardner Marsh after reconnection with Lake Wingra • Actions detailed in Year 3 should be repeated to catch any surviving carp. The precautions with native fish should be followed. Utilizing Gardner Marsh as a carp trap should be an integral part of the Lake Wingra carp harvesting techniques.

Year 5

***Esox** sp. habitat promotion in Gardner Marsh* • After Gardner Marsh is used as a trap for four years, the focus should shift to restoration of "desired" fish—either northern pike or muskie. Much in the way the connection between Lake Wingra and Gardner Marsh was utilized in Years 3 and 4, stop logs should be removed in the spring and water allowed to be temporarily diverted from Lake Wingra. Spawning fish will find new habitat with few carp, and the chances of natural reproduction will be significantly increased from past years. Recruitment of muskie or pike should be closely monitored during this period, to determine whether the species is reproducing. Water level fluctuations that will benefit pike or muskie closely mimic the seasonal fluctuations described in Section 14.10.

14.9 Phase A—Invasive species control

In Plan 2, being able to raise and lower water levels makes it possible to flood specific areas more reliably, to control invasive species and establish native plants. Areas of Southeast Marsh that could be reliably flooded are shown in Figure 14.3.

Reed Canary Grass Removal • Even if RCG is best controlled through herbicide, carbon additions, biomass harvesting, and competition from native species, managers could still explore the minimum water level required to control RCG. All of the following flooding experiments require inundation for at least weeks. Southeast Marsh is the only location where water levels are assured to be sufficient. If managers want to apply these methods to Gardner Marsh, additional construction will be required in order to guarantee high water levels (Chapter 14.8). Therefore the following experiments should be tested in Southeast Marsh where water levels can be manipulated regardless of storm events or time of year (Figure 14.4).

Experiment 1

RCG flooding ✦ We propose testing water depth where RCG growth significantly slows or stops. Treatment depths should be set at 30 and 50 cm. Plots should be located in an area of uniform RCG density. This experiment is intended to pinpoint the minimum standing water depth needed to control RCG. Due to the deep standing water required for this experiment, plots can only be located in a small area of Southeast Marsh. Varying water treatments levels can be obtained by using areas of Southeast Marsh where water levels are already at desired heights, or by installing levees around areas dominated by RCG.

Cattail Removal ✦ Cattails are susceptible to imazapyr and glyphosate herbicide. Cattails can be controlled by other means, namely, cutting or burning followed by flooding (Steven Hall pers. comm. 2007; Sale and Wetzel 1983; Buele 1979). Hall and Zedler in prep. 2007) found that cattail must be cut at least four times without flooding before a cattail growth is significantly reduced. One cutting followed by flooding had the same effect as four cuttings without flooding (ibid.).

The depth of water that is required to kill cattail once they have been cut may vary on the site and season of treatment (Botany 670 Class 2006). In Utah, most cattails were killed when a stand was flooded to 45 cm after two cuttings separated by six weeks (Nelson and Dietz 1966 cited in Mallik and Wein 1986). In another study by Shekhov (1974), cattail cut once and flooded with 40 cm of water also killed most cattail biomass. In a third study, where topography varied, cattail mortality was greatest at 26 cm of flooding after a cut (Murkin and Ward 1980).

Most cattail belowground biomass was killed when ramets (individuals of a clone) were cut 5 cm below the water surface three times in one season (Sale and Wetzel 1983). In the same study, ramets were cut three times 5 cm above the water surface, killing aboveground biomass, but biomass underwater remained healthy and able to regrow. This shows that cutting kills the entire plant only when the site is submersed following cutting. Once aboveground biomass is removed, whether from cutting or burning, cattail must be flooded for some time. If previously cut ramets are exposed to the air, either from decreasing water levels or from vegetative growth, then the ramet can recover. The plant accomplishes this by moving oxygen from leaves exposed to air to the submerged parts via aerenchyma (air tissue). Since the necessary depth and duration of submersion are unknown, we propose to test these variables. Also, we suggest using a handheld brushcutter or aquatic mower to cut standing cattail.

Experiment 2

Ideal water levels for flooding ✦ Cattails can be removed by cutting and flooding (Beule 1979, Sale and Wetzel 1983, Nelson and Dietz 1966 cited in Mallik and Wein 1985, Shekhov 1974). In all of these studies, the water level needed for cattail to die varied from 26–45 cm. Cattail have also been found to continue to grow in up to 30 cm of water (Yeo 1964). It is most likely that site characteristics and intensity of invasion determine how deep an inundation must be. It is important to determine the minimum level of water needed because of precarious location of the Eastern Wetlands to surrounding residential areas. Increased flooding in the marshes could also cause flooding to neighboring buildings and the adjacent sewer system. Also, flooding could also negatively affect adjacent native vegetation. The lower the water level, the less effect flooding would have on nearby vegetation or neighborhoods.

We propose testing the minimum level of water required to kill all above- and belowground cattail biomass. Inundation will last for at least 4 months, a full growing season. If, upon observation, it seems that longer time is necessary, inundation should be extended. Two water level treatments should be implemented. We suggest 8 × 8-m plots. Water level depths should be set at 15 and 30 cm above the ground surface. In addition to a uniform inundation time, we suggest two cuttings. This is to ensure that cattails will respond to flooding. Cutting should occur just before the plant flowers, when the most energy is being spent, and the plant is vulnerable to disturbance. The second cutting should occur whenever there is enough biomass to cut, but before the ramets regrow above the water surface, approximately three weeks from the first cut.

Experiment 3

Time of submersion ✦ The necessary time of inundation could vary considerably depending on the level of invasion and the water and soil chemistry of the site. Once the results of Experiment 1 are available and the minimum water level is known, the minimum time of submersion should be determined. Shorter inundation time would allow additional restoration to proceed and reduce the release of phosphorus via internal eutrophication (Boers et al. 2007).

In this experiment, the minimum water depth determined from Experiment 1 will be used in all plots. Two cuttings will be used, at the same time as in Experiment 1, with similar size plots. Here, time of inundation will be varied. We suggest inundations times of 15, 30, 60, or 90 days. If 15 days is sufficient, then fewer days could be tested in an additional experiment.

Experiment 4

Cutting swaths along ecotones ✦ We propose cutting and flooding areas where remnant sedge meadow overlaps cattail stands. Native sedge meadow species could outcompete cattail stands when both are cut and inundated with water (Steve Hall, pers. comm. 2007). We suggest establishing plots in a line following the ecotone between sedge meadow and cattail where each community is approximately equally represented. Half of the plots would be cut, the other half not cut. Then all plots should be flooded to a depth such that all vegetation would be inundated. In addition, cut plots should be divided into further treatments. Cutting should be continued at varying rates such as monthly or seasonally. It is important that plots be large so that growth of new vegetation will be from seed or regrowth of cut plants and not from cattail rhizomes outside of treatment plots that were not cut. Meanwhile, inundation should be monitored.

Additional experiments

Not yet addressed is the role of fire to remove biomass. Burning could replace cutting. It can be a quicker, more thorough method of biomass removal. It can also remove aboveground biomass and possibly some belowground, depending on moisture levels. But, fire could also release nutrients that could give cattail an additional competitive advantage over native species. Also, burning requires fuel breaks, which must be cut.

Shrub removal ✦ Mature shrubs can be controlled through cutting and herbicide treatments and burning. But due to the prolific seeding of shrubs in the Eastern Wetlands, especially buckthorn and honeysuckle, we believe that water level manipulation could best reduce or eliminate the shrub seed bank.

Experiment 1

Shrub flooding ✦ A first test will examine sites that have had no prior shrub control. We propose testing water levels at 30 cm above the soil surface, at the soil surface, and 30 cm below. Plots should be large, at least 100 m^2, and located in areas with dense shrub cover of the same species. All three shrub species should be tested with the same treatments to see which most reduces shrub cover.

Experiment 2

Flooding and lowering of water levels ✦ Kogler (1979) suggests a method of raising water levels in spring and then significantly dropping levels later in the growing season to control dogwood. A water level five cm above the surface, until the end of June, followed by a drop to 30 cm below the surface for the rest of the growing season could test this idea. Adjustment of water levels and duration of each level may be necessary to determine an effective depth and duration.

Experiment 3

Flooding after removal of seed-producing trees ✦ While flooding of dogwood seeds reduced germination rate to nearly zero (Kogler 1979), we hypothesize that mature trees will not be affected by minor flooding. A proven method of control is to apply herbicide treatments to a cut-stump. We suggest using this method (Chapter 13) to kill adult trees. Once this is accomplished, flooding should continue similar to Experiment 1 above.

14.10 Phase B—Native community establishment

Once invasive species are controlled, revegetation can proceed in a fashion similar to that in Plan 1. Elevations in the Eastern Wetlands are similar enough that similar species can be planted throughout. If plants seemed to be stressed in areas with higher water levels, more water-tolerant species should be added to plantings. Species such as *Carex lacustris, Carex aquatilis, Sparganium eurycarpum, Schoenoplectus* sp. and *Saggitaria* sp. generally tolerate wetter conditions than those listed in Plan 1. But in general, experiments similar to Plan I should be carried out here.

Experiment 1

Preferred hydrologic regime of native species plugs ✦ Once the preferred water depths are determined for species establishment, the preferred hydroperiod should be determined. Water levels in mid-spring and early-summer are critical, as they occur during planting season. But water levels during the rest of the growing season and in subsequent years are also important. Budelsky and Galatowitsch (2000) found that growth rates of *Carex lacustris* varied from the first to the third growing season. Survival and growth of seedlings were lowest in the first growing season in the lowering hydroperiod, but by the third year height and biomass in this same treatment was highest of all treatments. We hypothesize that in this hydroperiod, water levels with highest water levels in spring, gradually reduced through the growing season, would promote native species.

We suggest three hydroperiod treatments: falling, rising, and constant. Water levels in spring and early summer should reflect those that were most effective in previous experimentation. For example, if 10 cm best promoted native species growth in Experiment 1, then water levels should start at 10 cm and then either decrease or rise depending on the treatment.

Experiment 2

Water level preferences of native species plugs • Sedge meadow restoration is difficult and uncommon (Budelsky and Galatowitsch 2004). One method is to restore hydrology and rely on the native seed bank to revegetate the area, but diverse sedge meadows rarely result (Galatowitsch and van der Valk 1996). Planting plugs of native *Carex* can influence the abundance and richness of sedge meadow restoration instead of relying on the seed bank. But plantings can fail if water depth and hydrologic regime are not properly understood. We suggest testing water depths and hydrologic regimes for desired species. We recommend testing species that are already common, such as *Carex lacustis, Calamagrostis canadensis,* and *Carex stricta.* Additional species could be tested in a similar fashion.

For *Carex stricta* we suggest using similar water levels to a similar experiment by Budelsky and Galatowitsch (2004). Rows of *C. stricta* should be planted along a water gradient. Water levels should be located at -20 cm, 0 cm, and 20 cm in relation to the ground surface. Lawrence and Zedler (In prep.) tested six hydroperiods and found most rapid growth with constant flooding at 18 cm depth. *C. stricta* can be planted in rows at each depth in the field. Similar water levels should be used for *Carex lacustris* and *Calamagrostis canadensis.* The water level treatments should be maintained for three growing seasons.

Carex stricta plants were found to form the largest tussocks in 18 cm of standing water compared other hydroperiods (Lawrence and Zedler In prep.). But, total root mass was higher in treatments of drier hydroperiods. It would be useful to know if *C. stricta* plants follow similar patterns plants in the Eastern Marshes under these water levels followed similar patterns.

Experiment 3

Test artificial tussocks • Because Plan 2 focuses on water level manipulation and flooding, native vegetation could have an advantage if artificial tussocks were added. Tussocks help to structure sedge meadow vegetation by increasing surface areas, creating microhabitats, and changing seasonally, all of which lead to increased diversity (Peach and Zedler 2006). During flooding for cattail control, native vegetation might establish on artificial tussocks. We propose testing plant plug establishment in plots with artificial tussocks (e.g. organic matter-filled peat pots) and without.

Plots with equally spaced, artificial tussocks, approximately 20 cm high should be set up. Additional treatments could be spacing of tussocks, height of tussocks, and number of plugs planted on tussocks. The number of plugs planted should be the same for both the treatment and control plots.

Chapter 15: Education and Outreach Plan

15.1 Outreach goals

The conversion of the landscape upstream of the Eastern Wetlands from oak savanna and scattered depressional wetlands to agriculture and then urban development has significantly altered stormwater behavior within the watershed. Infiltration and evapotranspiration have drastically decreased as a result of the rapid conveyance of runoff through the storm sewer system (Apfelbaum 1993). As discussed throughout the report, nutrients, sediments, and contaminants that are no longer assimilated upstream now burden the Eastern Wetlands and Lake Monona.

Education and outreach within the watershed and at the Arboretum are intended to benefit the quality of the Eastern Arboretum Marshes. By focusing efforts within the watershed, as well as within the Arboretum, residents and visitors will experience the importance of the marshes and may participate in programs aimed at increasing upstream infiltration. Goals and strategies have been developed based on results of surveys, current use of the Arboretum, and available resources.

A key outreach goal is to raise awareness within the watershed about the impacts of stormwater management on downstream water quality and ground water supply. Almost two-thirds of 137 respondents to the Arbor Hills Greenway survey were unaware that stormwater running through the Greenway eventually reaches marshes in the Arboretum. An additional 14% of respondents did not agree that it is important to slow the flow of water through the Greenway to promote infiltration in the watershed, leaving a greater portion of residents who are either supportive or relatively neutral on the idea. In a 2003 countywide assessment of community stormwater awareness, 20% of survey respondents were unsure about the fate of stormwater after it leaves their neighborhoods, and 14% responded incorrectly that stormwater leaving their property runs to a municipal sewage treatment system (UWEX 2003).

Although education is an essential component of this plan, numerous studies in social psychology indicate that programs designed solely to raise awareness can be ineffective in changing attitudes and opinions, and are even less effective in prompting behavioral change (Midden 1983; Jordan et al. 1986; Rothschild 1999). As a result, another goal is to implement community-based social marketing (CBSM) programs within the watershed to encourage residents and businesses to take action to improve stormwater management on their properties.

Raising awareness and changing behaviors are two overarching goals that have been narrowed and attached to specific actions to move towards the goals. The following is a list of specific goals and milestones for the education and outreach plan. There is no timeline attached to the milestones because the achievement of each objective will depend on funding and staff availability. In the face of limited resources, we recommend that the Arboretum pursue these goals sequentially.

Goal #1

Raise Awareness about the marshes and then educate residents about restoration efforts with in the Eastern Wetlands.

- ***Milestone #1:*** Create visual exhibits occur at the Visitor Center to display the aesthetic value of the marshes to raise awareness of the marshes and gain public support for restoration.
- ***Milestone #2:*** Install interpretive signage and continually update it along the berm in Southeast Marsh and the lookout boardwalk in Gardner Marsh.
- ***Milestone #3:*** Install an interactive watershed demonstration in the Visitor Center to display the functions of a wetland.
- ***Milestone #4:*** Offer guided tours of the wetlands, especially targeting upstream residents to participate.

Goal #2

Increase community involvement in promoting stormwater detention and infiltration in existing green spaces to reduce the quantity and improve the quality of runoff water entering the Arboretum.

- ***Milestone #1:*** The Arboretum works with the City of Madison to redesign the Arbor Hills Greenway based on recommendations of the Biological Systems Engineering

Senior Design Class and input from the community during neighborhood meetings and via the WRM Practicum survey.

- *Milestone #2:* Arboretum conducts surveys and focus groups to determine upstream neighbors' perceived benefits and barriers to installing rain gardens on their properties.
- *Milestone #3:* The Arboretum expands its current rain garden workshops into a series of informational sessions about rain gardens and hands-on training workshops.
- *Milestone #4:* Arboretum staff implement a community-based social marketing (CBSM) campaign to encourage rain garden installation in upstream communities.

Goal #3

Encourage businesses within the Pond 3 and Pond 4 sewersheds to complete self-assessments of their stormwater management practices and promote the installation of best management practices (BMPs) where appropriate.

- *Milestone #1:* The Arboretum initiates contact with the forty-five businesses that have received the Stormwater Self-Assessment Guide but have yet to communicate with David Liebl or Kevin McSweeney.
- *Milestone #2:* Arboretum facilitates business participation in the WDNR's Green Tier program.
- *Milestone #3:* Arboretum develops and distributes informational materials pertaining to the attributes and costs of various commercial stormwater BMPs.
- *Milestone #4:* Arboretum holds informational meetings and workshops to encourage the installation of stormwater BMPs on commercial properties.
- *Milestone #5:* Ten to fifteen businesses in the watershed have installed at least one of the following BMPs: vegetated buffer strips or infiltration trenches around parking lots, shared detention basins, bioretention facilities, permeable or modular pavement, rain barrels or cisterns, or green rooftops.

Goal #4

Raise community awareness of business and neighborhood efforts to reduce upstream effects on the Eastern Wetlands.

- *Milestone #1:* Businesses that have installed stormwater BMPs receive a certificate of approval from the Arboretum that may be used as a marketing tool to increase patronage.
- *Milestone #2:* Arboretum provides interpretive signage for upstream program participants to place near newly installed BMPs (at the Greenway, by businesses, on residential and school properties).
- *Milestone #3:* Arboretum institutes an annual Parade of Rain Gardens within one year after the start of the CBSM rain garden project.
- *Milestone #4:* Arboretum distributes mailbox stickers or yard signs to all residents with rain gardens to raise awareness of the rain garden project.

15.2 Outreach at the Arboretum

Milestones associated with Goal #1 are concentrated at the Visitor Center and the Eastern Marshes. Here, the goal of raising awareness is not specific to watershed residents, but rather targets all Arboretum visitors. Watershed residents are specifically target within other goals and milestones. Educational outreach to all Arboretum visitors and local residents is anticipated to build general support and understanding for the importance of restoring the wetlands. The following sections described the milestones associated with Goal #1.

Outreach at the Arboretum Visitor Center ✦ Outreach at the Visitor Center will reach a broad audience. Both Gardner and Southeast marshes have few access points for visitors and are not adjacent to the Visitor Center. These barriers make it difficult for outdoor education material to reach a large audience. Therefore, large-scale educational exhibits regarding these marshes should be at a point of congregation: the Visitor Center. We suggest two exhibits with separate education goals: a photography exhibit and an interactive watershed demonstration.

1. Photography exhibit.

Using visual exhibits at the Visitor Center is intended to spark an aesthetic appeal for the marshes. Specifically, we recommend a photography exhibit. The exhibit would include a large collection (50–100 photos) and appeal to a wide range of visitors. It would contain pictures exclusive to Southeast and Gardner Marshes, since they are not readily accessible to the public. The photos would raise awareness of the flora and fauna of urban marshes. This includes photography with subjects of birds, wildlife, amphibians, native plants, rare flowers, landscapes, etc. Potential design details:

- Gain participation by incorporating a photo contest with visitor voting.
- Photos change with season to display seasonal appearance of the marshes.
- Use UW photography students to limit cost of professional photography.
- Offer photos for sale to raise money for restoration projects.
- Include an online photo gallery for website visitors.
- Incorporate sounds of wetlands in the gallery while visitors observe the photos.

We recommend the photography exhibit not focus on restoration experiments and infrastructure. These types are subjects are not typically aesthetically appealing, but rather are associated with different education goals. In general, the photography would raise awareness to the existence of the marshes and characteristics aesthetically appealing to protect. It would bring visitors emotionally closer to the wetlands without venturing into Southeast or Gardner Marsh. (Figure 15.1).

Figure 15.1 The existing art gallery at the Visitor Center where a photography exhibit of the Eastern Wetlands could be displayed.

2. Interactive watershed demonstration.

In addition to creating a visually stimulating exhibit at the Visitor Center, we recommend raising awareness through an interactive demonstration. Such an exhibit goes beyond raising awareness of the existence and beauty of the marshes. It specifically educates visitors on the ecological importance of a wetland. By creating scaled versions of the Southeast and Gardner watersheds, Arboretum staff can demonstrate how theses marshes currently function and potentially function.

The exhibit should be interactive in the sense that educators can simulate rainfall on the watershed, fill ponds with sediment, and alter vegetation. To accomplish this, we recommend three physical watershed models. Each model would represent the conditions of the watershed and wetlands at varying time periods. The temporal change would illustrate the change in urbanization and functional quality of the wetlands. The earliest model would have

Figure 15.2 A closeup of a watershed model used for environmental education. Source: Commonwealth of Kentucky, Division of Water http://www.water.ky.gov/sw/nps/Displays+and+Interactive+Models.htm

Figure 15.3 A series of runoff models used to display land use changed with urbanization and the affects of runoff. Source: Commonwealth of Kentucky, Division of Water (http://www.water.ky.gov/sw/nps/Displays+and+Interactive+Models.htm

less urban stormwater effect compared to the third model. Additionally, the stormwater ponds would have less volume in the third model to simulate sediment build up (Figure 15. 2, 15.3).

Other potential design details:

- Educators pour water to simulate rainfall and ask visitors to predict how it will flow.
- Have a variety of options (i.e.. pond failing); show effects on vegetation (i.e. velocity)
- Narrative explanations that describe how the three models differ.
- Allow water to flow through the entire model to show the difference in clarity from rain to discharge in Lake Monona for each scenario.
- Use natural materials like clay, sand, rock, etc to build the model to simulate how water actually reacts with such surfaces.
- Models should be 3-D and incorporate relative topographic characteristics to accurate display how water will move.
- Display video of the demonstration online for those who visit the website.

Visitors will gain accurate awareness of how both Gardner and Southeast marshes are used to capture and filter stormwater before it enters Lake Monona. Because each model displays a different temporal urban setting, visitors will also gain awareness of the effects urbanization has on marsh ecosystem functions. A narrative explanation will need to accompany the exhibit to ensure visitors understand why characteristics change among the models.

Both the photography exhibit and interactive watersheds share the purpose of educating visitors and gaining awareness. The displays may lead to future behavioral change, but that is not the targeted goal. Additionally, both exhibits have flexibility based on resources, funds, and staff available at the time of launch. For this reason, the specific design details of the exhibits are not identified.

Outreach within the marshes ✦ Although we have suggested educational outreach at the center, it is still important to assist visitors who would like to experience Gardner and Southeast marshes in their natural setting. For this reason, we have incorporated two milestones that will raise awareness among neighborhood residents and those who may not travel to the Visitor Center. In addition to raising awareness of the current conditions, these milestones are intended to educate visitors on continuing restoration efforts.

Interpretive signage ✦ It is evident that people do enter Southeast Marsh, since we observed people walking on the berm along the north side of Southeast Marsh. There are no other trails or public access points in this marsh. The level berm path and its elevated view of the marsh makes an ideal point for educational signage. Signs would offer a variety of benefits, including asking the public to stay on the berm and not travel into the sensitive marsh. Sign information could:

- Picture the failure of Pond 4 and explain the importance of rebuilding it.
- Identify the WHA Radio Tower and explain why the site was chosen for the tower.
- Show pictures of native and non-native plants and suggest visitors try identifying them.
- Point out and describe the sacred rock and its Native American significance.
- Change displays on modular signs as restoration experiments are implemented–signs would update visitors on progress.
- Illustrate birds found in the marsh and identify where a visitor may look to see them (e.g. hawk in a snag tree).

Access to Gardner Marsh is limited to a narrow plank walkway that leads to a wooden overlook on the north side of the lagoon and a second walkway across from the former parking lot. While we observed few visitors using the first overlook, it offers excellent views of the lagoon and of a sedge meadow. The overlook is another ideal spot to offer education on Gardner Marsh. Many of the same topics can be covered on signs at this point; however, some signage would be specific to this marsh:

- Identify sandhill cranes and suggest looking on the island for them.
- Explain the habitat benefits of the sedge meadow community that can be seen from this look out point, and explain efforts to increase this community throughout the marsh.
- Show historical diagram of how the marsh was once connected to Lake Wingra.
- Illustrate where the water exits the marsh and enters Wingra Creek—and explain how the wetland filters water before in enters the creek.

Signage locations were based on existing structures or high current use. In compliance with Arboretum Outreach staff opinions, we do not recommend encouraging further formal access to the marshes. Allowing visitors to experience the marsh in person is an important education tool, but formal trails and boardwalks could become a liability issue or disrupt restoration efforts. Additionally, concentrating signs at existing access points would make signs more effective.

Guided walks of the marshes ✦ Guided walks through the Eastern Wetlands are a way to continue to connect people to the marshes without implementing adding access points. Walks through the marsh with an Arboretum guide would also allow visitors to gain appreciation for native marsh plants and ecology. We recommend targeting watershed residents to participate in the walks. For watershed residents to participate in upstream outreach programs to improve the quality of the marsh, it is important to connect them to the marsh. Residents may be more willing to participate if they have seen the marsh in person and can see improvement in quality due to upstream efforts. To encourage upstream residents to participate, promote the walks in the Arbor Hills Neighborhood Association Newsletter, Association meetings, Leopold School PTA meetings, associate and school website calendars, and local newspapers.

Walks should include:

- An introductory tutorial and what to expect in the marshes and current restoration efforts.
- Tours of the major plant communities in each marsh, with additional information on the native and non-native plants.
- Explanation of the past engineering (i.e., fish ponds) and research activity in the marshes.
- Air photos for participants to view while in the marsh – include historical photos that show how the marsh has changed.

- Charts that illustrate fish and wildlife that inhabit the marshes.
- Discussion of the cultural resources in the marshes.

The walks would complement the goal of raising awareness. Visitors and watershed residents would see evidence of the effects of urbanization on wetlands. Awareness of such effects could influence watershed residents to participate in positive behavioral changes that would benefit the marshes. About 65% of Arbor Hills Survey respondents strongly or moderately agreed that it was important to increase infiltration to protect the Arboretum Wetlands. Connecting residents to the marsh during guided walks could move positive opinions toward behavioral change.

15.3 Watershed Outreach

Neighborhood rain gardens as a tool for urban stormwater management ✦ Messages to neighbors should include summaries of information noted earlier, namely, that

- Impervious surfaces such as rooftops, driveways, streets, and sidewalks significantly impact watershed hydrology by increasing stormwater flow velocities and decreasing rates of infiltration (USGS 2004).
- As development in southern Madison and Fitchburg has expanded in the last fifty years, increased impervious surface area has led to increased surface water runoff to Southeast and Gardner Marshes (Arboretum 2006).
- Stormwater accumulates pollutants, nutrients, and sediment and increases in velocity as it flows over hard surfaces (Dietz and Clausen 2005), thus increasing the level of contamination in the Eastern Wetlands.
- Increasingly impervious watersheds also decrease rates of groundwater recharge, further impacting downstream hydrology (USGS 2004).

Rain gardens are one way to manage stormwater on individual parcels and to reduce non-point sources of pollution within the watershed of the Eastern Wetlands (Figure 15. 4). A rain garden is a shallow depression planted with wildflowers, shrubs, or grasses to slow the flow of stormwater, absorb nutrients, trap sediments and encourage infiltration (WDNR 2006). Well-designed rain gardens with appropriate plant assemblages have the capacity to promote infiltration within a concentrated area. This prevents water from ponding in low-lying areas or eroding the land surface on its way to storm drains or surface water bodies (ibid.).

Figure 15.4 An example of a residential rain garden. Source: Wisconsin Department of Natural Resource. http://dnr.wi.gov/runoff/rg/RainGarden_genl_newsletter.pdf

City of Madison rain garden programs • Within the past decade, the City of Madison Engineering Division developed informational materials and programs promoting the installation of rain gardens on residential and commercial properties. In 2003, the Friends of Lake Wingra received a grant to fund the Adams Street Rain Garden Project, an effort to install a series of rain gardens in the terrace between the street and sidewalk along Adams Street, one of nine streets slated for reconstruction within the Wingra watershed at the time of the proposal (FOLW 2003; C-MED 2007). To date, the City of Madison and Friends of Lake Wingra have partnered with Adams Street residents to install nine rain gardens (C-MED 2007). The gardens are carefully engineered to receive runoff from both sidewalks and the street, with overflow pipes to the storm sewer system to prevent flooding (ibid.). The City has encouraged rain garden installation throughout Madison, tracking the community's progress on a webpage with a map denoting all reported rain garden sites (ibid.). Known as the 1,000 Rain Gardens Program, it attempts to invoke a social norm by demonstrating the increasing popularity of rain gardens in Madison. In doing so, it underscores the importance of a community-wide solution to the city's stormwater management problems.

Madison is not alone in its efforts to promote rain garden development. Programs across the country provide educational materials, technical assistance and cost-sharing opportunities to residents, businesses and public institutions interested in building gardens to help manage their own stormwater runoff. However, despite the growing interest in rain gardens, the body of research is relatively small on how to guide decisions about planting and siting gardens to optimize their effectiveness (Fisher 2007).

Community-based social marketing as an outreach strategy • Community-based social marketing, or CBSM, is a relatively new strategy among environmental educators and natural resource managers to raise citizen awareness of environmental issues and reduce the negative impacts we have on natural resources by promoting pro-environmental behaviors. The five tools of CBSM are effective communication, effective commitments, effective incentives, effective prompts, effective norms.

This approach recognizes three primary reasons why people do not engage in activities that would benefit the environment (McKenzie-Mohr and Smith 1999). First, they may not be aware of the activity or its benefits. Second, if they are aware of the activity, they may perceive barriers that prevent them from engaging in it. Third, people who are aware of an activity and do not perceive any barriers to performing it may still perceive a greater benefit from engaging in their present behavior (ibid.). Therefore, a critical first step in the CBSM process is to identify perceived benefits and barriers to a desired behavior or activity as compared to those for an existing behavior. The emphasis of a CBSM program is on changing people's actions by bridging gaps that sometimes exist between attitudes, beliefs and behaviors. This is the fundamental difference between CBSM and a strictly educational approach.

We suggest that the Arboretum employ a CBSM strategy in future community outreach efforts. Because a CBSM program can only target one behavior at a time, this approach should be used in conjunction with an ongoing educational program covering a broader array of topics. Rain garden installation is a behavior that the Arboretum should promote through CBSM, because social marketing tools such as communication, norms and incentives lend themselves well to the promotion of this residential stormwater BMP.

Unlike many generic information and education campaigns, CBSM is tailored to a particular community. Program planners should select target communities based on the relative potential impact they will have on surface and ground water resources. Neighborhoods in the sewersheds of Ponds 3 and 4—such as Arbor Hills and Burr Oaks—should take priority, although this approach can be applied to any number of nearby communities to raise awareness and effect positive environmental change. Political boundaries delineating neighborhoods do not necessarily match those of the Southeast Marsh watershed, but we still recommend that the Arboretum target an entire neighborhood at a time. A large part of the CBSM process involves establishing a new social norm and encouraging commitment to a community-wide program, so it is important to work within existing social boundaries.

After selecting a target neighborhood, program planners should identify residents' perceived benefits and barriers to installing rain gardens on their properties. A barrier is any perceived economic, social, cultural, or physical factor that prevents or discourages a person from performing an activity. Physical labor and concerns about the cost and aesthetics of rain garden plants are examples of perceived barriers to installing a rain garden. Conversely, a benefit encourages a person to engage in an activity by offering an economic or social payoff. Perceived benefits to installing rain gardens may include bird and butterfly attraction and a sense of pride in reducing negative impacts to local water resources. We suggest a survey similar to the one found in Appendix K to identify the most common perceived benefits and barriers of the target population. If time permits, we also recommend holding focus group sessions to gain a deeper understanding of the community's perceptions and concerns. Focus groups will allow Arboretum staff to assess neighborhood residents' understanding of rain gardens and the functions they serve, as well as document more specifically the perceived benefits and barriers to installing rain gardens.

Typical CBSM programs involve a comparison of the target behavior to current, competing behaviors. Realistically, there are not many situations in which building a rain garden would be mutually exclusive with another type of behavior. Residents with lawns will not be required to remove all of their turf grass to make room for a rain garden and those with wooded lots will not have to remove trees or excavate large portions of their properties. Given the nature of this target behavior, program planners can center the design of the CBSM program on increasing the perceived benefits and decreasing the perceived barriers to installing and maintaining a rain garden.

The selection and application of specific tools will depend on the target population's perceived benefits and barriers, but there are general considerations for the effective use of each tool. Appendix L summarizes guidelines for the use of the five CBSM tools, effective communication based on the book Fostering Sustainable Behavior, by Doug McKenzie-Mohr and William Smith (McKenzie-Mohr and Smith 1999). We suggest utilizing the full array of CBSM tools: ***communication, commitment, incentives, prompts and norms.***

Communication involves creating effective messages by capturing the audience's attention and presenting information vividly in speech, writing, graphs and pictures. For a rain garden program, the Arboretum should continue to offer informational workshops at which participants have an opportunity to get hands-on experience in site preparation and planting in a demonstration garden. Ideally, the Arboretum would work with neighborhood associations to select public locations such as parks, schools, or community centers as demonstration garden sites. Additionally, increase awareness by publishing neighborhood newsletter articles and eye-catching door hangers with information about rain gardens and the community effort to manage stormwater runoff.

Commitment involves coaxing people to agree to a small request in hopes that this will lead to future, possibly larger, commitments. By committing to something small, such as signing a petition in favor of improving neighborhood stormwater management, people often alter the way they perceive themselves (McKenzie-Mohr and Smith 1999). Those who commit to one request often "feel a strong internal pressure to behave consistently" when asked to commit to another (ibid.). For a CBSM program encouraging rain garden installation, the commitment tool is critical to garner initial support from neighborhood residents and ties strongly to the establishment of a norm. We recommend soliciting the commitment of those with properties well-suited for rain gardens, where lots are gently to moderately sloping and soils are not likely to have high clay content (although homeowners should test this prior to excavation of a garden site). We suggest using a form similar to the one in Appendix K and request residents' signatures by making personal contact. Surveyors should emphasize that the forms are not contracts and that people are not legally bound to follow through on their commitments. Targeting clusters of properties will have the greatest effect, because people who sign a form committing to rain garden installation will not only feel an internal obligation to fulfill their promise but a responsibility to others in the surrounding community.

We suggest that the Arboretum offer ***incentives*** to program participants in order to persuade community members to commit to installing and maintaining a rain garden. These incentives should be available only to participants willing to sign the written commitment forms. Public recognition and social incentives, such as winning the approval of family, friends, or neighbors, can be just as motivating as financial incentives (McKenzie-Mohr and Smith 1999), so it is not necessary for the Arboretum to offer cost-sharing if its budget is limited. We recommend offering labor and technical support, free workshop discounts on plant material at the Friends of the Arboretum's annual Native Plant Sale to help participants build their rain gardens. Memberships to the Friends of the Arboretum could be discounted for new members. The Arboretum should promote public recognition by providing participants with bumper stickers, lawn signs, or mailbox decals stating that they have committed to installing and maintaining a rain garden.

Program administrators should use ***prompts*** to remind people of their own commitments and persuade others to imitate them, with the goal of establishing a social norm (Gardner and Stern 2002). Yard signs and stickers will not only serve as incentives, but can establish a sense of camaraderie among individuals with established rain gardens and prompt a reaffirmation of the sign or sticker user's own commitment. Rain gardens sited in public places such as schools, parks, or churches can also serve as prompts, along with maps in public locations that identify established rain gardens and announcements of community members' commitments. In short, prompts serve as reminders of an ongoing program and ensure a heightened level of awareness about stormwater management issues within a community.

As previously mentioned, tools such as commitment, incentives and prompts, all link to the establishment of a new social norm. People often observe the behavior of friends, family and community members to determine how they should behave, and CBSM makes use of this urge to conform by positively reinforcing desired behaviors and making them visible (McKenzie-Mohr and Smith 1999). The Arboretum should encourage workshop participants and other enthusiastic community members to make personal contacts within their neighborhoods and model the desired behavior of installing a rain garden. Further reinforcement of a norm could include hosting annual seed or plant exchanges and organizing a neighborhood Parade of Rain Gardens each summer.

We recommend that the Arboretum conduct a pilot program in the Arbor Hills Neighborhood using a combination of all five CBSM tools listed above. The establishment of a norm is critical if the rain garden program is expected to continue without regular outreach efforts by the Arboretum, but staff should still monitor and evaluate the success of the program on an annual basis. Because CBSM is used to promote a behavioral change, the most obvious measurement of progress will be the number of rain gardens installed in the neighborhood as a result of the program. Each year, program administrators should conduct visual site inspections of properties within the neighborhood to locate newly installed rain gardens. We recommend that the Arboretum use this information to create a monitoring database that tracks rain garden installations within the community and contains pertinent information such as property owner, location, date of installation and any other site-specific facts worth noting. This will allow Arboretum staff to determine the effectiveness of the commitment tool by tracking the number of property owners who follow through on their commitments and monitoring whether they are upholding the proper design and maintenance specifications established for the community.

15.4 Outreach to businesses

To date, sixty businesses in the sewersheds of Ponds 2, 3 and 4 have received the Arboretum's stormwater management "Self-Assessment Guide for Wisconsin Businesses" (David Liebl, personal communication, 2007). Of those, only 15 have initiated contact with the Arboretum (ibid.). While business owners likely appreciate the information and detailed advice the guide offers, it is clear that they need additional incentive to follow through on assessing stormwater management issues on their properties and installing best management practices to mitigate negative environmental impacts.

We recommend that the Arboretum engage local businesses by facilitating participation in the WDNR's Green Tier program. Green Tier is an innovative approach that shifts the regulatory focus on compliance to achievement of "superior environmental performance" (McDermid 2006). Under Green Tier, businesses are expected to improve environmental performance beyond current regulatory standards and to change or mitigate unregulated practices that pose significant environmental impacts (ibid.). Green Tier encourages businesses with shared environmental performance goals to join together to establish charters with the WDNR (ibid.). Business owners in the Pond 3 and 4 sewersheds may be more likely to participate in a joint effort to improve stormwater management. Together, businesses would form a support network and build a sense of camaraderie. This would lessen individual burdens and participants would feel compelled to continue contributing to the team effort.

The Green Tier program would also provide economic incentives to businesses. The WDNR publicly recognizes program participants, which could translate into improved sales and customer relations. "Green marketing" is a growing trend, empowering consumers to support the environment through their purchases of products and services (Ottman, Stafford et al. 2006). According to the WDNR, the Green Tier program can support a company's brand equity and can increase employee pride in the business (McDermid 2006). Additionally, the permitting process is often expedited for program participants and permit exemptions are possible in some circumstances (ibid.).

Stormwater best management practices (BMPs) • Businesses participating in the Green Tier program will be expected to install BMPs consistent with the standards outlined in the state statutes. According to NR 154, a relatively new WDNR rule on non-point source pollution control and stormwater best management practices (BMPs), urban BMPs include detention basins, wet basins, infiltration basins and trenches and wetland basins (§154.42 Wis. Stats.). Additional BMPs may include porous pavement, green rooftops and the use of cisterns or rain barrels to collect rain water. The purpose of an urban BMP is to slow the rate, reduce the volume and improve the quality of runoff (§154.42 Wis. Stats.).

The selection of a BMP should depend on site-specific conditions identified in a stormwater self-assessment (David Liebl, personal communication, 2007). The following section offers brief descriptions of a variety of urban BMPs and the circumstances under which they are best applied.

1. ***Detention basins*** are temporary storage facilities used for controlling peak discharge rates after storm events (UWEX 2003). These facilities also allow some pollutants to settle from runoff water. Detention basins are often practical BMPs in urbanized areas, because they do not require property owners to replace existing pavement with vegetation or porous pavement. Basins may also be shared by multiple property owners. The cost of a detention basin varies with size, location and engineering complexity. Contractors can provide site-specific estimates to property owners and organizations considering basin installation (UWEX 2003).
2. ***Wet detention basins*** are permanent pools of standing water, allowing pollutants and suspended solids to settle out of water over extended time periods (UWEX 2003). In wet basins, water from one storm event is displaced by water from the next (EPA 1999). Due to biological activity, nutrient removal in wet basins is generally high (ibid.). Properly sited and maintained wet basins can provide significant storm water quantity and quality benefits, but pond performance is dependent on a number of factors. Ponds must receive water from a large enough drainage area to maintain a permanent pool of water and soils cannot be highly permeable (ibid.). Additionally, wet basins require regular cleaning to remain functional (UWEX 2003).
3. ***Bioretention facilities*** are vegetated depressions that store, treat and infiltrate storm water (Garcia et al. 2005). Deep-rooted native vegetation aids in water uptake and pollutant filtration. Below the vegetated surface, a basin consists of layers of engineered soil and coarse aggregate (Scott 2007). The design allows for efficient infiltration and a minimal ponding period after storms. Bioretention basins are aesthetically pleasing and are well-suited for parking lot perimeters and islands (Figure 15. 5). Typical installation costs run from $10 to $40 per square ft.
4. ***Infiltration trenches*** are stone-filled channels that slow the flow of runoff, infiltrate stormwater and treat pollutants (Garcia et al. 2005). Trenches are also a common BMP for parking lot perimeters and can accommodate pedestrian traffic. A typical infiltration trench consists of a relatively deep layer of two- to four-in (5-10 cm) diameter clean stone over thin layer of sand that aids in pollutant treatment and prevents soil compaction (ibid.). The addition of an upper layer of pea gravel over filter fabric can reduce maintenance costs by trapping sediments. Without the pea gravel,

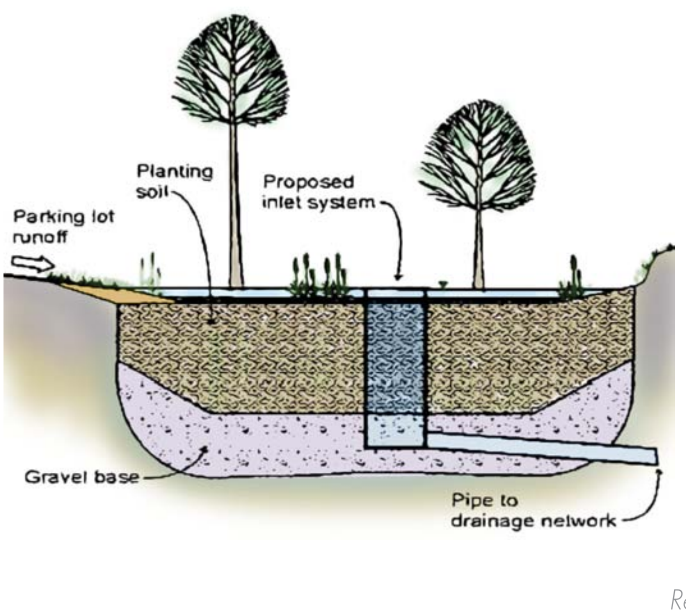


Figure 15.5 A general schematic of a bioretention system. Source: Center For Watershed Protection, Urban Stormwater Retrofit Practices. http://www.cwp.org/PublicationStore/USRM.htm#usrm3

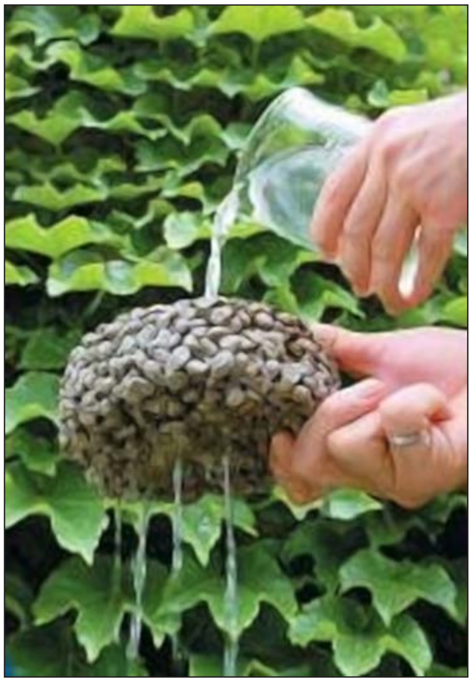


Figure 15.6 An aggregate of pervious concrete used in permeable parking lots, demonstrating the infiltration capability. Source: National Ready Mix Concrete Association. www.nrmca.org

Figure 15.7 Green roof.

pretreatment is necessary to remove litter, oil and excess sediments. Grass filter strips are a common pretreatment mechanism (ibid.).

5. ***Constructed wetlands*** are designed to allow specific ponding depths based on stormwater storage needs (EPA 2004). Plant communities vary with water levels, but all constructed wetlands should consist of a diverse mix of native species. These wetlands use natural processes to filter and treat stormwater and involve low operating and maintenance expenses (ibid.). Upkeep generally involves weeding, selective spraying, debris removal, and, where feasible, burning (Garcia et al. 2005). Constructed wetlands are best suited for relatively level sites that already receive a significant amount of runoff discharge (ibid.).
6. ***Porous pavement*** allows water to pass through void spaces surrounding asphalt particles (Figure 15. 6). The pavement is similar in appearance to traditional asphalt, but does not contain the very fine particles typically found in asphalt mixes (SWC 2007). Stormwater is able to pass through the pavement into an underlying stone bed and then infiltrates into the native soils below parking lots and other paved surfaces. As the Self-Assessment Guide points out, porous pavement should not be used in areas where there is a risk of oil, grease, road salt, or chemicals entering the groundwater (David Liebl, personal communication, 2007). While porous pavement can be two to three times more expensive than traditional asphalt, businesses may attract more customers if they are able to advertise improved stormwater management practices. However, business owners must commit to continual maintenance to keep surfaces free from debris so pore spaces remain open (SWC 2007).
7. ***Green, or vegetated, rooftops*** capture and retain stormwater that would otherwise run off the traditionally impervious surfaces (Figure 15. 7). While green roofs lose moisture to evapotranspiration and do not recharge groundwater, they do reduce runoff volumes from highly developed sites (Garcia et al. 2005). Roofs used to grow herbaceous species typically have a soil layer that is two to four in deep over a

protective layer and a waterproof roofing membrane (ibid.). Green roofs can last up to twenty years longer than conventional ones, but do require routine maintenance and can cost between $10 and $25 per square ft (ibid.). Green roofs should only be used in areas where it is not practical to promote infiltration and ground water recharge.

8. ***Cisterns and rain barrels*** (Figures 15. 8, 15. 9) are tanks that capture and store rooftop runoff for reuse as irrigation or washing water (Garcia et al. 2005). Cistern capacity ranges from 100 to 40,000 gallons, while rain barrels are smaller and generally hold between 50 and 80 gallons (ibid.). Overflow devices are necessary to prevent backup when storm runoff exceeds capacity. The cost of a rain barrel ranges from $100–$400 and large, reinforced cisterns can cost up to $10,000 (ibid.). This BMP is effective where space is limited and captured water can be used to irrigate landscaping or wash equipment. Rain gutters must be cleaned on a regular basis for rain barrels and cisterns to maintain proper functioning.

Figure 15.8 An example of a rain barrel. Source: Center For Watershed Protection, Urban Stormwater Retrofit Practices. http://www.cwp.org/PublicationStore/USRM.htm#usrm3

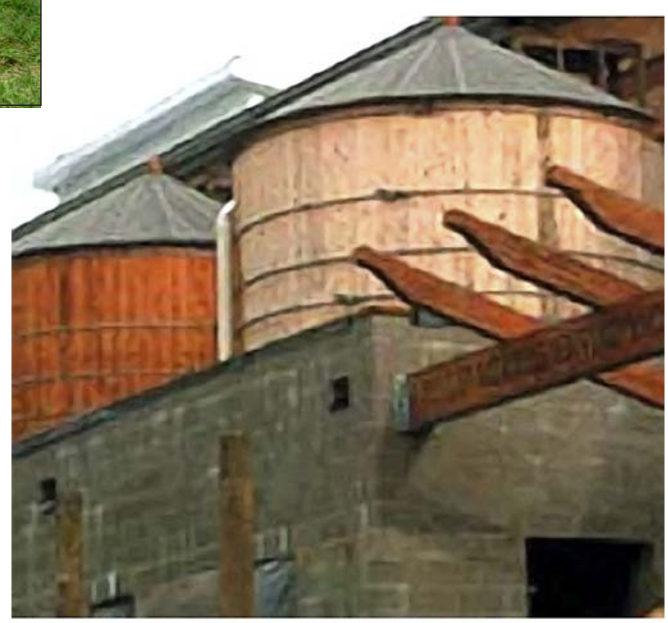


Figure 15.9 An example of large cisterns for commercial business. Source: Center For Watershed Protection, Urban Stormwater Retrofit Practices. http://www.cwp.org/PublicationStore/USRM.htm#usrm3

Chapter 16: Future Research Opportunities in the Eastern Wetlands

While studying the Eastern Wetlands, we identified many opportunities for research. Some of our suggestions involve sampling to update previous baseline data, while others might catalyze university students to develop projects that will help Arboretum staff develop management plans.

- ***Plant Species Inventory*** ✦ The 2007 survey conducted by the WRM Practicum documented plant species in both Gardner and Southeast marshes. These data were cross-referenced with historical plant surveys. However, more extensive surveys are needed in both marshes to track changes in species presence and abundance.
- ***Aquatic Vegetation Inventory*** ✦ The 2007 WRM Practicum conducted a cursory survey of aquatic vegetation in Gardner Marsh; however, a more thorough survey is needed both in early and late summer. Because aquatic plants differ in life cycles, some species can only be observed in early summer.
- ***Wildlife Inventory*** ✦ Past research papers cite wildlife that were casually observed. The 2007 WRM Practicum conducted a general survey of bird species in the marshes. A systematic and comprehensive wildlife surveys is needed for both marshes.
- ***Fish Species Inventory*** ✦ The primary fish species have been identified through general observation and cross-referencing with past data. A more detailed survey of native and invasive fish species and their relative populations is needed.
- ***Blue-joint Grass Competition Studies*** ✦ In the field, native blue-joint grass (*Calamagrostis canadensis*) appears to compete with invasive reed canary grass (*Phalaris arundinacea*). Future studies to determine competitive ability of native grasses and potential remediation practices using native grasses are needed. Wisconsin DNR has related information at http://dnr.wi.gov/org/es/science/publications/WRH_6.pdf
- ***Invasive Species Removal*** ✦ Further experiments, tailored to the environmental conditions of Southeast and Gardner Marshes, are recommended to find the most cost-effective ways to remove invasive species
- ***Water Quality Monitoring*** ✦ Supplies purchased by the 2007 WRM Practicum are available for continued baseline water quality monitoring (storm and non-storm events) at established sites. We suggest adding data from consecutive summers on temperature, dissolved oxygen, transparency and pH within the marsh.
- ***Stormwater Infiltration*** ✦ We recommend further research on stormwater infiltration in both Southeast and Gardner Marshes. Specifically, we suggest more thorough analysis of elevation data and infiltration capacities during summer months, as well as the installation of piezometers.
- ***Water-Level-Control Experiments*** ✦ Given the interconnected nature of the marshes, their differing topography size, and proximity to residential and commercial areas, it will be a challenge to manage water levels to control invasive plant species. Studies are needed to develop further a system-wide approach to controlling water level in the marshes. Past hydrological studies of Gardner Marsh could be expanded and applied to Southeast Marsh.
- ***Species Mortality Due to Arboretum Drive*** ✦ The impacts of Arboretum Drive on native plant species in or along the edges of Gardner marsh are relatively unknown. We suggest research on road kills and animal movements.
- ***WHA Tower Impacts*** ✦ In-depth studies are needed on how the WHA tower impacts Southeast Marsh. Of particular interest are studies involving bird and bat mortality rates and levels of copper wire corrosion and heavy metal accumulation in the soil of the antenna field, as well as release of contaminants to downstream waters.

Other research needs:

- ***Effects of Road Salt Use*** ✦ Chloride levels in the marshes could well affect heavy metal release; ecological effects are uncertain and unquantified.
- ***Hydrology of Gardner Marsh*** ✦ We suggest dilution-gauging tests to determine how water moves through the Gardner Marsh system. During periods of standing water, it is unclear how much comes from upstream (Southeast Marsh) vs. downstream (Wingra Creek, Lake Monona). The effect of the Gardner Marsh fish ponds on overall Gardner Marsh hydrology is unknown. Groundwater inputs are known to exist south of Pond E, but the water might be confined to the fish ponds and might be unable to reach the greater marsh area.

Chapter 17: Funding Sources

We compiled a short list of potential funding sources for each aspect of the plan to restore the Eastern Wetlands. Many of the grants listed are for modest amounts that may be well suited for individual portions of the project. Funders are more likely to consider proposals that link the smaller aspects of the project to a larger goal, as is the case with this project. For that reason, the Arboretum should stress the strategic plans and overall visions of the Arboretum in any funding application. In addition to the grants listed below, many private foundations also fund restoration efforts and should be considered for potential funding sources.

17.1 Upstream mitigation and stormwater pond improvements

- ***EPA Region 5 Wetland Program Development Grants***
  www.epa.gov/etopetop/funding/clean_water.html
  The Wetland Program Development Grants are authorized through the Clean Water Act section 104(b)(3) to fund projects to reduce or eliminate water pollution. The program funds research, experiments, training, demonstrations, surveys and studies. The program specifically does not fund implementation (likewise, the 319(s) program funds implementation and does not fund research or study). Funds from this program could possibly be used to further study methods to reduce non-point source pollution from upstream sources, or innovative treatments within the stormwater ponds themselves.
- ***EPA Five-Star Restoration Grant Program***
  www.epa.gov/wetlands/restore/5star/
  The Five Star Restoration Program, administered through the EPA, provides modest grants to restore streambanks and wetlands. Average grants are between $5,000 and $20,000. The program is designed to bring "together students, conservation corps, other youth organizations, citizen groups, corporations, landowners and government agencies to provide environmental education…" (EPA Five Star Restoration Grant Program website). Past recipients have used the grants work with school groups for hands on restoration work.
- ***Wisconsin DNR Urban Nonpoint Source Grant Program***
  http://dnr.wi.gov/runoff/grants/unps.htm
  These funds are for planning or construction to improve stormwater runoff. These funds can be used for upstream stormwater improvements through swales and infiltration areas or towards the stormwater ponds. The program funds up to 50% of construction and design costs.
- ***Wisconsin DNR Targeted Runoff Management***
  http://dnr.wi.gov/runoff/grants/trm.htm
  The Targeted Runoff Management grants are similar to the Urban Nonpoint Source Grants in that they can be used to control polluted runoff from urban areas. The TRM grants, however, are designed to target high-priority resources on small sub-watershed areas. These grants may be useful for the small watershed of Pond 3 and Pond 4.

17.2 Direct Wetland Restoration

- ***USDA-NRCS Wildlife Habitat Incentives Program (WHIP)***
  www.wi.nrcs.usda.gov/programs/whip.html
  WHIP funding is for habitat improvement. Arboretum wetlands restoration would qualify as a "special project" under the Wisconsin NRCS priorities. The fund could be used for prescribed burning or wetland restoration. Monies must be used

for implementation and generally do not exceed $25,000. The grant program is administered from the NRCS county office.

- ***National Fish and Wildlife Foundation*** • Keystone Initiative Grants
  www.nfwf.org/Content/NavigationMenu/Grants/GrantGuidelines/default.htm
  The National Fish and Wildlife Foundation awards matching grants for Wildlife and Habitat conservation and control of invasive species (among other priorities) through its Keystone Initiative Grants. Grants typically range from $50,000–$300,000.
- ***National Fish and Wildlife Foundation*** • Special Grants Program.
  www.nfwf.org
  The National Fish and Wildlife Foundation partners with numerous special grants.
- ***North American Wetland Conservation Act***
  www.fws.gov/birdhabitat/Grants/NAWCA/index.shtm
  The North American Wetland Conservation Act provides matching grants for wetland conservation associated with migratory birds and other wildlife. The NAWCA administers two programs, the Standard (eligible in Canada, United States and Mexico) and Small Grants (U.S. only) programs. Both require at least a 1 to 1 match from non-federal sources.
- ***EPA Five-Star Restoration Grant Program***
  www.epa.gov/wetlands/restore/5star/
  This modest grant program already described above could also be used as a component of a larger set of grants for direct, on the ground restoration.

17.3 Education and visitor improvements

- ***EPA Five-Star Restoration Grant Program***
  www.epa.gov/wetlands/restore/5star/
  Described in more detail above, this EPA grant program provides matching grants for wetlands restoration. Past examples from the program's website have examples of portions of this grant being used for education components of projects. Used as a match to a larger restoration project, and in conjunction with volunteer work at the Arboretum, these funds could be used for educational signs and new trails or trail improvements in the Eastern Marshes.
- ***EPA Environmental Education Grant Program***
  www.epa.gov/enviroed/pdf/grants_fs.pdf
  The EPA Environmental Education Grant Program was established to raise public awareness of environmental quality. These monies could be used towards enhancing the visitor experience at the eastern marshes.

BIBLIOGRAPHY

Aerts, R. and F. Bernendse. (1988). The effect of increased nutrient availability on vegetation dynamics in wet heathlands. Vegetatio 76:63–69.

Albert, D. A. (1995). Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: A working map and classification. St. Paul, MN: North Central Forest Experiment Station, Forest Service–U.S. Department of Agriculture.

Anderson, R. V. (1996). Effects of streambed modification on stream quality and carp in the Des Plaines River. Chicago, IL: Wetlands Research, Inc.

Anderson, R. V. (1999). Further study of the effects of streambed modification on stream quality and carp in the Des Plaines River. Chicago, IL: Wetlands Research, Inc.

Apfelbaum, S. (1993). The Role of Landscapes in Stormwater Management: Applied Ecological Services, Inc.

Apfelbaum, S. I., and C.E. Sams (1987). Ecology and control of reed canary grass. Natural Areas Journal, 7(69–74).

Archibold, O. W., Brooks, D., & Delanoy, L. (1997). An investigation of the invasive shrub European buckthorn, *Rhamnus cathartica* L., near Saskatoon, Saskatchewan. Canadian Field-Naturalist, 111(4), 617–621.

Ayres-Associates (2007). Draft Environmental Impact Assessment of WHA Tower. Madison, WI: Ayres Associates

Baumann, P. C., Kitchell, J. F., Magnuson, J. J., & Kayes, T. B. (1974). Lake Wingra, 1837–1973: a case history of human impact. *In* E. McCoy (Ed.), Transactions of the Wisconsin Academy of Sciences, Arts and Letters (Vol. 62, pp. 57–94).

Beckel, A. L., & Egerton, F. N. (1987). Breaking new waters: a century of limnology at the University of Wisconsin. Madison, Wis.: Wisconsin Academy of Sciences, Arts and Letters.

Bedford, B. L., Zimmerman, E. H., Wisconsin. Dept. of Natural Resources., & Zimmerman, J. H. (1974). The wetlands of Dane County, Wisconsin. [Madison, Wis.]: Dane County Regional Planning Commission.

Beule, J. D., & Hine, R. L. (1979). Control and management of cattails in southeastern Wisconsin wetlands. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA, Publication 39.

Boers, A. M., Veltman, R. L. D., & Zedler, J. B. (2007). *Typha* × *glauca* dominance and extended hydroperiod constrain restoration of wetland diversity. Ecological Engineering, 29(3), 232–244.

Bonilla-Warford, C. M., & Zedler, J. B. (2002). Potential for using native plant species in stormwater wetlands. Environmental Management, 29(3), 385–394.

Botany 670 Class Report, University of Wisconsin–Madison (2006). Cattail Control and Adaptive Restoration in the Lulu and Eagle Spring Lake System.

Boudreau, D., & Wilson, G. (1992). Buckthorn research and control at Pipestone National Monument. Restoration & Management Notes, 10, 94–95.

Budelsky, R. A., & Galatowitsch, S. M. (2000). Effects of water regime and competition on the establishment of a native sedge in restored wetlands. Journal of Applied Ecology, 37(6), 971–985.

Budelsky, R. A., & Galatowitsch, S. M. (2004). Establishment of *Carex stricta* Lam. seedlings in experimental wetlands with implications for restoration. Plant Ecology, 175(1), 91–105.

Burton, G. A., & Pitt, R. (2002). Stormwater effects handbook : a toolbox for watershed managers, scientists, and engineers. Boca Raton, Fla.: Lewis Publishers.

C-MED (2003). Draft Wingra Creek Parkway Master Plan. *In* C. O. M. E. Division (Ed.). Madison, WI: City of Madison.

C-MED (2007). Water Quality Initiatives: City of Madison–Engineering Division.

Cahn, A. R. (1915). An ecological survey of the Wingra springs region near Madison, Wisconsin : with special reference to its ornithology / by Alvin Robert Cahn (Vol. 13): Bulletin of the Wisconsin Natural History Society.

Caraco, D., & Claytor, R. (1997). Stormwater BMP Design Supplement for Cold Climates for US EPA Office of Wetlands, Oceans and Watersheds and US EPA Region 5: Center for Watershed Protection.

Casselman, J. M., & Lewis, C. A. (1996). Habitat requirements of northern pike (*Esox lucius*). Canadian Journal of Fisheries and Aquatic Sciences, 53, 161–174.

Coops, H., vandenBrink, F. W. B., & vanderVelde, G. (1996). Growth and morphological responses of four helophyte species in an experimental water-depth gradient. Aquatic Botany, 54(1), 11–24.

Corbin, J. D., & D'Antonio, C. M. (2004). Can carbon addition increase competitiveness of native grasses? A case study *from* California. Restoration Ecology, 12(1), 36–43.

Crain, C. M., & Bertness, N. D. (2005). Community impacts of a tussock sedge: Is ecosystem engineering important in benign habitats? Ecology, 86(10), 2695–2704.

Dietz, M. E., & Clausen, J. C. (2005). A field evaluation of rain garden flow and pollutant treatment. Water Air and Soil Pollution, 167(1–4), 123–138.

Dinkelacker, S. A., Costanzo, J. P., Iverson, J. B., & Lee, R. E. (2004). Cold-hardiness and dehydration resistance of hatchling Blanding's turtles (*Emydoidea blandingii*): implications for overwintering in a terrestrial habitat. Canadian Journal of Zoology-Revue Canadienne De Zoologie, 82(4), 594–600.

Donohue, & Associates (1981). Lake Forest Stormwater Detention Facility, Preliminary Engineering: Town of Madison, Dane County, WI.

Dziuk, P. M. (1998). European (Common) Buckthorn: Minnesota Department of Agriculture Fact Sheet.

Engelhardt, K. A. M., & Ritchie, M. E. (2001). Effects of macrophyte species richness on wetland ecosystem functioning and services. Nature, 411(6838), 687–689.

EPA (1999). Storm Water Technology Fact Sheet: Wet Detention Ponds: Environmental Protection Agency (EPA).

EPA (2004). Constructed Treatment Wetlands Environmental Protection Agency (EPA).

Fargione, J. E., & Tilman, D. (2005). Diversity decreases invasion via both sampling and complementarity effects. Ecology Letters, 8(6), 604–611.

Figiel, C. R., Collins, B., & Wein, G. (1995). Variation in survival and biomass of 2 wetland grasses at different nutrient and water levels over a 6-week period. Bulletin of the Torrey Botanical Club, 122(1), 24–29.

Fisher, M. (2007). Study explores effectiveness of rain gardens: UW–Madison News Homepage.

FOLW (2003). Rain Garden Street Demonstration: Friends of Lake Wingra (FOLW).

Fox, W. H., & Vroman, W. (1877). Fitchburg. *In* Madison, Dane County, and surrounding towns : being a history and guide (pp. 448–462). Madison, Wis.: W.J. Park & Co.

Friedman, J. M. (1987). Gardner Marsh: Drainage, subsidence and restoration of a peat deposit. Unpublished Thesis M.S., University of Wisconsin–Madison 1987.

Galatowitsch, S. M., & vanderValk, A. G. (1996). The vegetation of restored and natural prairie wetlands. Ecological Applications, 6(1), 102–112.

Garcia, C., Lisi, R., Owen, K., & Young, L. (2005). Storm Water Runoff Management plan for Facilities Planning and Management. Madison, WI: University of Wisconsin–Madison.

Gardner, G., & Stern, P. (2002). Educational Interventions: Changing Attitudes and Providing Information. *In* Environmental Problems and Human Behavior. Boston, MA: Allyn & Bacon.

Gelber, D. (1995). Policy on naturalized, non-native plants fails to protect native communities (Michigan). Restoration Management and Notes, 13, 129–130.

Gilliam, J. W. (1994). Riparian Wetlands and Water-Quality. Journal of Environmental Quality, 23(5), 896–900.

Groy, J. (1981). Lake Forest, The Lost City: One of Wisconsin's first totally planned communities. University of Wisconsin–Madison, Madison, WI.

Hall, S., & Zedler, J. B. (2007). In Prep.

Hall, S., & Zedler, J. B. (2007). Can sedge meadows self-restore following the harvest of invasive *Typha*. In Review.

Hansson, L. A., Bronmark, C., Nilsson, P. A., & Abjornsson, K. (2005). Conflicting demands on wetland ecosystem services: nutrient retention, biodiversity or both? Freshwater Biology, 50(4), 705–714.

Hartwig, T. S., & Kiviat, E. (2007). Microhabitat association of Blanding's turtles in natural and constructed wetlands in southeastern New York. Journal of Wildlife Management, 71(2), 576–582.

Healy, M.T. and J.B. Zedler (2007). In Prep.

Hurst, M. B. (1992). A Brief History of Arbor Hills. Retrieved May 22, 2007 *from* http://www.arborhills.org/brief_history.htm

Inskip, P. D., & Magnuson, J. J. (1983). Changes in Fish Populations over an 80-Year Period—Big-Pine Lake, Wisconsin. Transactions of the American Fisheries Society, 112(3), 378–389.

Irwin, H. A. (1973). A natural history study of East Marsh of the University of Wisconsin Arboretum. Unpublished Thesis M.S., University of Wisconsin–Madison 1973.

Jaeger, J. (1985). Effects of recent ecosystem changes on Lake Wingra bluegills. *In* P. Whitford & K. Whitford (Eds.), Transactions of the Wisconsin Academy of Sciences, Arts and Letters (Vol. 73, pp. 160–166).

JFNew (2008). Native Plant Nursery—Habitat Restoration, Ecological Consulting, Wetlands, *from* http://www.jfnew.com/

Johnston, C. A. (1991). Sediment and Nutrient Retention by Fresh-Water Wetlands—Effects on Surface-Water Quality. Critical Reviews in Environmental Control, 21(5–6), 491–565.

Jones, S. E. (1947). An ecological study of large aquatic plants in small ponds. Unpublished Thesis Ph. D. , University of Wisconsin–Madison 1947.

Jordan, J. R., Hungerford, H. R., & Tomera, A. N. (1986). Effects of two residential environmental workshops on high school students. Journal of Environmental Education 18, 15–22.

Jordan, W. R. (Ed.). (1984). Our first 50 years: The University of Wisconsin Arboretum, 1934–1984. Madison, Wis.: University of Wisconsin Arboretum.

Joyal, L. A., McCollough, M., & Hunter, M. L. (2001). Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. Conservation Biology, 15(6), 1755–1762.

Kadlec, R. H., & Knight, R. L. (1996). Treatment wetlands. Boca Raton: Lewis Publishers.

Kennedy, T. A., Naeem, S., Howe, K. M., Knops, J. M. H., Tilman, D., & Reich, P. (2002). Biodiversity as a barrier to ecological invasion. Nature, 417(6889), 636–638.

Kercher, S. (2004). Interrelationships of Hydrological Disturbance, Reed Canary Grass, and Native Plants in Wisconsin Wet Meadows. Journal of the Natural Areas Association, 24(4), 316–325.

Kercher, S. M., & Zedler, J. B. (2004). Flood tolerance in wetland angiosperms: a comparison of invasive and noninvasive species. Aquatic Botany, 80(2), 89–102.

Kilbride, K. M., & Paveglio, F. L. (1999). Integrated pest management to control reed canarygrass in seasonal wetlands of southwestern Washington. Wildlife Society Bulletin, 27(2), 292–297.

Kleiman, B. (2003). Oh Boy…Geoboy! A Brush Clearing Project at Nachusa Grasslands. Gatherings: The Nature Conservancy of Illinois.

Klemens, M. W. (2000). Turtle conservation. Washington [D.C.]: Smithsonian Institution Press.

Kline, V. (1981). Control of honeysuckle and buckthorn in oak forests. Restoration & Management Notes, 1, 18.

Kline, V. (1992). University of Wisconsin Arboretum Long Range Management Plan. Madison, WI: University of Wisconsin–Madison.

Knight, R. L., Clarke, R. A., & Bastian, R. K. (2001). Surface flow (SF) treatment wetlands as a habitat for wildlife and humans. Water Science and Technology, 44(11–12), 27–37.

Kogler, B. K. (1979). An analysis of the process of shrub invasion in wetlands with special reference to the ecology of red-osier dogwood (*Cornus stolonifera*). Unpublished Thesis M.S.. University of Wisconsin–Madison.

Lathrop, R. (2007). Lake Wingra Aquatic Plant Restoration Demonstration Project. University of Wisconsin

Lawrence, B. and J. Zedler (2007). In Prep.

Lee, J. H., Bang, K. W., Ketchum, L. H., Choe, J. S., & Yu, M. J. (2002). First flush analysis of urban storm runoff. Science of the Total Environment, 293(1–3), 163–175.

Lillie, R. A., Mason, J. W., & Wisconsin. Dept. of Natural Resources. (1983). Limnological characteristics of Wisconsin lakes. Madison, WI: Dept. of Natural Resources.

Lindig-Cisneros, R., & Zedler, J. (2001). Effect of light on seed germination in *Phalaris arundinacea* L. (reed canary grass). Plant Ecology, 155(1), 75–78.

Mallik, A. U., & Wein, R. W. (1986). Response of a typha marsh community to draining, flooding, and seasonal burning. Canadian Journal of Botany-Revue Canadienne De Botanique, 64(9), 2136–2143.

Maron, J. L., & Jefferies, R. L. (2001). Restoring enriched grasslands: Effects of mowing on species richness, productivity, and nitrogen retention. Ecological Applications, 11(4), 1088–1100.

Maurer, D. A., R. Lindig-Cisneros, K. J. Werner, S. Kercher, R. Miller, and J. B. Zedler (2003). The replacement of wetland vegetation by *Phalaris arundinacea* (reed canary grass). Ecological Restoration, 21, 116–119.

McDermid, M. (2006a). The Business Case for Green Tier: Realizing Business Value in Regulatory Innovation: Wisconsin Department of Natural Resources.

McDermid, M. (2006b). The Environmental Case for Green Tier: Moving from Compliance to Performance: Wisconsin Department of Natural Resources.

McKenzie-Mohr, D., & Smith, W. A. (1999). Fostering sustainable behavior : an introduction to community-based social marketing. Gabriola Island, BC: New Society Publishers.

Michaud, B. J. (1994). The hydrological restoration of Gardner Marsh, Madison, Wisconsin. Madison, WI: Water Resources Engineering, Dept. of Civil and Environmental Engineering, University of Wisconsin–Madison.

Midden, C. J. H., Meter, J. E., Weenig, M. H., & Zieverink, H. J. A. (1983). Using Feedback, Reinforcement and Information to Reduce Energy—Consumption in Households—a Field-Experiment. Journal of Economic Psychology, 3(1), 65–86.

Miller, R. C., & Zedler, J. B. (2003). Responses of native and invasive wetland plants to hydroperiod and water depth. Plant Ecology, 167(1), 57–69.

Minns, C. K., Randall, R. G., Moore, J. E., & Cairns, V. W. (1996). A model simulating the impact of habitat supply limits on northern pike, *Esox lucius*, in Hamilton harbour, Lake Ontario. Canadian Journal of Fisheries and Aquatic Sciences, 53, 20–34.

Mitsch, W. J., & Gosselink, J. G. (2000). The value of wetlands: importance of scale and landscape setting. Ecological Economics, 35(1), 25–33.

Monthey, R. (1974). The Arboretum Marshes: Problems and Management with Specific Reference to the East Marsh. Madison, WI: University of Wisconsin–Madison Arboretum.

Morgan, J. P. (1997). Plowing and Seeding. *In* S. Packard (Ed.), The tallgrass restoration handbook : for prairies, savannas, and woodlands (pp. 193–216). Washington, D.C.: Island Press.

Morghan, K. J. R., & Seastedt, T. R. (1999). Effects of soil nitrogen reduction on nonnative plants in restored grasslands. Restoration Ecology, 7(1), 51–55.

Moriarty, J. J. (1998). The Trouble With Backyard Buckthorn. *In* M. D. O. N. Resources (Ed.), Minnesota Conservation Volunteer (Vol. July–August).

Mulhouse, J. M., & Galatowitsch, S. M. (2003). Revegetation of prairie pothole wetlands in the mid-continental US: twelve years post-reflooding. Plant Ecology, 169(1), 143–159.

Murkin, H. R., & Ward, P. (1980). Early spring cutting to control cattail in a northern marsh. Wildlife Society Bulletin, 8, 254.

Nelson, N. and R. Dietz (1966). "Cattail control methods in Utah." Publication 66. Utah State Department of Fish and Game.

NOAA (2007). NOAA's National Weather Service Milwaukee/Sullivan August 2007 Rainfall. Retrieved January 22, 2007, *from* http://www.crh.noaa.gov/mkx/climate/pcpn-wrapper.php?MO=aug&YR=2007

Noland, W. E. (1951). The hydrography, fish, and turtle population of Lake Wingra. *In* A. J. Ihde (Ed.), Transactions of the Wisconsin Academy of Sciences, Arts and Letters (Vol. 40, pp. 5–58). Madison, WI.

Osmond, D. L., Line, D. E., Gale, J. A., Gannon, R. W., Knott, C. B., Bartenhagen, K. A., Turner, M. H., Coffey, S. W., Spooner, J., Wells, J., Walker, J. C., Hargrove, L. L., Foster, M. A., Robillard, P. D., & Lehning, D. W. (1995). Functions of Wetlands (Processes). WATERSHEDS: Water, Soil and Hydro-Environmental Decision Support System, 2007, *from* http://www.water.ncsu.edu/watershedss/info/wetlands/function.html

Parkos, J. J., Santucci, V. J., & Wahl, D. H. (2006). Effectiveness of a plastic mesh substrate cover for reducing the effects of common carp on aquatic ecosystems. North American Journal of Fisheries Management, 26(4), 861–866.

Peach, M., & Zedler, J. B. (2006). How tussocks structure sedge meadow vegetation. Wetlands, 26(2), 322–335.

Pennequin, D. F., & Anderson, M. P. (1983). Groundwater Budget of Lake Wingra, Dane County Wisconsin: University of Wisconsin, Madison.

Perry, L. (2001). Controlling Phalaris arundinacea Invasion in Restored Sedge Meadow Wetlands. University of Minnesota, Minneapolis, MN.

Perry, L. G., Galatowitsch, S. M., & Rosen, C. J. (2004). Competitive control of invasive vegetation: a native wetland sedge suppresses *Phalaris arundinacea* in carbon-enriched soil. Journal of Applied Ecology, 41(1), 151–162.

PLSW (2007). Public Land Survey of Wisconsin: Interior Field Notes of Lorin Miller (1833) and Orson Lyon (1835): Wisconsin Board of Commissioners of Public Lands.

Reinartz, J. A. (1997). Controlling glossy buckthorn (*Rhamnus frangula* L) with winter herbicide treatments of cut stumps. Natural Areas Journal, 17(1), 38–41.

Reinhardt-Adams, C. R., & Galatowitsch, S. M. (2006). Increasing the effectiveness of reed canary grass (*Phalaris arundinacea* L.) control in wet meadow restorations. Restoration Ecology, 14(3), 441–451.Richardson, C. J. (1985). Mechanisms Controlling Phosphorus Retention Capacity in Fresh-Water Wetlands. Science, 228(4706), 1424–1427.

Roe, J. H., Gibson, J., & Kingsbury, B. A. (2006). Beyond the wetland border: Estimating the impact of roads for two species of water snakes. Biological Conservation, 130(2), 161–168.

Rothschild, M. L. (1999). Carrots, sticks, and promises: A conceptual framework for the management of public health and social issue behaviors. Journal of Marketing, 63(4), 24–37.

Rubin, C. S., Warner, R. E., Ludwig, D. R., & Thiel, R. (2004). Survival and population structure of Blanding's turtles (*Emydoidea blandingii*) in two suburban Chicago forest preserves. Natural Areas Journal, 24(1), 44–48.

Rust, A. J., Diana, J. S., Margenau, T. L., & Edwards, C. J. (2002). Lake characteristics influencing spawning success of Muskellunge in Northern Wisconsin lakes. North American Journal of Fisheries Management, 22(3), 834–841.

Sachse, N. D. (1965). A Thousand Ages. Madison, WI: The Regents of the University of Wisconsin–Madison.

Sale, P.J.M. and R.G. Wetzel. (1983). Growth and metabolism of *Typha* species in relation to cutting treatments. Aquatic Botany 15:321–334.

Scott, T. E. (2007). Bioretention.com. Retrieved October 10, 2007, *from* http://bioretention.com/

Seabloom, E. W., & van der Valk, A. G. (2003). Plant diversity, composition, and invasion of restored and natural prairie pothole wetlands: Implications for restoration. Wetlands, 23(1), 1–12.

Shekhov, A. G. (1974). Effect of cutting time on renewal of stands of reed and cattail. Hydrobiological Journal 45–48.

Smith, S. G. (1967). Experimental and natural hybrids in North American *Typha* (Typhaceae). American Midland Naturalist, 78(2), 257–287.

Solecki, M. K. (1997). Controlling invasive plants. *In* S. Packard (Ed.), The tallgrass restoration handbook : for prairies, savannas, and woodlands (pp. 135–150). Washington, D.C.: Island Press.

Stuart, I. G., Williams, A., McKenzie, J., & Holt, T. (2006). Managing a migratory pest species: A selective trap for common carp. North American Journal of Fisheries Management, 26(4), 888–893.

SWC (2007). Stormwatercenter.net (SWC). Retrieved October 9, 2007, *from* http://www.stormwatercenter.net/Assorted_20Fact_20Sheets/Tool6_Stormwater_Practices/Infiltration_20Practice/Porous_20Pavement.htm

Swink, F., & Wilhelm, G. (1994). Plants of the Chicago Region.

Tilman, D., & Downing, J. A. (1994). Biodiversity and Stability in Grasslands. Nature, 367(6461), 363–365.

Toet, S., Van Logtestijn, R. S. P., Schreijer, M., Kampf, R., & Verhoeven, J. T. A. (2005). The functioning of a wetland system used for polishing effluent from a sewage treatment plant. Ecological Engineering, 25(1), 101–124.

USDA (1978). Soil Survey of Dane County, Wisconsin: USDA Soil Conservation Service.

USGS (2004). Water Resources Investigations in Wisconsin (Open File Report NO. 2004–1403): United States Geological Survey (USGS).

UW–Arboretum (2000). Strategic Plan. Madison, Wi: University of Wisconsin–Madison Arboretum.

UW–Arboretum (2006). University of Wisconsin–Madison Arboretum Facility Stormwater Management Plan. Madison, WI: Univeristy of Wisconsin–Madison Arboretum.

UW–Madison (1996). Comprehensive Master Plan: Summary Report. Madison, WI: University of Wisconsin–Madison.

UWEX (2003a). Dane County Community Storm Water Awareness Assessment: Final Report by Environmental Resources Center for Dane County Joint Storm Water Permit Group Information and Education Plan Subcommittee. Madison, WI: University of Wisconsin Extension (UWEX).

UWEX (2003b). Protecting Our Waters: University of Wisconsin Extension.

Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. Science of the Total Environment, 380(1–3), 48–65.

WDNR (2004). Red Osier Dogwood (*Cornus serices*). 2007, *from* http://www.dnr.state.wi.us/invasives/fact/wetshrubs_red.htm

WDNR (2006a). Blanding's Turtle (*Emydoidea blandingii*). Retrieved January 12, 2008, *from* http://dnr.wi.gov/org/land/er/herps/turtles/blandings.htm

WDNR (2006b). Rain Gardens Infiltrating Wisconsin: Wisconsin Department of Natural Resources (WDNR).

WDOA (2006). All Agency Request: 2005–2007 Biennium; University of Wisconsin–Madison Project Number 062GR, Storm Water Pond Repair: Wisconsin Department of Administration (WDOA).

Werner, K. J., & Zedler, J. B. (2002). How sedge meadow soils, microtopography, and vegetation respond to sedimentation. Wetlands, 22(3), 451–466.

Wetzel, R. G. (2001). Fundamental processes within natural and constructed wetland ecosystems: short-term versus long-term objectives. Water Science and Technology, 44(11–12), 1–8.

Wilcox, J. C., Healy, M. T., & Zedler, J. B. (2007). Restoring native vegetation to an urban wet meadow dominated by reed canarygrass (*Phalaris arundinacea* L.) in Wisconsin. Natural Areas Journal, 27(4), 354–365.

Wright, J. P., Naeem, S., Hector, A., Lehman, C., Reich, P. B., Schmid, B., & Tilman, D. (2006). Conventional functional classification schemes underestimate the relationship with ecosystem functioning. Ecology Letters, 9(2), 111–120.

Yeo, R. (1964). Life history of common cattail. Weeds, 12, 284–288.

Zedler, J. B. (2003). Wetlands at your service: reducing impacts of agriculture at the watershed scale. Frontiers in Ecology and the Environment, 1(2), 65–72.

Zedler, J. B. (2005). Restoring wetland plant diversity: A comparison of existing and adaptive approaches Wetlands Ecology and Management, 13, 5–14.

Zedler, J. B., & Callaway, J. C. (2003). Adaptive restoration: A strategic approach for integrating research into restoration projects. *In* D. J. Rapport, W. L. Lasley, D. E. Rolston, N. O. Nielsen, C. O. Qualset & A. B. Damania (Eds.), Managing for Healthy Ecosystems (pp. 167–174). Boca Raton, FL: Lewis Publishers.

Zink, T. A., & Allen, M. F. (1998). The effects of organic amendments on the restoration of a disturbed coastal sage scrub habitat. Restoration Ecology, 6(1), 52–58.

Zorn, S. A., Margenau, T. L., Diana, J. S., & Edwards, C. J. (1998). The influence of spawning habitat on natural reproduction of muskellunge in Wisconsin. Transactions of the American Fisheries Society, 127(6), 995–1005.

Appendix A: History of Arbor Hills

The history of Arbor Hills has been well documented by Marilyn Hurst (1992) for the Arbor Hills Neighborhood Association. Development began in the late 1950s after the creation of the Arbor Heights Development Corporation (AHDC). The AHDC sponsored a Parade of Homes in 1958 to encourage families to purchase show homes along lower Grandview Boulevard. By 1960, development had expanded along Nottingham Way, Kingston Drive and Leyton Lane and Circle. The Arbor Hills Garden Club was established in 1962 and had almost 50 members by 1966. The Club was responsible for park development within the neighborhood and also contributed to boulevard landscaping (Hurst 1992).

Development in Arbor Hills soon expanded from Grandview Boulevard to include Post and Pelham roads. Todd Drive was constructed in 1965 on land formerly belonging to the Bowman Dairy. By 1967, all roads in the neighborhood were paved and curbs and gutters were installed. Directly east of the neighborhood along Post Road, Aldo Leopold Elementary School was built in 1969 (Hurst 1992).

The Arbor Hills Neighborhood Association (AHNA) was formed in August of 1967 to contest the plans of a developer to convert the Frederick Farm east of the Arbor Hills entrance to commercial uses. As a compromise, the newly formed neighborhood association allowed the construction of two apartment buildings, four duplexes and a five-story professional building along Grandview Boulevard (Hurst 1992). The agreement upset many Arbor Hills residents and the AHNA Executive Board has been attentive to all development-related issues within the neighborhood since that time (Hurst 1992).

Park development and neighborhood beautification efforts have always been important to the residents of Arbor Hills. Originally only 4.4 acres (1.8 hectares) were designated as park space for what is now Arbor Hills Park along Pelham Road. Land to the southwest was platted for development as of 1970, but members of the Garden Club and Neighborhood Association Board requested that the Madison Parks Commission seek federal funding to maintain the length of the hillside as green space (Hurst 1992). As a result, the park now offers an unobstructed view of the City of Fitchburg and provides ample recreational space for neighborhood residents.

The Garden Club and AHNA have been responsible for the installation and maintenance of play equipment and plantings in Arbor Hills Park since its dedication in 1972. After the original wooden play structures were condemned in the spring of 1992, the AHNA president appointed a park committee to collaborate with the City of Madison Parks Department as it selected new equipment for the park. The neighborhood raised $2,000 in addition to available funding from the city so that a full package of desired equipment could be installed (Hurst 1992).

Appendix B: WHA Tower EIA Memos

Memo

Date: 4/25/2007
To: Ayres Associates
From: Erica E. Schmitz
Re: WHA-AM transmitter tower replacement draft EIA

This memorandum is in response to the Draft Environmental Impact Statement prepared by Ayers Associates pertaining to the WHA-AM Transmitter Tower Replacement Project proposed for the UW–Madison Arboretum. After carefully reviewing the Draft Environmental Impact Statement, I am left with a number of concerns that I feel were not adequately considered or addressed. I urge you to give special attention to the thoughtful comments submitted by Professor Joy Zedler, as well as my UW–Madison Graduate student colleagues, in addition to my own that follow.

Consideration

- Southeast Marsh is part of an ecologically complex watershed. A complete evaluation of the impacts of the proposed new tower construction must consider not only the impacts to the construction site, but to the larger system, including upstream neighborhoods and downstream features including Gardner marsh, Wingra Creek, and Lake Monona.
- Removing access to a significant portion of the marsh creates a safe haven for harmful invasive species and impedes study of this component of adaptive management of the marsh. In addition, the existing buried wires and proposed new ones eliminate the ability to create swales or other features as part of a stormwater treatment system. Both of these consequences will certainly limit the research and education value of the marsh by removing the opportunity to improve both structure and function. Certainly these problems are also associated with the current tower, but will be expanded with construction of a new tower.
- The tower's lack of a threat to ecologically important birds and bats cannot be inferred from lack of anecdotal evidence from employees who have no incentive for reporting observed mortality in these species. The draft EIA states that location is one of two key risk factors for bird and bat collision (page 16). Surely the tower's location in the habitat-rich Arboretum within an urban area elevates the risk of collision and warrants further study.

Timing

- The use of construction vehicles in the marsh creates a significant negative impact by causing compaction of the soils, and a general disturbance of the soil that changes vegetation patterns by favoring invasive species, which already pose a threat to restoration goals. The use of mats will not prevent this; it will merely increase the surface area of the disturbance. Delaying the project just a few short months until early 2008, when the ground will be frozen, will help reduce the impacts of heavy construction vehicles.
- The Arboretum declares research to be a vital component of its land care vision. The students of the Water Resources Management Practicum continue to put a significant amount of work into drafting an adaptive restoration plan for Southeast and Gardner Marshes and their upstream and downstream counterparts as a crucial component of our educational experience. Completing the project this summer would prevent these research, restoration, and educational opportunities and goals from being realized at this unique site.

Unavoidable Adverse Impacts

- When adverse impacts are unavoidable, it is appropriate and necessary to offset the impacts to the greatest extent possible by introducing measures that will meet or exceed the removed potential of the area affected.

Memo
Date: 4/25/2007
To: Ayres Associates
From: Matthew Krueger
Re: Draft EIA—WHA Replacement Tower

I write this memo in support of Dr. Joy Zedler's comments regarding Ayres Associates' draft EIA for the WHA-AM Replacement Tower. I urge you to thoroughly evaluate Dr. Zedler's comments, as well as the additional comments listed below.

- Southeast Marsh, proposed site for the Replacement WHA Tower, it must be acknowledged, is 'upstream' of many other valuable water resources readily accessed and celebrated by countless residents of Dane County. It should be emphasized that whatever environmental impacts are imparted upon Southeast Marsh as a result of this project are also imparted directly downstream to Gardner Marsh, then downstream to Wingra Creek, then downstream to Lake Monona, then downstream to Lake Waubesa, and downstream to the Rock River, and further on downstream. The spill of a contaminant, the dispersal of invasive seeds, increased sedimentation from construction—all of these instances are not confined to Southeast Marsh. They have, and always will have significant downstream repercussions. I encourage you to explicitly acknowledge the hydrologic system of which Southeast Marsh is an 'upstream' part.
- On Page 2, the guy wires anchoring the tower is said to be "expected to be similar in size to the existing anchors." This statement is completely devoid of any concrete admission of environmental impact, but certainly one exists. Additionally, we expect to be informed of defined dimensions of these structures.
- The stated "start of construction" date as July 2007, and date of "substantial completion" as August 2007 not only conflicts with our intended dates of fieldwork and research in Southeast Marsh, but it also hampers completion of our respective graduate degrees, if not rendering completion of said degrees entirely impossible in this context.

  There are repeated references to WHA's Ideas Network fulfilling the "Wisconsin Idea" throughout the EIA. It is stated on Page 4 that "research conducted at the University of Wisconsin should be applied to solve problems and improve health, quality of life, the environment and agriculture for all citizens of the state." The very goal of the research and subsequent management plan to be put forth by the WRM Practicum is to fulfill almost exactly the Wisconsin Idea as defined on Page 4. Water quality, especially in Dane County, has a direct impact on the quality of residents' lives. We are undertaking research to solve problems and improve health and quality of life, as well as environment. Please take this into consideration when determining the proposed timeline for this project.
- I encourage and request of Ayres Associates and WHA to consider postponing the timeline of this project until the end of the summer of 2007, when we will have completed our research in Southeast Marsh. Additionally, I encourage the re-evaluation of the environmental impact of the Replacement WHA Tower, and urge the consideration of mitigation for the inevitable environmental impacts that are not divulged in the draft EIA.

Memo

Date: 4/25/2007
To: Ayres Associates
From: Marisa K. Trapp
Re: Draft EIA—WHA Replacement Tower

This memorandum pertains to Dr. Joy Zedler's comments on the draft EIA for the WHA-AM transmitter tower replacement. After reviewing the draft EIA, I support and agree with Dr. Zedler's remarks. In particular, I would like to emphasize the following concerns:

- Construction of the new tower is slated to begin in July and finish by August, 2007. During this same time period, graduate students from UW–Madison's Water Resource Management program will be conducting fieldwork and collecting data in Southeast Marsh—an essential component of their thesis project. However, the draft EIA makes no mention of this or the possibility that these students could be restricted from or be unable to collect quality data during the summer fieldwork season. The draft EIA also provides little scientific data supporting tower construction during the summer months. A fall or winter construction schedule should be considered more seriously.
- The draft EIA indicates there is no or little adverse impact on birds in the area surrounding the tower because dead birds have not been observed by WHA staff (p. 15). This statement lacks scientific credibility and should be researched more thoroughly.

Memo

Date: 4/25/2007
To: Ayres Associates
From: Emily Sievers
Re: WHA-AM transmitter tower replacement draft EIA

As a student of the Water Resources Management graduate program and a member of the group planning a summer practicum project pertaining to the restoration of the Eastern Arboretum Wetlands, I have concerns about the draft Environmental Impact Assessment for the proposed construction of a new WHA radio tower in Southeast Marsh. Specifically:

1. The fact that the replacement site is "rather hidden" in a small portion of the "more than 1,200-acre Arboretum" (p. 25) does not automatically imply that the project will not result in any significant environmental impacts. As Dr. Joy Zedler points out, wetlands provide invaluable ecosystem services such as flood attenuation and storm water infiltration and purification. Urban wetlands are especially important in these respects.
2. The draft EIA makes no mention of the additional impacts of the fence that would need to be installed to surround the new tower and the base of the old tower.
3. Southeast Marsh is currently degraded with reed canary grass and other invasive species, but there is a high potential for restoration and ecological research in this portion of the Arboretum. The disturbance associated with the construction of the new tower would facilitate further species invasions and make restoration of the marsh more difficult.

More generally, the draft EIA disregards the mission of the UW Arboretum and ignores the inherent value of the Southeast Marsh ecosystem. I request that WHA provide funding for mitigation at the site and that the project be postponed until the winter of 2008.

Memo

Date: 4/25/2007
To: Ayres Associates
From: Molli M. MacDonald
Re: WHA-AM transmitter tower replacement draft EIA

After reviewing the draft EIA, I would like to express the following concerns:

- On pages 7–8 of the report, the metals used in the construction of the tower and all of the copper wires concern me. The EIA draft provides no scientific data on the current soil conditions surrounding the tower and the antenna field. I would like to see soil testing in that area to provide evidence that the copper is not corroding and zinc and lead are not leaching into the soil. Since the wires are buried, a few "inspections" of 17 miles of wires does not prove to me that there is no corrosion. These wires have been in the ground for more than 30 years. The input of corrosive road salt that washes into the marsh in the winter months could be having an effect that cannot be determined by observations alone.
- Water sampling at the Martin Street culvert would determine if metals are mobilizing. The water path from the detention basin flows directly through the antenna field and into the Martin Street culvert.
- Finally, I am one of eight students working in this area this summer and the quality of my thesis work depends on getting good data. A section of the marsh that is under construction would impede our access to the entire site and the disruption of soils and vegetation could have an impact on our research.
- I would like to propose that tower construction be delayed until the winter months when the soil will be frozen and less compaction would occur. I am worried about irreversibly damaging the peat with heavy equipment driving over it.

Memo

Date: 4/25/2007
To: Ayres Associates
From: Elizabeth Fogarty
Re: Draft EIA—WHA Replacement Tower

This memorandum pertains to the Draft EIA for the proposed WHA Replacement Tower in the Southeast Marsh of the UW Arboretum. As a UW–Water Resources graduate student who is conducting present and future research in the marsh as part of a group practicum, I am concerned about the environmental impact and the ability to access the site for our research. I have developed comments directed at specific portions of the report. Additionally I endorse the comments of Dr. Joy Zedler, as well as, other graduate students participating in the UW–Water Resource Practicum.

The following are statements quoted directly from the Draft EIA Report with comments directly following:

- "The Arboretum does not actively use this area for recreational activities, though on-going research is conducted in this area and the general public uses the top of the berm as a walking path." (P. 5.)

Using the berm as a walking path is considered recreation. Furthermore, the berm is also used for cross country skiing and bird watching. This is one of the many contradictions and false statements through out the report.

On going research is frequent in the SE Marsh, including this summer. The UW–Water Resources Practicum is equivalent to an individual master's thesis. This summer we have plans to conduct research in SE Marsh and Gardner Marsh. The construction phase of this project may prevent us from completing such research required for graduation.

- "As a low lying area, it serves an important role in allowing sediment to settle prior to discharging to Gardner Marsh and Wingra Creek." (P. 6.)
- "Acquiring the southeast marsh area where the tower resides was done to utilize this area for stormwater management." (P. 6.)

Such statements acknowledge the importance of filtering water before reaching Gardner Marsh and Wingra Creek. The UW–Water Resources Practicum Group is currently looking at ways to increase such filtering. The construction phase of the new tower will disrupt such research by skewing data and limiting access to the site.

- "Furthermore, iron oxide is a common naturally occurring compound that is not reported to be very toxic." (P. 8.)

- "The impact of paint ships on the wetland environment has not been studied but, as with the iron oxide, it is not likely to be extensive. If the paint contains lead, the alkaline concrete would tend to keep the lead from mobilizing and moving through the soil beyond the tower base." (P. 8.)

Both statements use ambiguous language that is making assumptions while providing no actual evidence to support the claim. This is common throughout the draft. Terms like "very toxic" are unspecific and give no solid support to make conclusion of impact.

- "A primary social benefit of this area of the Arboretum is the research opportunity that it provides to study the southeast marsh and its surroundings." (P. 9.)

The report is acknowledging the social benefit of research opportunity in SE Marsh. Such a benefit would be lost for a field season by completing the construction phase in late summer. Specifically, the loss of future research associated with the Water Resources Practicum, but also existing research that has gone into planning this summer's practicum.

- "Replacing the tower will require a 3-ft square excavation to a depth of approximately 10 ft below ground, though the actual size of this footing excavation is dependant on the results of the geotechnical investigation. Excavated soil will be removed from the site. Some tree branches may need to be removed or trimmed in order to allow access by the construction equipment, but it is unlikely that entire trees will be removed." (P. 12.)

Removing tree branches and trimming trees in the UW–Arboretum is considered an environmental impact. Trimming trees may lead to the loss of valued trees by encouraging the infestation of tree diseases and invasive insects.

- "The tower is located in a wetland and, to minimize the impact of the construction equipment on the soft soil there, construction during wet seasons will use "swamp pads" or other rutless methods, such as low ground pressure equipment." (P. 12.)
- "There will, however, be some surface disturbance from excavation and construction activities." (p.14)

The report is stating that there is a potential for construction activities to impact the soft soil. Rather than try to implement methods to prevent such impact, moving the construction phase to a alternative season would limit such impact. Additionally it would also allow for research to continue during the summer months unobstructed—which is listed as a social benefit in the report.

- "Construction limits are estimated at approximately 4 acres, although only a small portion of that area will be temporarily disturbed by construction equipment that will be used to excavate the soil and install the tower base." (P. 12.)

This may be true for direct disturbance, but this is not true for associated long term disturbances. Virtually all land disturbance fuels the spread of reed canary grass. The disturbance within the four acres may have this effect, which can lead to the further spreading of reed canary grass across the marsh.

- "The zinc layer is very thin (a micro-layer) and is used because zinc corrodes much more slowly than steel. In fact, galvanized pipe generally only corrodes when pH is low and the pipe is immersed in water. As the tower will generally be dry and in a neutral pH environment, the galvanized steel of the replacement tower is not expected to contribute metals to the ground or surface water in the area of the tower." (P. 15.)

Assuming that the tower will be dry is presumptuous. Currently the area around the existing tower frequently has standing water. This is supported by the concentration of cattails within the fence enclosure. Therefore, the future tower may not remain dry and could contribute zinc to surface water.

Additionally, this state provides no evidence that the soil conditions currently have a low pH. The lack of scientific evidence throughout the report builds on the uncertainty surrounding the mobilization of metals into the soil, surface water, and ground water.

- "The work for this project will be done in a manner that minimizes disruption to the site environment and limits physical impacts." (P. 18.)

Minimizing the disturbance to social and environmental benefits would require reconsidering the timing of the construction phase. As demonstrated earlier, the current timing will cause ground disturbance and loss of research abilities. This supports the proposal to move the construction phase to the winter months.

- "Considering the existing and proposed tower replacement site which is situated at the rather hidden southeast end of the more than 1,200 acre-Arboretum, the potentially disturbed site is not rendered as a significant impact." (P. 18.)

Southeast Marsh is hardly hidden. As stated in the report itself, the berm is used recreationally and the entire marsh is used by students/faculty/scientist for research. The construction phase will impact such people utilizing the marsh. Again this is another contradicting statement to the other sections of the report.

Additionally, no matter how small a portion the marsh is, it still is a part of the UW–Arboretum and should me managed under their mission: "…to conserve and restore Arboretum lands, advance restoration ecology, and foster the land ethic." The activities associated with the replacement tower do not follow this mission.

- "The requirements of those permits and approvals will be incorporated into the construction plan for the replacement tower and this will mitigate the impact of the construction on the local environment." (P. 18.)

The permits issued by the DNR and Army Corp. of Engineers can not require mitigation, but mitigation can be offered to provide support for approving the permits. Furthermore, using best management practices is not considered mitigation. The report suggests the potential for land disturbance. Offering mitigation to offset such impacts would be in accordance with the UW- Arboretum mission and reduce long term ecological impacts.

- "The existing tower base is not proposed to be demolished and removed in order to limit the short-term environmental impacts such as construction vehicle emissions and physical disturbance of the site." (P. 19.)

This is another statement inconsistent with other sections of the report. Here it is stated that the removal of the existing tower base would cause environmental impact and therefore will not be complete. The report is conceding to the fact that construction vehicles emissions and physical disturbances will have impact, but yet when such vehicles are used for construction of the new tower there is not impact found.

- "Changing the tower location would affect the broadcast area, the adjacent radio stations, and the WHA-AM license." (P. 24.)

Earlier in the document it is stated that utilizing the existing copper ground radials will increase the broadcast range. According to your above statement, this would effect licensing and pose the same problem as relocating the tower. The is another contradicting statement that causes confusion and questions the validity of particular statements.

Overall the report provides inconsistent assessments and offers little evidence to support the claims of no impact. In portions of the document it is reported that there will be some ground disturbance and loss of social benefits, yet there is no mitigation offered or possible alternatives. All alternative mentioned were refuted. Additional alternatives to consider would include mitigation and the timing of the construction phase to limit the environmental and social impacts.

Memo

Date: 4/25/2007
To: Ayres Associates
From: Amy Singler
Re: Draft EIA—WHA Replacement Tower

To Whom It May Concern:

I am writing to express my concerns with the recent Draft Environmental Impact Statement (EIS) for the WHA-AM Transmitter Tower Replacement completed by Ayres Associates. Overall the report does not adequately recognize and address the impacts to the habitat of Southeast Marsh. As a graduate student in the Water Resources Management Program (WRM) at UW–Nelson Institute for Environmental Studies, I am part of a graduate student group working on a practicum this summer to develop a restoration plan for Southeast Marsh. I support the extensive comments submitted by Dr. Joy Zedler, Director of Arboretum Research, related to the EIS and would like to add to her comments by highlighting a few issues in particular.

The continued placement of the tower in Southeast Marsh diminishes the quality of the marsh and the extent to which the Arboretum can carry out its mission of education, research and restoration related to the Arboretum lands. The EIS discusses that the tower does not degrade the quality of the marsh or impact future work in the marsh. The presence of the tower and the in-marsh copper wires constrains options for restoration and management as digging or prescribed burns in the wire area will not be possible. The report also considers the impacted area to be small relative to the 72-acre marsh, but in fact, because the system is connected the impact is broader. Disturbance of that area opens opportunity for continued establishment of invasive species such as reed canary grass and invasive cattails, which can easily spread to other areas of the marsh and Arboretum at large. One of the goals of the WRM practicum is to better manage stormwater in Southeast Marsh. Initial options under consideration include channelizing stormwater from the ponds through the marsh. Constrained management of the tower area of Southeast Marsh impacts water quality downstream in Gardner Marsh, Wingra Creek and Lake Monona.

I am also concerned that the proposed timeline would seriously impact our ability as Water Resources Management students to complete our study of the marsh this summer. This summer's research has been planned since the fall and we have been working for several months on our fieldwork and research plans. We are working to develop a restoration plan for the marsh that is in line with the goals of the Arboretum: research, education and habitat restoration and protection. If the project were at least delayed until the winter months we could complete our research.

Finally, even if the tower is to remain in the marsh the report should accurately reflect that there are impacts to wildlife and habitat. If the project moves forward, WHA could consider mitigating for those impacts by partnering with the Arboretum. One possibility would be to set up a restoration and education fund specifically for the marsh, giving the Arboretum the opportunity to improve walking and educational trails in and around the marsh and begin habitat restoration in the marsh. WHA could also consider partnering with the Arboretum by broadcasting informational news and stories about Southeast Marsh and Gardner Marsh, immediately to the north (hydrologically connected to Southeast Marsh).

Thank you for the opportunity to comment on the Draft Environmental Impact Statement for the WHA Transmission Tower.

Appendix C: Samples of Past Research in the Eastern Wetlands

Ayres-Associates (2007). Draft Environmental Impact Assessment of WHA Tower. Madison, WI, Ayres Associates

Baumann, P. C., J. F. Kitchell, et al. (1974). Lake Wingra, 1837–1973: a case history of human impact. Transactions of the Wisconsin Academy of Sciences, Arts and Letters. E. McCoy. 62: 57–94.

Beckel, A. L. and F. N. Egerton (1987). Breaking new waters : a century of limnology at the University of Wisconsin. Madison, Wis., Wisconsin Academy of Sciences, Arts and Letters.

Bedford, B. L., E. H. Zimmerman, et al. (1974). The wetlands of Dane County, Wisconsin. [Madison, Wis.], Dane County Regional Planning Commission.

C-MED (2003). Draft Wingra Creek Parkway Master Plan. C. o. M. E. Division. Madison, WI, City of Madison.

C-MED (2007). Water Quality Initiatives, City of Madison-Engineering Division.

Cahn, A. R. (1915). An ecological survey of the Wingra springs region near Madison, Wisconsin : with special reference to its ornithology / by Alvin Robert Cahn, Bulletin of the Wisconsin Natural History Society.

Donohue and Associates (1981). Lake Forest Stormwater Detention Facility, Preliminary Engineering: Town of Madison, Dane County, WI.

Friedman, J. M. (1987). Gardner Marsh: Drainage, subsidence and restoration of a peat deposit: ix, 170 leaves.

Groy, J. (1981). Men and the Marsh: Lake Forest II. Arboretum News: Univesity of Wisconsin–Madison. 30.

Hall, S. and J. B. Zedler (2007). "Can sedge meadows self-restore following the harvest of invasive *Typha*." In Press.

Hasler, A. D. and E. Jones (1949). "Demonstration of the Antagonistic Action of Large Aquatic Plants on Algae and Rotifers." Ecology 30(3): 359-364.

Hasler, A. D., H. P. Thomsen, et al. (1946). "Facts and comments on raising two common bait minnows." Wisconsin Conservation Bulletin 210-A-46: 1-13.

Hasler, A. D. and W. J. Wisby (1958). "The Return of Displaced Largemouth Bass and Green Sunfish to a "Home" Area." Ecology 39(2): 289-293.

Hunter, J. R. (1963). "The Reproductive Behavior of the Green Sunfish, *Lepomis cyanellus*." Zoologica 48(1): 13-24.

Hunter, J. R. and A. D. Hasler (1965). "Spawning Association of the Redfin Shiner, *Notropis umbratilis*, and the Green Sunfish, *Lepomis cyanellus*." Copeia 1965(3): 265-281.

Hunter, J. R. and W. J. Wisby (1961). "Utilization of the Nests of Green Sunfish (*Lepomis cyanellus*) by the Redfin Shiner (*Notropis umbratilis cyanocephalus*)." Copeia 1961(1): 113-115.

Irwin, H. A. (1973). A natural history study of East Marsh of the University of Wisconsin Arboretum: 61 leaves.

Jones, S. E. (1947). An ecological study of large aquatic plants in small ponds: 166 leaves.

Jordan, W. R., Ed. (1984). Our first 50 years: The University of Wisconsin Arboretum, 1934–1984. Madison, Wis., University of Wisconsin Arboretum.

Kline, V. (1981). "Control of honeysuckle and buckthorn in oak forests." Restoration & Management Notes 1: 18.

Kline, V. (1992). University of Wisconsin Arboretum Long Range Management Plan. Madison, WI, University of Wisconsin–Madison.

Kogler, B. K. (1979). An analysis of the process of shrub invasion in wetlands with special reference to the ecology of red-osier dogwood (*Cornus stolonifera*): ix, 127 leaves.

Lathrop, R. (2007). Lake Wingra Aquatic Plant Restoration Demonstration Project. Zoology 315 Lecture. Madison, WI, University of Wisconsin

Michaud, B. J. (1994). The hydrological restoration of Gardner Marsh, Madison, Wisconsin. Madison, WI, Water Resources Engineering, Dept. of Civil and Environmental Engineering, University of Wisconsin–Madison.

Monthey, R. (1974). The Arboretum Marshes: Problems and Management with Specific Reference to the East Marsh. Independent research paper. Madison, WI, University of Wisconsin–Madison Arboretum.

Noland, W. E. (1951). The hydrography, fish, and turtle population of Lake Wingra. Transactions of the Wsconsin Academy of Sciences, Arts and Letters. A. J. Ihde. Madison, WI. 40: 5–58.

Pennequin, D. F. and M. P. Anderson (1983). Groundwater Budget of Lake Wingra, Dane County Wisconsin, Uiversity of Wisconsin, Madison.

Sachse, N. D. (1965). A Thousand Ages. Madison, WI, The Regents of the University of Wisconsin–Madison.

UW–Arboretum (2000). Strategic Plan. Madison, Wi, University of Wisconsin–Madison Arboretum.

UW–Arboretum (2006). University of Wisconsin–Madison Arboretum Facility Stormwater Management Plan. Madison, WI, Univeristy of Wisconsin–Madison Arboretum.

WDOA (2006). All Agency Request: 2005-2007 Biennium; University of Wisconsin–Madison Project Number 062GR, Storm Water Pond Repair, Wisconsin Department of Administration (WDOA).

Zedler, J. B. (2005). Opportunities for sedge meadow restoration at Gardener Marsh, Botany 670: Adaptive Restoration Lab. Arboretum Leaflet 6.

Appendix D: Ranking of Soil Cores Based on Concentrations of Pollutants

A rank of 1 means highest concentration and a rank of 33 means least concentration.
The soil core sites with the lowest 'Total' ranking are the sites with the highest accumulated concentrations of all metals

	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Zn	Li	Total
G1	21	30	30	29	25	28	7	3	26	30	33	262
G3	25	27	27	27	28	21	7	3	28	29	30	252
G5	28	25	25	30	22	22	7	3	32	31	18	243
G7	30	22	20	24	27	24	5	3	27	25	20	227
G9	4	24	19	21	21	33	1	3	7	20	22	175
G11	24	29	28	28	29	29	7	3	25	27	27	256
G13	29	31	32	32	32	19	7	3	30	32	28	275
G15	9	20	21	19	20	32	2	3	12	11	23	172
G17	8	18	23	22	23	30	3	3	10	16	21	177
G19	11	23	22	25	24	25	7	3	20	26	24	210
G21	10	21	24	26	26	12	7	3	11	23	25	188
G23	33	33	33	33	33	23	7	3	33	33	32	296
G25	18	28	26	23	30	26	7	3	15	24	26	226
G26	22	32	29	31	31	17	7	3	16	28	29	245
SE1	7	15	15	8	15	16	7	3	5	7	12	110
SE2	17	1	18	7	1	4	7	3	6	2	16	82
SE3	5	17	4	6	16	27	4	1	3	15	15	113
SE4	31	5	12	12	6	10	7	3	17	12	3	118
SE4.5	20	8	10	11	4	11	7	3	14	14	5	107
SE5	12	2	9	5	2	2	7	3	13	8	1	64
SE6	23	6	6	13	5	3	7	3	29	18	7	120
SE7	13	11	2	9	12	8	7	3	18	10	2	95
SE8	15	9	1	16	7	6	7	2	19	13	8	103
SE8.8	32	3	13	20	10	1	7	3	24	17	9	139
SE9	27	16	8	4	19	13	7	3	22	5	19	143
SE10	6	13	3	2	17	14	7	3	9	3	17	94
SE11	14	4	5	15	11	5	7	3	4	9	10	87
SE12	1	7	7	3	8	9	6	3	1	1	6	52
SE13	2	10	11	1	13	7	7	3	2	4	13	73
SE14	19	12	16	17	9	18	7	3	21	19	4	145
SE15	3	14	17	10	18	20	7	3	12	6	14	124
SE16	16	26	31	18	3	31	7	3	23	21	31	210
SE17	26	19	14	14	14	15	7	3	31	22	11	176

Soil Core Sites

with metal rankings totaled and sorted from most polluted (1) to least polluted (33).

Site	Rank Sums	Total Rank	
SE12	52	1	most polluted
SE5	64	2	
SE13	73	3	
SE2	82	4	
SE11	87	5	
SE10	94	6	
SE7	95	7	
SE8	103	8	
SE4.5	107	9	
SE1	110	10	
SE3	113	11	
SE4	118	12	
SE6	120	13	
SE15	124	14	
SE8.8	139	15	
SE9	143	16	
SE14	145	17	
G15	172	18	
G9	175	19	
SE17	176	20	
G17	177	21	
G21	188	22	
G19	210	23	
SE16	210	24	
G25	226	25	
G7	227	26	
G5	243	27	
G26	245	28	
G3	252	29	
G11	256	30	
G1	262	31	
G13	275	32	
G23	296	33	least polluted

Appendix E: Detailed Soil Sampling Methods

Soil cores were taken along two transects in each marsh, although two individual outlier samples in each marsh were taken to provide a more comprehensive picture of the marshes.

At each sample site, a variety of tests and observations were taken. First, a core was dug to approximately 30 cm deep. It was laid out on a tarp, labeled and photographed and then a quart-sized plastic bag was filled with sample. Generally, the top 10 cm^3 of soil was collected for each lab sample. The sample was dug approximately 0.5 m below the surface and only the top 10 cm of soil was collected for analysis. A 0.75 m spade 'sharpshooter' was used to dig a small pit to extract the sample. Samples were dried in for 3 days in a hot room, ground and sieved and then sent to the University of Wisconsin Soil and Plant Analysis Lab (SPAL) for analysis. This method was outlined by Dr. Cynthia Stiles, UW Soil Professor (2007).

In addition, at each sample site, a deeper soil core probe was taken to characterize the physical composition of the strata of soil. A 15 cm corer was used with a 1 m handle. The core went down 90–100 cm in 15 cm increments. Color, texture, and horizonation were determined for each core. Special attention was given to trying to find the depth of peat and the subsoil layer. Oftentimes this was not possible given the depth of peat and our limited equipment.

In Southeast Marsh, two transects were established (Figure 4.2) from the outlet and leading up to each pond in a V shape. The transect locations were created to coincide with water outflow from Ponds 3 and 4. Samples along transects were spaced fifty meters apart. Fifty meters was determined to be an adequate distance to determine any major differences in nutrient and metal concentrations (Stiles 2007 personal comm.). If vegetation type varied significantly a sample was taken at a finer scale to further investigate possible soil composition differences. Two samples were taken off the transect lines; one on the northwest side and one on the southeast side of the main transect. In Southeast Marsh, 19 total samples were taken.

In Gardner Marsh, two transects were also established, this time forming an 'X'. Due to the channelized flow of water in Gardner Marsh and the overgrowth of trees and shrubs along the channel, transects were not designed to follow water flow. Instead, transects were designed to maximize acreage and create a representative sample of the marsh in general. Again, samples were taken every 50 meters, yielding 26 samples. In addition to the two transects, two additional samples were taken from the very northern section of Gardner Marsh.

Soil Core Descriptions

SOUTHEAST MARSH

SE 1: RCG and Jewelweed

0–16 cm peat
16–20 cm peaty muck
20–30 cm muck w/ red oxidized granular spots (10%)
30–60 cm silt

SE 2: Cattail, RCG and Jewelweed

0–12cm peat
12–20 cm peaty muck
20–45 cm muck
45–58 cm silty loam w/ some gray
65 cm water table, specific gravity 3.4

SE 3: Blue-joint grass, Cattail, Jewelweed

0–9 cm peat
9–23 cm muck
23–30 cm silt loam
30–35 cm black silt w/ a little sand and reduced sulfur

SE 4: Cattail and Jewelweed

0–12 cm peat
12–19 cm peaty muck

19–35 cm silt loam and fine roots
35 cm to water table

SE 4.5: Tussock sedge, Jewelweed, Blue-joint grass

0–13cm peat
13–30 cm muck
30–55 cm silty muck
55–75 gray gleying
75 cm thin decomposing OM layer
76–115 cm gleying
117–120 cm sand
20 cm to water table

SE 5: RCG and Jewelweed

0–17 cm peat
17–30 cm peaty muck, granular
30–75 cm silt
75–90 cm silt w/ gleying
90–110 cm silt, no sand
No water table reached

SE 6: Woolgrass, RCG and Red-osier dogwood

0–12 cm peat
12–20 cm muck with a little red/brown coloring
20–47 cm silt w/ gleying
47 cm water table

SE 7: RCG and Jewelweed

0–35 cm peat with some red oxidization
35–45 cm muck and clay
45–65 cm clay
65–70 cm clay, silt, gleying
70–75 cm gleying, brown in color
75–85 cm brown/gray gleying; no sand
83 cm water table

SE 8: RCG, Jewelweed and Honeysuckle

0–14cm dry granular, not peat
14– 50 cm muck/clay
50–55 cm brown gray gleying
55–60 cm gray gleying
60–70 cm gray/brown gleying
70–75 cm sand and water
Water at 75 cm

SE 8.8: Goldenrod and Sedge sp.

0–15cm dry OM sediment
15–20 cm brown dry loam
20–40 cm brown, dry silt loam
40–50 cm mottled clay
50–65 cm clay with sand
65 cm sand
66–90 cm gleying (2.5Y 6/2)
Water table 90–100 cm

SE 9: In Pond 4—RCG, Jewelweed and Waterpepper

0–10 cm silty sand
10–30 cm sand

30–60 cm sand w/ silty gleying
60–90 cm silty gleying 4/10GY
90–105 cm gleying 2.5/10GY w/ sand
Water table at 100 cm

SE 10: Inside Pond 4—RCG and Waterpepper
0–3 cm sand
3–27 cm silty sand w/ red spotting
27–29 cm sand w/ red specks 2.5 YR 3/6
29–60 cm gleying 5 YR 2.5/1 and gleying 4/10Y

SE 11: Goldenrod, RCG and Canadian thistle
0–10 cm peat w/ fine roots throughout
10–30 cm peaty muck
30–40 cm silty clay, smooth
40–50 cm gleying 4/5 GY
50–60 cm gleying 5/5 GY

SE 12: Cattail, Jewelweed and RCG
0–16cm fibric peat
15–40 cm silty clay w/ red specks and fine roots
40–60 cm silt clay, dark gray gleying 2.5/5 GY
60 cm fibric peat

SE 13: Jewelweed, RCG and Sedge
0–10 cm fibric peat
10–30 cm peaty muck w/ fine roots
30–50 cm peaty muck
50–55 cm fibric peat
55–69 cm mucky peat
70 cm sand
Water table at 80 cm

SE 14: RCG, Blue-joint grass and Jewelweed
0–10 cm fibric peat
10–30 cm peaty muck w/ structure and fine roots, some red specks
30–55 cm peaty muck
55–57 cm silty clay
58 cm sand
Water table at 55 cm

SE 15: RCG and Jewelweed
0–8 cm fibric peat
8–30 cm mucky peat w/ fine roots and red specks
30–55 cm muck, black
55–69 cm sticky silt, a lighter brown
70 cm sand
No water

SE 16: Tussock sedge, Canadian clearweed and Jewelweed
0–32 cm peat with oxidation spots from 15–32 cm
32–40 cm dark gray gleying
40–50 cm sand
Water at 50 cm

SE 17: Sedge sp., Goldenrod and RCG
0–40 cm peat
40–90 cm gray and brown gleying with little oxidation red spots

Soil Core Descriptions
GARDNER MARSH:

G 1: Jewelweed, Canadian clearweed and Alder buckthorn

0–30 cm dry black organic matter
30–32 cm brown decaying organic matter
32–100 cm mixture of black organic matter and brown decaying vegetation
No water

G 2: Jewelweed, Canadian clearweed and Common dodder

0–40 cm dry black organic matter
40–60 cm marl deposits w/ shells
60–100 cm marl

G 3: Jewelweed, Canadian clearweed and Alder buckthorn

0–35 cm dark organic matter w/ marl spots
35–90 cm light gray marl
Water around 70 cm

G 4: Jewelweed, RCG and Stinging nettle

0–35 cm dry dark brown soil w/ fine roots
35–70 cm light gray marl
70–75 cm marl w/ sand
75–90 cm marl and sand
90–110 cm light gray marl

G 5: Thick Red-osier Dogwood forest with a RCG and Jewelweed opening

0–40 cm medium brown soil w/ fine roots of RCG
40–90 cm light gray marl

G 6: Goldenrod, Canadian clearweed and Blue-joint Grass, edge of sedge meadow

0–22 cm dark organic matter soils
22–30 cm dark organic matter soils mixed w/ marl
30–100 cm light gray marl

G 7: Goldenrod, Marsh bedstraw and Blue-joint grass, edge of sedge meadow

0–17cm dark organic matter
17–90 cm light gray marl

G 8: Lake sedge, False nettle and Canada thistle, edge of meadow

0–12 cm peat w/ fine roots
12–90 cm light gray marl
Water at 60 cm

G 9: Blue-joint grass, Cattail and Marsh bedstraw

0–12 cm Peat w/ roots
12–30 cm med gray marl
30–90 cm light gray marl

G 10: Cattail, Red-osier dogwood and Wild mint

0–10 cm peat
10–90 cm light gray marl
Water at 50 cm

G 11: Cattail, Burreed, Arrowhead

0–5: fibric peat
5–80: dry marl
80–~90: wet marl

G 12: Alder buckthorn, Lake sedge and Grass spp.

0–18: dry structured marl
18–50: dry marl with little sand around 40 cm, marl breaks apart more easily than above
50–90: wet marl with some sand mixed in, mostly marl

G 13: Cattail

0–15: moist fibric peat, with fine roots
15–60: wet marl
60–90: very wet marl

G 14: Blue-joint Grass, RCG and Stinging nettle

0–1 cm peat w/ marl
1–25 cm dark brown organic matter w/ peat
25–32 cm dark brown organic matter
32–90 cm marl
Water at 69 cm

G 15: Blue-joint Grass, Marsh bedstraw and Waterpepper

0–12 cm peat
12–30 cm dark black organic matter w/ marl spots
30–90 cm marl
Water at 60 cm

G 16: Bluejoint Grass, Waterpepper and Marsh bedstraw

0–20 cm peat
20–28 cm dark black organic matter
28–90 cm marl

G 17: Waterpepper, Marsh bedstraw

0–15 cm peat
15–30 cm peat mixed with marl
30–90 cm marl
Water at 65 cm

G 18: Cattail, Red-osier dogwood and Marsh bedstraw

0–9 cm peat
9–80 cm marl
Water at 75 cm

G 19: Marsh Bedstraw, Blue-joint grass and Red-osier dogwood

0–7 cm peat
7–17 cm dark gray marl
17–30 cm light gray marl
30–90 cm med gray marl
Water at 75 cm

G 20: Blue-joint grass, Marsh bedstraw and Wild mint

0–10 cm peat
10–30 cm dark gray marl
30–90 cm light gray marl
Water at 70 cm

G 21: Lake sedge, Common water-horehound

0–10 cm peat
10–50 cm med gray marl
50 cm some red oxidation mixed in with marl
50–90 cm light gray marl
Water at 75 cm

G 22: Cattail

0–11 cm peat
11–30 cm medium gray marl
30–90 light gray marl
Water at 80 cm

G 23: Alder buckthorn and Creeping yellow wood sorrel

0–50 cm marl mixed with sand
50–80 cm medium gray marl
80–90 cm brown fibric decomposing matter mixed with marl
Water at 75 cm

G 24: Cattail and Bittersweet nightshade

0–15 cm peat w/ small amount of marl
15–30 cm dark gray marl
30–90 cm light gray marl
Water at 28 cm

G 25: Cattail

0–9 cm peat
9–13 cm medium gray marl
13–90 cm light gray marl

G26: Grass sp., Rush sp. and Canadian thistle

0–6 cm peat
6–12 cm dark gray marl
12–30 medium gray marl
30-90 light gray marl

Appendix F: Vegetation Survey Methods

In order to record the biological resources and their current states as accurately and comprehensively as possible, a vegetation sampling plan was designed to collect baseline data in Southeast and Gardner Marshes. The primary goals of the vegetation sampling plan for each marsh included:

- A vegetation communities map for each marsh (including dominant plant communities and their boundaries in the marshes);
- A detailed vegetation survey data based on sampling along 2 transects in each marsh;
- A comprehensive vegetation species list for each marsh.

Vegetation Map

In developing a vegetation map for each marsh, aerial photos, past literature and research were first reviewed and cross-referenced to develop a preliminary vegetation map for each marsh, including areas of dominant species. The question our research team then sought to answer was: Does the current vegetation patterns match the literature and aerial photos reviewed?

To answer this question, our research team used a high precision, survey-grade GPS unit (model: Leica SR530) to map the perimeters of major vegetation zones within each marsh. At the same time, the most dominant plant species (species which made up at least 50% of the total plant cover in an area) and their approximate percent cover in each vegetation zone were documented.

After collecting GPS data on the dominant plant communities in Southeast and Gardner Marshes, the data was analyzed to determine if vegetation and/or wetland boundaries and species had shifted in recent years. It was then possible to create a comprehensive vegetation zone map based on literature, aerial photos, and current field data, as well as comparisons between these data sources.

Detailed Vegetation Survey Data

To obtain detailed vegetation data, we identified and sampled along 2 transects in each marsh, which were the same transects used for soil sampling (Figures 4.2, 4.3). The goal of vegetation sampling was to: a) collect detailed vegetation data at each of the soil sampling points, including all observed plant species and their percent cover, and b) compare this data with the soil data to make connections between wetland soils and the plant species they support, or do not support.

The 2 transects in SE marsh included 17 sampling points, while the 2 transects in Gardner marsh included 25 sampling points. Sampling points along each transect were chosen at random, at intervals of 50m. At each point a $1m^2$ quadrat was sampled, and included:

- Identifying all observed plant species within the $1m^2$ area;
- Collecting plant sample for second-opinion identification at the UW–Madison Herbarium;
- Estimating each plant species' percent of both each point sampled ($1m^2$) and the total area sampled (total of $1m^2$ points).

Lastly, our research team compared and analyzed vegetation data with soil sample data in order to calculate species richness, species diversity and other relevant factors based on this comparison of data in both Southeast and Gardner Marshes.

Appendix G: Southeast Marsh Vegetation Species Observed and Identified (2007)

	Scientific Name	Common Name
1.	*Acer negundo*	Box elder
2.	*Andropogon gerardii*	Big blue-stem
3.	*Asclepias incarnata*	Swamp milkweed
4.	*Aster puniceus*	Purple-stem aster
5.	*Calamagrostis canadensis*	Blue-joint grass
6.	*Carex lanuginosa*	Woolly sedge
7.	*Carex scoparia*	Broom sedge
8.	*Carex stipata*	Common fox sedge
9.	*Carex stricta*	Common tussock sedge
10.	*Chelone glabra*	White turtlehead
11.	*Cichorium intybus*	Chicory
12.	*Cirsium arvense*	Canada thistle
13.	*Cirsium muticum*	Swamp thistle
14.	*Cirsium vulgare*	Bull thistle
15.	*Cornus canadensis*	Bunchberry
16.	*Cornus racemosa*	Northern swamp dogwood
17.	*Cornus stolonifera*	Red osier dogwood
18.	*Daucus carota*	Queen Anne's-lace
19.	*Dryopteris cristata*	Crested wood fern
20.	*Eleocharis elliptica*	Spike-rush
21.	*Epilobium coloratum*	Purple-leaf willow-herb
22.	*Epilobium leptophyllum*	American marsh willow-herb
23.	*Equisetum arvense*	Field horsetail
24.	*Erigeron strigosus*	Daisy fleabane
25.	*Erysimum sp.*	Wallflower sp.
26.	*Euphorbia corollata*	Flowering spurge
27.	*Eupatorium maculatum*	Spotted joe-pye weed
28.	*Eupatorium rugosum*	White snakeroot
29.	*Euthamia graminifolia*	Grass-leaved goldenrod
30.	*Fraxinus americana/pennsylvania*	White ash/Green ash
31.	*Galium labradoricum*	Labrador marsh bedstraw
32.	*Geum canadense*	White avens
33.	*Helianthus giganteus*	Swamp sunflower
34.	*Heliopsis helianthoides*	False sunflower
35.	*Hypericum perforatum*	Common St.John's-wort
36.	*Impatiens capensis*	Jewelweed
37.	*Iris virginica*	Southern blue flag
38.	*Lilium michiganese*	Michigan lily
39.	*Lonicera oblongifolia*	Honeysuckle
40.	*Lycopus americanus*	American water-horehound
41.	*Lysimachia thyrsiflora*	Swamp loosestrife
42.	*Mentha arvensis*	Wild mint
43.	*Monarda fistulosa*	Bee balm
44.	*Phalaris arundinacea*	Reed canary grass
45.	*Pilea pumila*	Canadian clearweed
46.	*Poa spp.*	Grass spp.
47.	*Polygonum amphibium*	Water smartweed
48.	*Polygonum hydropiper*	Water-pepper
49.	*Polygonum sagittatum*	Arrow-leaved tear-thumb
50.	*Pycnanthemum virginianum*	Common mountain mint
51.	*Rhamnus alnifolia*	Alder buckthorn
52.	*Rhamnus cathartica*	Common buckthorn
53.	*Rhus hirta*	Staghorn sumac
54.	*Rubus idaeus*	Wild red raspberry
55.	*Rumex orbiculatus*	Great water dock
56.	*Salix exigua*	Sandbar willow
57.	*Salvia azurea*	Blue sage
58.	*Scirpus cyperinus*	Wool grass
59.	*Scutellaria galericulata*	Common skullcap
60.	*Sinapis arvensis*	Charlock mustard
61.	*Solanum dulcamara*	Bittersweet nightshade
62.	*Solidago canadensis*	Canada goldenrod
63.	*Thalictrum dasycarpum*	Purple meadow-rue
64.	*Tilia americana*	Basswood
65.	*Typha angustifolia*	Narrow-leaved cattail
66.	*Typha x glauca*	Hybrid cattail
67.	*Typha latifolia*	Broad-leaved cattail
68.	*Verbena hastata*	Blue vervain
69.	*Vitis riparia*	Riverbank grape

Appendix H: Gardner Marsh Vegetation Species Observed and Identified (2007)

	Scientific Name	Common Name
1.	*Acer negundo*	Box elder
2.	*Acer saccharinum*	Silver maple
3.	*Acer saccharum*	Sugar maple
4.	*Alisma subcordatum*	Water plantain
5.	*Alliaria petiolata*	Garlic mustard
6.	*Arisaema triphyllum*	Jack-in-the-pulpit
7.	*Articum minus*	Common burdock
8.	*Asclepias incarnata*	Swamp milkweed
9.	*Asclepias syriaca*	Common milkweed
10.	*Aster novae-angliae*	New England aster
11.	*Aster puniceus*	Swamp/purple-stem aster
12.	*Barbearea vulgaris*	Winter cress
13.	*Boehmeria cylindrica*	False nettle
14.	*Calamagrostis canadensis*	Blue-joint grass
15.	*Campanula aparinoides*	Marsh bellflower
16.	*Carex aquatilis*	Water sedge
17.	*Carex hystericina*	Bottlebrush/porcupine sedge
18.	*Carex lacustris*	Common lake sedge
19.	*Carex lasiocarpa*	American woolly-fruit sedge
20.	*Carex stricta*	Common tussock sedge
21.	*Carex utriculata*	Common yellow lake sedge
22.	*Carya ovat*	Shagbark hickory
23.	*Catalpa speciosa*	Northern catalpa
24.	*Celtis occidentalis*	Hackberry
25.	*Centaurea sp.*	Knapweed sp.
26.	*Cicuta bulbifera*	Bulblet water-hemlock
27.	*Cichorium intybus*	Chicory
28.	*Cirsium arvense*	Canada thistle
29.	*Cirsium muticum*	Swamp thistle
30.	*Cirsium vulgare*	Bull thistle
31.	*Cornus stolonifera*	Red osier dogwood
32.	*Cuscuta gronovii*	Common dodder
33.	*Cyperus esculentas*	Yellow nut sedge
34.	*Cyperus odoratus*	Fragrant flat sedge
35.	*Cyperus diandrus*	Umbrella flat sedge
36.	*Dalea purpurea*	Purple prairie-clover
37.	*Decodon verticillatus*	Swamp loosestrife/water-willow
38.	*Dryopteris sp.*	Fern sp.
39.	*Echinocystis lobata*	Wild cucumber
40.	*Eleocharis elliptica*	Spike-rush
41.	*Eleocharis obtusa*	Blunt spike-rush
42.	*Epilobium coloratum*	Purple-leaf willow-herb
43.	*Epilobium leptophyllum*	American marsh willow-herb
44.	*Erechtites hieracifolia*	Fireweed
45.	*Erigeron philadelphicus*	Daisy fleabane
46.	*Eriophorum angustifolium*	Narrow-leaved cottonweed
47.	*Eupatorium perfoliatum*	Boneset
48.	*Eupatorium maculatum*	Spotted joe-pye weed
49.	*Eupatorium rugosum*	White snakeroot
50.	*Euthamia graminifolia*	Grass-leaved goldenrod
51.	*Fragaria virginiana*	Wild strawberry
52.	*Galium labradoricum*	Labrador marsh bedstraw
53.	*Gleditsia triacanthos*	Honey locust
54.	*Hesperis matronalis*	Dame's rocket mustard
55.	*Hypericum perforatum*	Common St.John's-wort
56.	*Impatiens capensis*	Jewelweed
57.	*Juglans nigra*	Black walnut
58.	*Juncus nodosus*	Joint rush
59.	*Juncus spp.*	Rush spp.

Continued on next page.

Continued from previous page.

60.	*Lobelia kalmii*	Bog lobelia
61.	*Lobelia siphilitica*	Great blue lobelia
62.	*Lonicera oblongifolia*	Honeysuckle
63.	*Lythrum alatum*	Winged loosestrife
64.	*Lycopus americanus*	American/common water-horehound
65.	*Lysimachia hybrida*	Lowland yellow/river loosestrife
66.	*Mentha arvensis*	Wild mint
67.	*Monarda fistulosa*	Wild bergamot
68.	*Mimulus ringens*	Monkey flower
69.	*Nepeta cataria*	Catnip
70.	*Nymphaea odorata*	American white water-lily
71.	*Oxalis corniculata*	Creeping yellow wood-sorrel
72.	*Phalaris arundinacea*	Reed canary grass
73.	*Phragmites australis*	Common reed
74.	*Pilea pumila*	Canadian clearweed
75.	*Phytolacca Americana*	American pokeberry/pokeweed
76.	*Pinus resinosa*	Canadian/red pine
77.	*Pinus strobus*	Eastern white pine
78.	*Poa spp.*	Grass spp.
79.	*Polygonum hydropiper*	Marsh-pepper knotweed (smartweed)
80.	*Polygonum sagittatum*	Arrow-leaved tear-thumb
81.	*Populus deltoides*	Eastern cottonwood
82.	*Populus tremuloides*	Quaking aspen
83.	*Populus trichocarpa*	Black cottonwood
84.	*Prunella vulgaris*	Heal-all/lawn prunella
85.	*Prunus serotina*	Wild black cherry
86.	*Pycnanthemum virginianum*	Common mountain mint
87.	*Quercus bicolor*	Swamp white oak
88.	*Quercus macrocarpa*	Bur oak
89.	*Ranunculus pensylvanicus*	Pennsylvania buttercup
90.	*Robinia pseudoacacia*	Black locust
91.	*Rhamnus alnifolia*	Alder buckthorn
92.	*Rhamnus frangula*	Glossy buckthorn
93.	*Rhamnus cathartica*	Common buckthorn
94.	*Rhus hirta*	Staghorn/velvet sumac
95.	*Rhus radicans*	Poison ivy
96.	*Rubus idaeus*	Wild red raspberry
97.	*Saggitaria latifolia*	Common arrowhead
98.	*Salix exigua*	Sandbar willow
99.	*Salix nigra*	Black willow
100.	*Sambucus canadensis*	American elderberry
101.	*Schoenoplectus acutus*	Hard-stem bulrush
102.	*Schoenoplectus tabernaemontani*	Soft-stem bulrush
103.	*Scutellaria galericulata*	Common/marsh skullcap
104.	*Solanum dulcamara*	Bittersweet nightshade
105.	*Solidago canadensis*	Canada/common goldenrod
106.	*Sparangium eurycarpum*	Common bur-reed
107.	*Teucrium canadense*	Wood sage
108.	*Thuja occidentalis*	Eastern white cedar
109.	*Tilia americana*	American basswood
110.	*Typha angustifolia*	Narrow-leaved cat-tail
111.	*Typha x glauca*	Hybrid cat-tail (*augustifolia x latifolia*)
112.	*Typha latifolia*	Common/broad-leaved cat-tail
113.	*Ulmus americana*	American elm
114.	*Urtica dioica*	Stinging nettle
115.	*Verbascum thapsus*	Common mullein
116.	*Verbena hastata*	Blue vervain
117.	*Viburnum opulus*	European cranberry bush
118.		Moss spp.

Appendix I: Water Sampling Methods

Water samples were collected from 5 sites during non-storm events and 3 sites during storm events (Table 1).

Table 1: Location of water sampling sites.
Monitoring sites listed from 'upstream' to 'downstream' in the order samples were taken

Non-storm event sampling	Storm-event sampling
Pond 3	Arbor Hills Greenway
Pond 4 inlet	Pond 3 inlet
Schmidt Lagoon	Pond 4 inlet
Redwing Marsh Channel	
Wingra Creek Bridge	

For non-storm event sampling, five locations were sampled (Figure 6.2). Locations started upstream at the south side of Southeast Marsh at Ponds 3 and 4. At Pond 3, samples were taken at the inflow channel in the pond itself. At Pond 4, samples were taken at the inflow channel just outside the pond below the train tracks. Moving downstream, the next location was the inflow culvert into the Schmidt Lagoon. Next, near Redwing Marsh we walked about 50 meters down the trail and cut in until we reached the channel. Finally, as water exits the Arboretum via Wingra Creek, a sample was taken under Fish Hatchery Road bridge.

Storm event sampling included 3 locations (Figure 6.1). Upstream of the Arboretum, samples were taken at the bottom of the Arbor Hills Greenway in the Arbor Hills neighborhood. This location was chosen to determine the chemistry of stormwater upstream before entering the Arboretum. The inflows of Ponds 3 and 4 were also measured during storm events. Due to time and budget constraints and storm timing, outflows to the ponds were not sampled. All samples were taken as a grab sample—a single sample taken at a point in time. Samples were taken in accordance with methods outlined in Eaton et al. (1995). Each bottle was first rinsed with the sample water and then each container was filled full and analysis was conducted within 2 hours of the sample being taken. All samples were taken approximately 1 m from shore when feasible. This insured a homogenous sample representative of the water body.

For both types of monitoring events, an Oakton DO 100 Series meter measured dissolved oxygen (mg/l) and temperature (°C) in the field. Transparency measurements were taken using a 120 cm long transparency tube. One 250 ml polyethylene bottle of water was taken back to the lab for analysis. Samples were stored in the dark in a cooler and analyzed within 2 hours of collection. A DR/2400 Portable Hach Kit Field Spectrophotometer measured reactive phosphorus (program number 490P, React. PV), nitrate (program number 353N, Nitrate MR) and total suspended solids (program number 630 Suspended Solids). The 10 and 25 ml cuvettes were triple rinsed with DI water and then rinsed once with the sample before preparation for analysis. Measurement of pH used (EMD brand) dipping sticks with pH range of 1–14.

During storm events only, an additional two samples were taken for metals and nutrients analysis performed by the State Lab of Hygiene (SLOH).

APPENDIX J: SOUTHEAST MARSHES BIRD SPECIES OBSERVED AND IDENTIFIED (2007)

1. American Goldfinch *Carduelis tristis*
2. American Bittern *Botaurus lentiginosus*
3. House Finch *Carpodacus mexicanus*
4. Song Sparrow *Melospiza melodia*
5. Swamp Sparrow *Melospiza georgiana*
6. Chipping Sparrow *Spizella passerina*
7. Marsh Wren *Cistothorus palustris*
8. Sandhill Crane *Grus canadensis*
9. Common Yellowthroat *Geothlypis trichas*
10. Cedar Waxwing *Bombycilla cedrorum*
11. Yellow Warbler *Dendroica petechia*
12. Indigo Bunting *Passerina cyanea*
13. Green Heron *Butorides virescens*
14. Yellow-bellied Sapsucker *Sphyrapicus varius*
15. Alder Flycatcher *Empidonax alnorum*
16. Northern Rough-winged Swallow *Stelgidopteryx serripennis*
17. Barn Swallow *Hirundo rustica*
18. Tree Swallow *Tachycineta bicolor*
19. American Crow *Corvus brachyrhynchos*
20. Chimney Swift *Chaetura pelagica*
21. Common Grackle *Quiscalus quiscula*
22. Brown-headed Cowbird *Molothrus ater*
23. Brown Thrasher *Toxostoma rufum*
24. Flycatcher *Epidomax sp*
25. Gray Catbird *Dumetella carolinensis*
26. Downy Woodpecker *Picoides pubescens*
27. Red-bellied Woodpecker *Melanerpes carolinus*
28. Great Blue Heron (nest sighted by fish ponds) *Ardea herodias*
29. Great Egret *Ardea alba*
30. Great Horned Owl (nest sighted north of fish ponds) *Bubo virginianus*
31. American Robin *Turdus migratorius*
32. Eastern Phoebe *Sayornis phoebe*
33. Osprey (nest across Fish Hatchery Rd by Wright M.S.) *Pandion haliaetus*
34. Red-tailed Hawk (possible nest in Gardner Marsh) *Buteo jamaicensis*
35. Belted Kingfisher *Ceryle alcyon*
36. Wood Thrush *Hylocichla mustelina*
37. White-breasted Nuthatch *Sitta carolinensis*
38. Red-winged Blackbird *Agelaius phoeniceus*
39. Northern Cardinal *Cardinalis cardinalis*
40. Mourning Dove *Zenaida macroura*
41. Turkey Vulture *Cathartes aura*
42. Eastern Kingbird *Tyrannus tyrannus*
43. Blue Jay *Cyanocitta cristata*

Species observed in Carver/Martin Street neighborhood, Lost City Forest, or Southeast/Gardner Marshes April–May 2007 during non-research periods

44. Hooded Warbler *Wilsonia citrina*
45. Northern Parula *Parula americana*
46. Red-eyed Vireo *Vireo olivaceus*
47. Black-capped Chickadee *Poecile atricapilla*
48. Blue-winged Teal *Anas discors*
49. Mallard *Anas platyrhynchos*
50. Canada Goose *Branta canadensis*
51. Bufflehead *Bucephala albeola*
52. Gadwall *Anas strepera*
53. Northern Shoveler *Anas clypeata*
54. Baltimore Oriole *Icterus galbula*

Appendix K: Cover Letter and Greenway Survey

Your opinion is important to us!

Please take a few minutes to complete the following survey regarding the potential redesign of the Arbor Hills Greenway. Your feedback will influence how the site plans incorporate interdisciplinary uses of the Greenway.

Dear Resident,

We are part of a team of UW–Water Resources graduate students developing a restoration plan for Southeast and Gardner Marshes in the UW–Arboretum. Part of our plan includes determining ways to reduce the amount of low quality stormwater entering the marshes via creeks and storm sewers. Currently, stormwater from the Arbor Hills neighborhoods is channeled through storm sewers and the Arbor Hills Greenway to a retention pond in Southeast Marsh. A portion of this water continues to flow northeast through Gardner Marsh to Monona Bay. Both, Gardner Marsh and Southeast Marsh have become degraded due to the large volume of low-quality stormwater they receive from surrounding neighborhoods.

The Arbor Hills Greenway offers an ideal location to reduce the amount of stormwater entering Southeast Marsh by retaining and slowing the flow of the stormwater. This would allow some water to infiltrate, or enter, the soil and become ground water. Thus, decreasing the volume that would continue to the marsh at the surface. There has been strong interest by the City of Madison and the UW–Arboretum to redesign the park in the Greenway to meet this purpose.

This fall, UW–Biological Science Engineering students with develop three potential designs for the Greenway. Each design will focus on using the Greenway to increase infiltration. However, the design will also incorporate current and potential uses of the Greenway by the neighborhood residents. We have partnered with the Biological Science Engineering students and the Arbor Hills Neighborhood Association students to gather your opinions on the redesign of the Greenway. Your opinions, gathered through this survey, will directly influence the design options.

Again, your opinion is important to us! Please take a few minutes to respond to the questions on the following pages.

Sincerely,

Betsy Fogarty Emily Sievers

Water Resources Management graduate students, UW–Madison

1. Do you live within the Arbor Hills Neighborhood? (please circle) YES NO

2. How many people live in your household? ____________________
How many are under the age of 16? ____________________

3. Does at least one person in your household use the Arbor Hills Greenway? YES NO
If NO, please skip to question 6

4. Please circle all of the following activities he/she uses the Greenway for:

Soccer Basketball Picnic Pet Activities Winter Activities Other (please specify)

5. How many times does he/she use the Greenway for those activities (please check one):
Daily = every day / Weekly = at least once a week / Monthly = at least once a month / Seasonally = at least once during the summer or winter months

Soccer: ___daily ____weekly ____monthly ____seasonally
Basketball:___daily ____weekly ____monthly ____seasonally
Picnic:___daily ____weekly ____monthly ____seasonally
Pet Activities:___daily ____weekly ____monthly ____ seasonally
Winter Activities:___daily ____weekly ____monthly ____ seasonally
Other:___daily ____weekly ____monthly ____ seasonally

6. If your household members do not use the Greenway, please circle the reason(s):

Safety Size Insects Location Other (please specify

7. People in your household would use the Greenway more often if (please fill in):

For the following questions please circle a given choice:

8. Stormwater running off of my property eventually drains to the Arbor Hills Greenway. ***Agree*** ***Disagree***

9. Prior to this survey I was (***aware*** ***unaware***) that stormwater channeled through the Arbor Hills Greenway eventually reaches the marshes in the UW–Arboretum.

10. Prior to this survey I was (***aware*** ***unaware***) of the potential redesign of the Arbor Hills Greenway.

11. I believe the Greenway increases my property value (***significantly*** ***very little*** ***not at all***).

12. I believe redesigning the Greenway (***would*** ***would not***) increase my property value.

13. I (***do*** ***do not***) value the open space offered by the Greenway.

14. I would (***support*** ***not support***) a series of retention ponds (standing water) in the Arbor Hills Greenway.

15. I would (***support*** ***not support***) more vegetation in the Arbor Hills Greenway.

Please place a check mark on the scale below each question based on your level of agreement for each of the following statements.

16. It is good that stormwater moves quickly through the Greenway without prolonged standing water:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

17. Water moving quickly through the Greenway poses a safety hazard:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

18. It would acceptable if standing water occurred temporarily in the Greenway after a storm:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

19. It would be acceptable if the soccer field was redesigned to retain water during large rain events:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

20. It would be acceptable if standing water occurred year round in ponds in the Greenway:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

21. I am concerned standing water poses a safety hazard:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

22. I am concerned standing water will attract nuisance insects:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

23. Retention ponds would be desirable if they attracted wildlife like herons and frogs:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

24. It is important to slow the flow of water through the Greenway to promote infiltration and improve the quality of the UW–Arboretum marshes:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

25. It would be possible to design aesthetically pleasing and functional retention basins for the Greenway:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

26. In general, native grasses and wildflowers are attractive:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

27. Native plantings in the Greenway might attract nuisance wildlife:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

28. Native planting in the Greenways might attract desirable wildlife:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

29. I would like to see a greater variety of wildlife in the Greenway:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

30. The Greenway would be more appealing if the concrete channel was removed|

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

31. The Greenway would be more appealing if the concrete channel was replaced with native grasses and vegetation:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

32. I would like to see more recreational opportunities in the Greenway:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

33. I like the Greenway as it is now:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

34. The Greenway should be redesigned:

STRONGLY DISAGREE |______|______|______|______|______|______| STRONGLY AGREE

In the space below please feel free to share any additional comments or concerns you have regarding the potential redesign of the Greenway.

Appendix L: Five CBSM Tools, based on the book Fostering Sustainable Behavior, by Doug McKenzie-Mohr and William Smith (1999).

1) Effective Communication:

- Make sure the message is vivid, personal, and concrete
- Know the attitudes and beliefs of your intended audience
- Have your message delivered by an individual or organization that is credible with the audience you are trying to reach
- Frame your message to emphasize what the individual is losing by not acting rather that what he or she is saving by acting
- If your message includes a warning, be sure to couple it with specific suggestions for action the individual can take
- Make your communication, especially instructions for a desired behavior, clear and specific
- Make it easy for people to remember what to do, and how and when to do it
- Integrate personal or community goals into the delivery of your program
- Model the activities you would like people to engage in
- Make sure that your program enhances social diffusion by increasing the likelihood that people will discuss their new activity with others
- Where possible, use personal contact to deliver your message

2) Effective Commitments:

- Emphasize written over verbal commitment
- Ask for public commitments
- Seek group commitments
- Actively involve the individual
- Consider cost-effective ways to obtain commitments
- Use existing points of contact to obtain commitments
- Help people view themselves as environmentally concerned
- Do not use coercion

3) Effective Incentives:

- Consider the size of the incentive (i.e. large enough to be attractive to the individual)
- Consider non-monetary incentives and disincentives
- Closely pair the incentive and the behavior
- Make the incentive visible
- Reward positive behavior
- Be cautious about removing incentives
- Provide feedback at both the individual and community levels about the impact of environmentally beneficial behaviors

4) Effective Prompts:

- Make prompts noticeable
- Make prompts self-explanatory (i.e. should explain simply what the person is to do)
- Present as close in time and space as possible to the target behavior
- Encourage people to engage in positive behavior rather than to avoid environmentally harmful actions

5) Effective Norms:

- Make norms noticeable
- Make norms explicit at the time the targeted behavior is to occur
- Encourage people to engage in positive behavior rather than to avoid environmentally harmful action