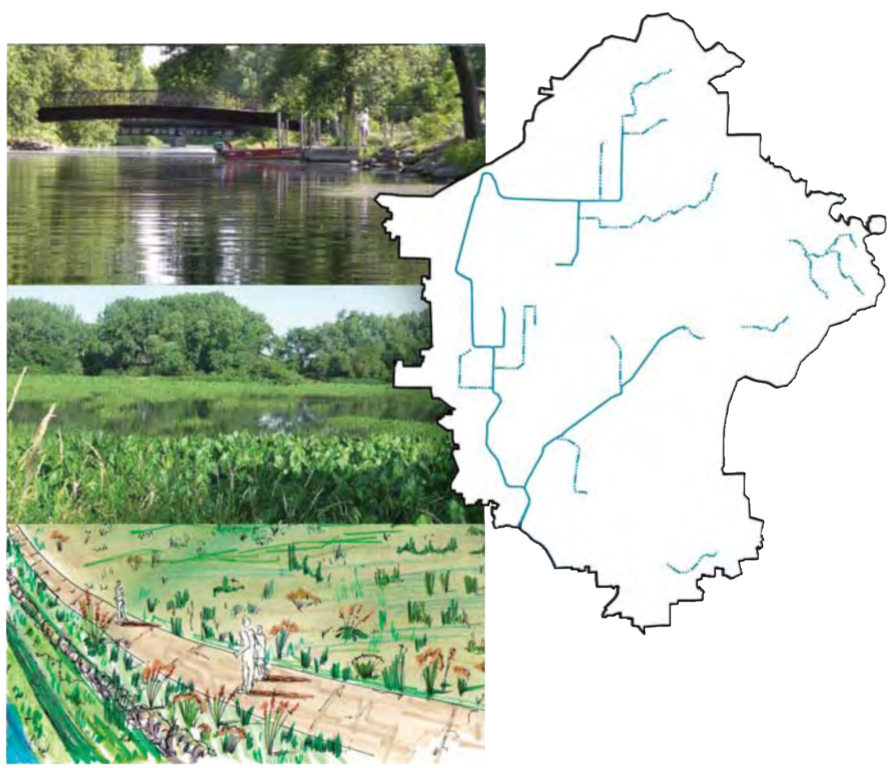
Starkweather Creek Watershed:

Current Conditions and Improvement Strategies in an Urban Context

2006



Water Resources Management Practicum 2005
Nelson Institute for Environmental Studies
University of Wisconsin–Madison

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The Water Resources Management Practicum is a regular part of the curriculum of the Water Resources Management (WRM) Graduate Program at the University of Wisconsin-Madison. The workshop involves an interdisciplinary team of faculty members and graduate students in the analysis of a contemporary water resources problem.

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PREFACE

The Water Resources Management (WRM) Practicum is a primary requirement for a WRM Master of Science degree in the Nelson Institute for Environmental Studies at the University of Wisconsin–Madison. The practicum consists of a two-credit planning seminar during the spring semester and a five-credit field seminar during the summer semester. During the 2005 practicum, 15 students specializing in a variety of areas related to water resources worked closely with university faculty, governmental organizations, nonprofit organizations, and citizen groups to identify watershed-enhancement opportunities in the Starkweather Creek watershed.

The WRM Practicum 2005 was funded by the Friends of Starkweather Creek, a nonprofit organization based in Madison committed to rehabilitating the Starkweather Creek watershed. Funding was also provided by the City of Madison Engineering Division and the Town of Blooming Grove due to interest in improving the quality of the Starkweather Creek watershed, a major urban watershed in Madison. This project was conducted under the direction of university faculty, the City of Madison, and the Friends of Starkweather Creek.

Goals for the WRM Practicum 2005

The goals of the WRM Practicum for 2005 were to identify enhancement opportunities for the Starkweather Creek watershed in the following areas:

- riparian and streambank rehabilitation/stabilization and water quality,
- infiltration and baseflow,
- wetland restoration,
- community outreach/education, and
- Starkweather Creek watershed geographic information system.

Participants in the WRM Practicum 2005

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EXECUTIVE SUMMARY

The Starkweather Creek watershed is a 24-square-mile basin in east-central Dane County it encompasses parts of the City of Madison and the Towns of Burke and Blooming Grove. Starkweather Creek consists of two branches that total nearly 20 miles in length. The headwaters of the West Branch of the creek originate northeast of Interstate 90–94 near Token Creek County Park; the East Branch originates east of Interstate 90–94 approximately four miles southwest of the City of Sun Prairie. The two branches of Starkweather Creek eventually converge near Olbrich Botanical Gardens in Madison and empty into the eastern end of Lake Monona. The basin is part of the Yahara River–Lake Monona Watershed, which is part of the larger Rock River Watershed that drains parts of eleven southeastern Wisconsin counties, including much of Dane County.

Prior to settlement of the area by European immigrants, the Starkweather Creek watershed consisted of a mix of oak savannah, prairie, and nearly 4,000 acres of wetlands. During this time, the wetlands were more connected than they are today; the connections helped maintain the discharge of the creek at what has been estimated at approximtely 5 cubic feet per second. Shortly after their arrival, settlers began channelizing the creek and constructing ditches to improve the drainage of the low-lying areas to increase their farmable acreage. As land development increased, much of the low-lying areas within the watershed were filled to allow for proper building sites. Today, land use within the watershed is a mix of residential, commercial, industrial, and agricultural development that has significantly affected the hydrology and ecology of the watershed. Current population growth in the Madison area is expected to continue at or above the current pace; as a result, there will likely be increasing pressure placed on the watershed's ecosystems. Polluted runoff, flooding, erosion to the creek from stormwater discharge, and municipal groundwater pumping threaten the health of the various ecosystems that depend on the creek. Without a concerted effort to mitigate groundwater withdrawals and to increase infiltration within the watershed, baseflow in Starkweather Creek is expected to continue to fall, eventually dropping below 1 cubic foot per second and making stretches of the creek stagnant except during flood events.

Urban watersheds present unique restoration challenges because of the competing land uses and converging municipal boundaries that can exist within them. The goal of the Water Resources Management (WRM) Practicum 2005 was to identify enhancement opportunities within the Starkweather Creek watershed for wetland restoration, infiltration, and baseflow improvements to the creek, riparian and streambank rehabilitation or stabilization, water-quality enhancements for streams, and community outreach and education programs that increase awareness of the interconnectedness of the ecosystems within the watershed and between watersheds in the Madison area. Additionally, the WRM Practicum 2005 is providing data for a Starkweather Creek watershed geographic information system that can be used as a tool for future restoration work in the watershed.

Runoff and Stream Corridor

Urbanization within the watershed has increased stormwater runoff entering the creek. The creek has long periods of stagnation interspersed with short, high velocity flood events. These floods events create erosion problems throughout the creek and flush contaminants, sediments, and trash into the creek. In an attempt to combat channel erosion in the lower reaches of the creek, the streambanks have been stabilized with materials such as riprap and steel piling, in many cases disassociating the channel from the riparian zones and creating safety hazards for the community. Agricultural fields are near the upper reaches of the creek, and in most cases riparian buffers between the creek and the fields are inadequate.

In an attempt to improve the stream corridor, runoff and water-quality conditions within the creek, we focused on several watershed issues.

- Stormwater runoff control within the watershed must be a high priority. Low impact design in urban development and use of pervious surfaces are ways to reduce excess runoff volumes in the increasingly urban watershed.
- Different techniques for bank stabilization are currently in use or that could be put into practice. Also areas of special concern within the stream channel are identified.
- To gain a quantitative understanding of Starkweather Creek's water quality, we deployed semi-permeable membrane devices. We found areas of special concern within the creek.
- We conducted a vegetation survey and analyzed the results to determine how habitat within the creek corridor could be improved.
- Eastmorland Park was selected as a case study for a detailed analysis and concept design for riparian enhancement. The design contains a preliminary site analysis as well as opportunities and constraints based upon the site analysis.
- From the stream corridor and vegetation surveys, we identified 19 sites as priority sites—their conditions are highly problematic and in need of prompt attention.

Baseflow

Springs have historically been a major contributor to the baseflow of Starkweather Creek; however, many of the springs within the watershed have disappeared or are now discharging at reduced rates. Declining baseflow in the creek is directly related to diminished recharge due to increased impervious surfaces in the watershed and groundwater pumping for municipal uses. In addition, water removed from the aquifer via groundwater pumping is not returned to the watershed after use and treatment, but is instead discharged to Badfish Creek south of Madison. Aquatic life and recreational qualities within the in the creek suffer as a result of low baseflow and its associated conditions.

To determine ways to improve aquatic life, recreational opportunities, and ecosystem health within the watershed, we analyzed the watershed in regard to the following hydrologic components:

- We used a geographic information system to determine locations for large-scale recharge operations to return stormwater to the aquifer. We used hydrologic simulation models to assess widescale implementation of infiltration practices. The results showed that despite the potential improvements in runoff reduction and water quality, the application of conventional infiltration practices in the watershed will not have a significant effect on recharge rates unless more extensive street infiltration takes place. However, modeling did demonstrate that the impact on a smaller geographic scale can be quite significant.
- Groundwater modeling was conducted to gain a greater understanding of the effects that groundwater pumping has on the watershed. Results indicated that groundwater pumping is the most significant factor affecting baseflow. Coupling modifications in groundwater pumping with increasing recharge opportunities within the watershed could provide the most realistic, natural mechanism to return baseflow to acceptable levels.
- Releasing treated effluent to the creek may be the most feasible method to aid in enhancement of the watershed's hydrologic regime.

Wetlands

At present, the Starkweather Creek watershed contains 900 acres of wetlands, which is less than one-quarter of the presettlement wetland acreage. Wetlands serve multiple purposes in an urban landscape. They are important habitat for a diversity of plant and animal species; they act as breeding grounds, nurseries, feeding areas, and travel corridors. Wetlands also have the potential to help mitigate urban runoff. They are able to slowly release stored water to rivers, lakes, and streams after storm events and are also able to absorb nutrients, pollutants, and sediments, filtering these materials from stormwater before it enters rivers and lakes. Urban wetlands also provide important opportunities for recreation and education.

We selected ten major wetland complexes within the watershed for analysis: three along the West Branch, four along the East Branch, one at the confluence of the two branches, and two isolated wetlands in the southern part of the watershed. The wetland located south of Lien Road, referred to as Lien Marsh, is one of the largest and most ecologically diverse wetlands in the watershed and holds the greatest promise for restoration because of its size, diversity of plant life, and because much of the property is owned by the city of Madison. This complex is also home to a calcareous fen; such fens have been classified by state statute as areas of special natural resource interest. Our restoration plan for Lien Marsh includes subdividing the area into five ecological units with individual management strategies: a fen area, a stormwater wetland, a wet prairie, the creek corridor, and the marsh area east of the creek.

Educational Outreach

Although a number of environmental education programs and plans exist for the greater Madison area, none of the plans were designed specifically with Starkweather Creek in mind and, as a result, do not include specific educational goals, objectives, or campaigns unique to this urban watershed. Therefore, it is important to develop an education plan specifically for the watershed based upon the objectives and goals generated from stakeholders residing within the Starkweather Creek watershed.

We offer the following campaign recommendations:

- *Infiltration campaign.* Municipal groundwater pumping and reduced infiltration are the two largest contributors to the low baseflow and resulting poor water-quality conditions of Starkweather Creek. To address these impacts, an ideal education campaign would motivate the Starkweather Creek watershed community to conserve water and reduce stormwater runoff using rain barrels and rain gardens. We recommend a rain-barrel campaign that focuses on encouraging homeowners to understand stormwater issues, conserve water, and gain a greater appreciation for the watershed. We also recommend rain-garden campaigns, which would extend beyond home owners to larger audiences: schools, businesses, and places of worship.
- *North Platte conceptual plan.* As planning of the North Platte (next to Olbrich Botanical Gardens and the Starkweather Creek confluence) unfolds, a unique opportunity for providing substantial watershed education about human impacts upon the landscape is presented. Therefore, we recommend developing the North Platte of Olbrich Botanical Gardens as an educational tool to promote watershed awareness, illustrate the historical pattern of watershed degradation in Madison, enhance the community value of the area, and to allow citizens to experience restoration efforts in their community. Our comprehensive conceptual plan can provide a framework for future dialogue on the development of the North Platte.
- *Citizen stewardship map.* We created a map of the Starkweather Creek watershed that illustrates some of the key attributes of the watershed as a tool to spearhead a citizen stewardship campaign. Accompanying text discusses highlights and problems facing the watershed, and gives ideas to citizens wishing to take action.

Geographic Information System

We used a geographic information system (GIS) to enhance our ability to assess the current conditions of the Starkweather Creek watershed and provide a data resource for future analysis. We also collected and catalogued relevant GIS data for the Starkweather

Creek watershed and organized the data with a simple to use and freely available GIS application, ArcReader. The individual data layers as well as the Starkweather GIS are available on CD-ROM. The CD-ROM can be found on the back jacket of the hard copy of this report or is available for download from the WRM Practicum 2005 section of the Nelson Institute for Environmental Studies Web site: www.nelson.wisc.edu/wrm/workshops/2005.

1 INTRODUCTION

The Yahara Chain of Lakes

Madison, Wisconsin, is home to aesthetically and recreationally pleasing diverse landscapes. One of the region's most prominent natural features is the Yahara chain of lakes, including the lakes of Mendota, Monona, Waubesa, Kegonsa, and Wingra. These interconnected lakes provide locals and visitors with an important and distinct sense of place within Madison. Many of the region's trademarks, such as the Isthmus, Memorial Union Terrace, Monona Terrace, Picnic Point, and numerous city parks owe their existence and uniqueness to the lakes.

For well over a century, the residents of Wisconsin's capital have embraced the Yahara Lakes as a means of industry, commerce, and recreation. As a result, the residents and institutions of the Madison area have taken active roles in the preservation of the lakes for future generations. These actions include legislation, citywide mandates and action programs, and a variety of citizen-based volunteer efforts. However, a stroll along any lakefront path or a leisurely paddle on Lake Monona or Mendota will quickly prove that despite a Herculean effort put forth by many parties, the lakes continue to be plagued by a variety of ecological problems. Years of limnological research by numerous dedicated professionals have helped make the Yahara chain of lakes one of the most studied systems in the world. In spite of this vast knowledge base, eutrophication problems, such as algae blooms and high bacterial concentrations, continue to afflict the lakes, negatively affecting aquatic life, causing odor issues, and leading to numerous beach closures.

The reasons for the ecological problems within the Yahara Lakes are many. To continue working toward healthier lakes, the sources of the problems must be identified and attacked. Tackling the pollution and degradation problems of large water bodies can never be accomplished in isolation. Recently, much attention has been focused on the smaller, less prominent watersheds that feed the large, urban water bodies. In terms of Madison, such an approach would involve taking a step back from Lake Monona, the picturesque lake that dominates the city's southern landscape, and refocusing attention on the Starkweather Creek watershed, Madison's largest watershed and a leading contributor to Lake Monona.

Starkweather Creek Watershed

The Starkweather Creek watershed encompasses most of Madison's east side and also includes sections of the Towns of Burke and Blooming Grove (fig. 1.1). The watershed covers an area of more than 24 square miles and drains into Starkweather Creek, which traverses the watershed and is 20 miles long. Starkweather Creek has two branches: The West Branch is 15 miles long, and the East Branch, nearly five. The two branches con-

Figure 1-1. *Map of Wisconsin watersheds; inset shows Starkweather Creek watershed and surrounding areas.*

verge, and the creek flows south approximately 0.5 mile before discharging into Lake Monona.

Land use within the Starkweather Creek watershed is highly urbanized (fig. 1-2). Agricultural land use dominates the northern reaches of the watershed, but industrial, commercial, and residential development become increasingly common in the southerly direction. The West Branch transects the Dane County Regional Airport and Interstate 90–94 crosses the northern part of the watershed.

Dane County and the City of Madison continue to experience rapid population growth. In 2003 Dane County's population reached 445,253 and is expected to surpass 525,000 by 2020, an increase of almost 18 percent (Dane County Regional Planning Commission, 2004). Due to urban sprawl, much of the population growth is expected to occur in rural areas that are currently dominated by agriculture. As populations continue to grow, the Starkweather Creek watershed will continue losing its remaining rural landscapes in exchange for urban development. Without intervention, the future health of Starkweather Creek watershed is in severe jeopardy. It is imperative to act quickly and decisively to protect, enhance, and restore the watershed for present and future generations.

Post-Settlement History

Some of the earliest inhabitants of the Starkweather Creek watershed were Native Americans of the Woodland Tradition. They lived in villages, practiced agriculture, and built effigy mounds. In fact, the Madison area is home to more effigy mounds than anywhere else in the country (Mollenhoff, 2003). Recent researchers have concluded that these early Native Americans of the mound-building tradition are ancestors of the more modern Wisconsin tribes such as the Winnebago (Ho-Chunk). The Winnebago would eventually dominate the Madison area, with major settlements scattered along the banks of Lakes Mendota and Monona. There, the Winnebago were engaged in rice harvesting, fishing, and the farming of watermelons, tobacco, potatoes, squash, and corn. This was the scene that European settlers and retreating Native American tribes from the eastern United States encountered as they moved west into present-day Madison (Mollenhoff, 2003).

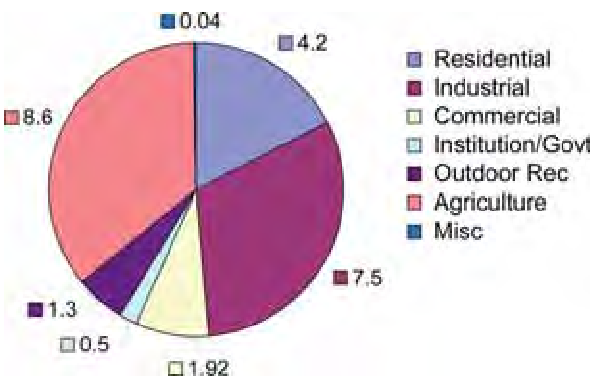

Figure 1-2. *Chart showing land use within the Starkweather Creek watershed (from Dane County Land Information Office,* 2000*).*

Early European settlers referred to the area encompassing Starkweather Creek watershed as the Four Lakes. This colloquialism, still used today, demonstrates the importance that water has played in shaping the human development of Dane County. Although at present the watershed encompasses 25 City of Madison neighborhoods as well as land within the Towns of Burke and Blooming Grove, the watershed had rather modest beginnings. Public land survey records from 1834 represent minimal to no human alteration of Starkweather Creek (Lyon, 2005). However, in less than ten years, records of sawmill and dam construction on the creek were recorded (Dane County Regional Planning Commission, 1983). Although wetlands and marshes dominated the landscape, this rapidly changed with the influence of large-scale agricultural practices. The first instance of wetland drainage in the watershed was recorded by 1858 (Dane County Regional Planning Commission, 1983). As farmers continued to settle, drainage increased. This shift to an agricultural land use with increased water demands prompted significant change in the natural stream channel. Soon the stream channel was straightened, altering the hydrologic regime of the watershed (Mollenhoff, 2003). Development of the watershed continued with expansions in commercial, residential, and industrial development, helping lead to the current degraded state of the creek today.

Causes of Degradation

Starkweather Creek has been severely impacted by urbanization. The watershed, once dominated by wetlands, has been modified by urbanization so that now 33.5 percent of the watershed is considered impervious cover. According to the impervious cover model developed by the Center for Watershed Protection (2004), Starkweather Creek is designated as a non-supporting stream that can no longer sustain its designated uses. According to the model, non-supporting streams with impervious cover of 25 to 40 percent are characterized by highly eroded stream channels and poor water quality. Such streams show promise for partial restoration, but are so altered that they cannot be restored to predevelopment conditions (Center for Watershed Protection, 2004).

Three main characteristics of urbanization have influenced Starkweather Creek's degradation. First, pollution associated with urban development has caused water-quality problems within the creek. Second, increased urban development in the watershed coupled with poor stormwater management causes severe flooding events and erosion within the creek. Third, continuous increases in groundwater pumping for municipal use have lowered the water table within the watershed, causing lower dry-weather flows in the creek. Taken together, these factors have impacted much of the original wetland ecology, stream stability, water quality, and water quantity, resulting in the present conditions of the creek and its watershed.

The Impact of Urbanization

When the watershed was first urbanized, the creek was used to convey polluted water from industrial as well as residential areas. Although discharge of sewage and industrial waste into Starkweather Creek is no longer taking place, organic contaminants can still be found in the creek. The Dane County Regional Airport, which composes 19 percent of the total watershed area, has impacted the quality of the creek as well. Pollution from extensive petroleum usage, deicing agents, and airplane maintenance throughout the twentieth century has severely increased degradation of the creek (Dane County Regional Planning Commission, 1983). However, industry is not the only source of pollution within the creek. Trash and garbage litter the creek, providing the most visible indicator of the creek's urbanization.

An increase in the amount of impervious surfaces is one of the main results of urbanization. Impervious surfaces are ground surfaces that do not allow precipitation to penetrate. Unlike native landscapes—such as grasslands, woodlots, and wetlands—impervious surfaces—such as concrete driveways, paved streets, and parking lots—do not allow rainwater to percolate through and reach the groundwater below. Decreased infiltration of rainwater into the ground decreases recharge of groundwater aquifers. In addition, runoff following storm events increases considerably when water is unable to infiltrate into the ground, resulting in flash floods.

Past stormwater-management practices in the watershed focused on conveying the water as fast as possible downstream. To move as much water as possible, natural meanders within the creek were removed and the creek was straightened and dredged, a practice known as channelization.

Constant flow in the stream during dry periods, termed baseflow, is derived from springs within the watershed. As the population within the watershed grew, so too did demands for water. Constant increases in groundwater pumping via high capacity wells in and around the watershed have caused the water table in the watershed to decrease

Figure 1-3. *Algae growth in Starkweather Creek.*

significantly. Because of that, springs in the watershed have disappeared or decreased in size, leading to less baseflow in both branches of Starkweather Creek.

Current Conditions

Decreases in baseflow have resulted in low flow rates and have had severe ecological impacts within the watershed. Because of low gradients in the creek, the water in the creek can be stagnant, creating favorable conditions for algae growth. With the decay of algae and benthic macrophytes, oxygen can become depleted, making it difficult for diverse ecosystems to exist (fig. 1-3). Low flows and gradients in the creek also cause the buildup of contaminants as they settle out into the sediments of the creek. This buildup further degrades aquatic habitats.

Development within the watershed has led to the destruction of most of the original wetlands. These wetlands, in many cases deemed "unnecessary" and "useless" have been replaced with residential, industrial, and commercial development and agricultural fields. The loss of wetlands causes a number of other problems. Because wetlands provide important habitat for a wide variety of flora and fauna, many native species have declined significantly. In addition, wetlands function to clean many environmental systems. The loss of wetlands has compounded the water-quality problems within the watershed. Small, geographically isolated wetlands still exist within the watershed, although many have been severely degraded. Invasive species, such as reed canary grass *(Phalaris arundinacea)*, have taken over large tracts of these wetlands. Channelization and riparian encroachment have further isolated these wetlands.

Riparian areas, the buffers between land and aquatic habitat, create important habitats for terrestrial and aquatic wildlife, stabilize streambanks, and improve stream water quality. The increase in flooding, due to impervious surfaces and associated stormwater runoff, creates the necessity of armoring streambanks to prevent erosion. Riprap and metal pilings have been used for bank stabilization in the lower reaches of the stream. Stream-bank armoring has caused discontinuity between the streambed, floodplains, and adjacent riparian areas. Armoring has also allowed development closer to the stream, thereby encroaching on the area available for riparian buffers. Erosion within the stream has been severe in the areas where no armoring has been implemented, most notably the upper reaches of both branches. Taken as a whole, the changes in the riparian areas within the watershed have caused habitat degradation, safety concerns, and loss of the natural beauty of the creek.

If action is not taken, continued degradation of the Starkweather Creek watershed will undoubtedly occur. The action must employ sound understanding of the principles governing the cause and effect relationship between urbanization and the environment. In addition, strong political will and the commitment of residents and property owners within the watershed will be paramount for any successful restoration and enhancement program. By implementing a watershed-management approach via a coordinated effort of stakeholders—the interested parties—the potential exists for the emergence of a healthy urban stream.

Management of the Starkweather Creek Watershed

Some factors that initially sparked interest in the management of the Starkweather Creek watershed include the degraded conditions described above, the creek's visibility as an urban stream, and efforts to revitalize neighborhoods within the watershed (Dane County Regional Planning Commission, 1983). Over the years, several management plans have been written as a way to formalize the watershed's management, and numerous stakeholders have been instrumental in how the watershed is managed.

Management Plans

Management plans can be a valuable tool for establishing goals, identifying problems that impede those goals, and finding alternative solutions (Hoch and others, 2000). In addition, plans can help "balance the protection of natural resources against the economic and social benefits of resource use" (Hoch and others, 2000).

The following three plans directly addressed the goals, problems, and solutions for the Starkweather Creek watershed:

- ***Starkweather Creek Water Quality Plan***

  The Starkweather Creek Water-Quality Plan provided a detailed inventory of the watershed. This inventory included water-quality conditions and causes for the poor water quality, such as channelization, urbanization, and groundwater withdrawal, among others. The plan outlined impacts of the poor water quality, such as limited stream uses for the public, degraded conditions for aquatic habitat, and nutrient loading of Lake Monona. The plan also provided management-program recommendations. After evaluating all the alternatives and obtaining public input, the final management-program recommendations stressed improving water quality, public access, and stream aesthetics (Dane County Regional Planning Commission, 1983).

- ***Starkweather Action Program 1987–1991***

  The Starkweather Action Program 1987–1991 was a five-year program designed to fulfill objectives from the 1983 plan. The action program focused on four areas: 1) stream improvements, 2) land acquisition, 3) bikeway construction, and 4) landscape amendments (Dane County Regional Planning Commission, 1987).

- ***Starkweather Creek Master Plan 2004 and 2005 Updates***

  In the 1990s, enthusiasm for the earlier plans waned. But in 2003, grassroots efforts and political influence resulted in a City of Madison resolution to "support initiatives to restore Starkweather Creek and promote recreational opportunities on surrounding lands" (City of Madison Engineering and Parks Division, 2004). The Starkweather Creek Master Plan is a result of this city resolution.

  The 2005 Master Plan revised the goals set forth in the 1983 plan to reflect current regulatory conditions, to include public input, and to include more current, viable restoration techniques (City of Madison Engineering and Parks Division, 2005). The Master Plan is updated annually and provides prioritized recommendations for bike paths, walking trails, and park amenities in the watershed. It also gives recommendations of water-resource projects, namely riparian corridor improvements, wetland improvements, infiltration practices, stream baseflow improvements, and wetlands improvements. The plan also presents goals for watershed education and outreach.

Numerous other management plans, with topics ranging from transportation to hydrologic studies, indirectly address the watershed; a listing and summary of these plans are presented in appendix A.

Stakeholders

With respect to watershed management, stakeholders are individuals or groups that have a vested interest or impact on the resource. Having all the stakeholders identified, or "at the table," potentially allows for more thorough management of a natural resource environment. Described below are the primary stakeholders of the Starkweather Creek watershed. This list is not all inclusive, but gives an overview of the parties involved in the watershed. Some of the parties are involved in its management, and others have a significant impact on the resource, whether through their actions or the policies and regulations they establish.

- ***City of Madison Engineering and Parks Divisions***

  The City of Madison is responsible for the annual updates of the Starkweather Creek Master Plan, with input from some of the other stakeholders. The city oversees many of the improvement projects that take place within the watershed. In addition, the city is a principal source of economic resources for water-resource-management programs: $40,000 was allocated in 2004, $180,000 was approved for the 2005 budget, and the Engineering Department recommended $180,000 annually from 2005 to 2007 (City of Madison Engineering and Parks Divisions, 2005). Often, master plans are written without being acted upon due to a lack of political will and different priorities. However, it is likely that funding and implementation of the Starkweather Master Plan will continue because of public pressure from the Friends of Starkweather Creek (Dave Benzchawel, verbal communication, 2005).

- ***Friends of Starkweather Creek***

  The Friends of Starkweather Creek was formally established in 2003 and has nearly 100 members. The group's main goals are to work for a healthy urban stream and to benefit the community through stewardship, advocacy, and education (Friends of Starkweather Creek, 2003). The group uses advocacy to tie water quality and shoreline enhancements to an improved quality of life in surrounding neighborhoods. The group's watershed education focuses on clean water threats, infiltration needs, and the nature and function of the water cycle. It also promotes stewardship by encouraging residents to put time and energy into watershed improvements on private property and public spaces (J. Steines, verbal communication, 2005).

  Friends of Starkweather Creek has made several accomplishments since 2003. For example, it has been working with developers to implement stormwater-management solutions that benefit the creek and newly constructed communities in the creek's headwaters. As mentioned earlier, the group successfully lobbied City of Madison officials to allocate money for the Starkweather Creek Master Plan and its implementation. The group also participates in smaller improvement projects, such as streambank stabilization and regrading, and educational outreach activities for many stakeholders in the watershed.

- ***Dane County Airport Commission***

  The Dane County Airport Commission is a primary stakeholder in the watershed, not only because of the airport's physical size, but because of the commission's authority over land-use activities. It controls zoning decisions within a 27-square-mile radius of the airport (Schenk-Atwood Starkweather Yahara Neighborhood Association, no date), and plans within the airport boundaries are subject to Federal Aviation Administration regulations. For example, these regulations restrict any activities (for example, natural restoration) that would attract wildlife. As a result, there has been minimal public input with respect to watershed activities within the airport boundaries.

- ***Neighborhood Associations and Community Organizations***

  Neighborhood associations and community organizations can be important in the planning process for the City of Madison and other municipalities in the watershed. These neighborhood associations lobby for programs that are priorities for residents, but might fall upon deaf ears of city officials otherwise. There are about 25 neighborhood associations located entirely or partially within the watershed boundaries. Eight of these associations have been actively communicating with the Friends of Starkweather Creek and have cooperated in various projects. The majority of the active partnerships are located in the near eastside neighborhoods; the neighborhoods farther east have showed less interest in dialoguing with the Friends of Starkweather Creek.

- ***Olbrich Botanical Gardens***

  Olbrich Botanical Gardens is located in the watershed, near the mouth of Starkweather Creek. The mission of Olbrich Gardens is to "enrich life by nourishing and sharing the beauty of gardens, the joy of gardening, the knowledge of plants, and the diversity of our world" (Olbrich Botanical Gardens, no date). Olbrich is owned and operated by City of Madison Parks Division in partnership with a nonprofit organization, Olbrich Botanical Society (Olbrich Botanical Gardens, no date). In 1997, the City of Madison and the Olbrich Botanical Society acquired 22 acres of land adjacent to Olbrich Gardens and Starkweather Creek. These 22 acres, known as the North Platte, include a five-acre parcel containing the Garver Feed Mill and are dedicated to future expansion and botanical garden development.

  Olbrich Botanical Gardens is a primary stakeholder because it provides a public service and can potentially provide a high degree of visibility to Starkweather Creek. In addition, it is adjacent to a commonly used public access point to the creek and Lake Monona. Finally, the 2005 Master Plan presents Olbrich as a leader in environmental education about Starkweather Creek, raising the possibility of using the North Platte as a venue.

- ***Developers***

  Suburbanization is taking place east and north of Madison, in the headwaters of the Starkweather Creek watershed. This development typically takes place as a result of large real-estate developers who purchase and develop the land for residential purposes. As a group, these developers are a primary stakeholder because stormwater-management practices in the headwaters are crucial to hydrology and flood risk downstream. As mentioned earlier, stormwater management is problematic in the watershed. The Friends of Starkweather Creek have worked with developers to address their stormwater-management practices and, to date, have maintained a fairly strong relationship with this group of stakeholders.

- ***Other Primary Stakeholders***

  In addition to the stakeholders mentioned above, others should also be recognized. The Dane County Lakes and Watershed Commission is very involved in policy matters and educational activities that protect and improve water quality in Dane County (Dane County Lakes and Watershed Commission, no date). Although local residents may not be actively involved in the watershed's management, many do have an interest in what happens within their local surroundings. Frequently, residents have been approached to complete surveys and to attend public meetings in an effort to insure that their input shapes planning and management of the watershed.

Areas of Study

The purpose of this study was not to gather baseline information on the conditions in the creek in detail, but rather to build upon past studies and plans because much of the background information on this watershed has already been compiled either on a watershed, city, county, or regional basis. The objectives of this study were to address the known conditions within the watershed, research the causes of the conditions, and to prioritize areas most in need for enhancement, restoration, and/or public attention. Throughout our study, we attempted to fill in gaps of prior studies and develop new and innovative approaches on the basis of our research and findings as well as the latest available watershed-management practices.

To focus efforts on the most necessary actions to improve conditions within the creek and watershed, our group selected and concentrated on several main areas of importance. The following are the main areas:

- **Stream corridor:** Assessment of condition of the stream corridor, riparian areas, and water quality on the creek and identification of priority areas for improvement.
- **Baseflow:** Reviews of historic baseflow data and simulation using models to aid in the recharge of groundwater supplies and subsequent baseflow enhancements; application of water-quality-testing technology to monitor organic contaminants present within Starkweather Creek.
- **Wetlands:** Inventory and analysis of wetlands within the Starkweather Creek watershed and prioritization of areas for enhancement and proposing means by which the enhancements should occur.
- **Educational outreach:** Evaluation of educational opportunities within the watershed and management practices to increase awareness in regard to issues facing Starkweather Creek and the entire watershed.
- **Geographical information system:** Inventories of existing information relevant to Starkweather Creek watershed and compilations of the information into a geographic information system database for future reference.

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2

STREAM CORRIDOR

Stream Corridor Survey

One of the first places to explore environmental enhancement and restoration opportunities is the stream corridor. We define the stream corridor as the stream channel and banks, floodplains, and the transitional upland fringe (fig. 2-1). In urban landscapes, however, the stream corridor can be limited by the presence of structures, utilities, or impervious surfaces that restrict or prevent the natural use of the corridor. Under urban conditions, stormwater runoff also can have significant impact on the stream corridor, producing flash floods and bank erosion. Because of this, physical alterations of the stream channel, such as channelization and bank stabilization, have been implemented.

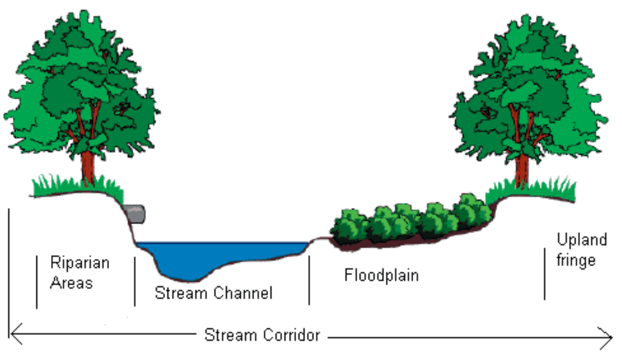


Figure 2-1. *Schematic showing the stream corridor definitions.*

Within the stream corridor are riparian zones, also called riparian buffers or riparian areas. They are the transitional zones between terrestrial and aquatic ecosystems and can generally be described as long strips of vegetation adjacent to streams, rivers, lakes, reservoirs, and other inland aquatic systems that affect or are affected by the presence of water (Fischer and others, 2000). The riparian areas are important for maintaining a healthy creek because they perform a range of functions with economic and social value, such as:

- Stabilizing streambanks by holding the soil together with extensive root systems, preventing banks from collapsing and eroding during periods of high water.
- Storing flood waters by obstructing runoff with vegetation and decreasing damage to property.
- Improving water quality by using plants to filter out sediments and excess nutrients and other pollutants before they enter the stream.
- Maintaining habitat for fish and other aquatic organisms by moderating water temperatures and providing woody debris as well as providing habitat for terrestrial organisms.
- Improving the aesthetics of stream corridors and offering recreational and educational opportunities.

—from Wenger (1999) and Washington State Department of Ecology (no date)

Riparian areas in urban watersheds are in many cases degraded and are not capable of the full functionality of riparian zones in undeveloped areas with similar geological features. Impervious surfaces change the hydrologic regime in the watershed and the stormwater piping and channel, in many cases bypassing, the riparian zones, impairing their functions of filtering out sediments and nutrients and attenuating peak flows. Schuler (1995, p. 155) found that "as much as 90 percent of the surface runoff generated in an urban watershed concentrates before it reaches the buffer, and ultimately crosses it in an open flow channel or enclosed storm drain pipe."

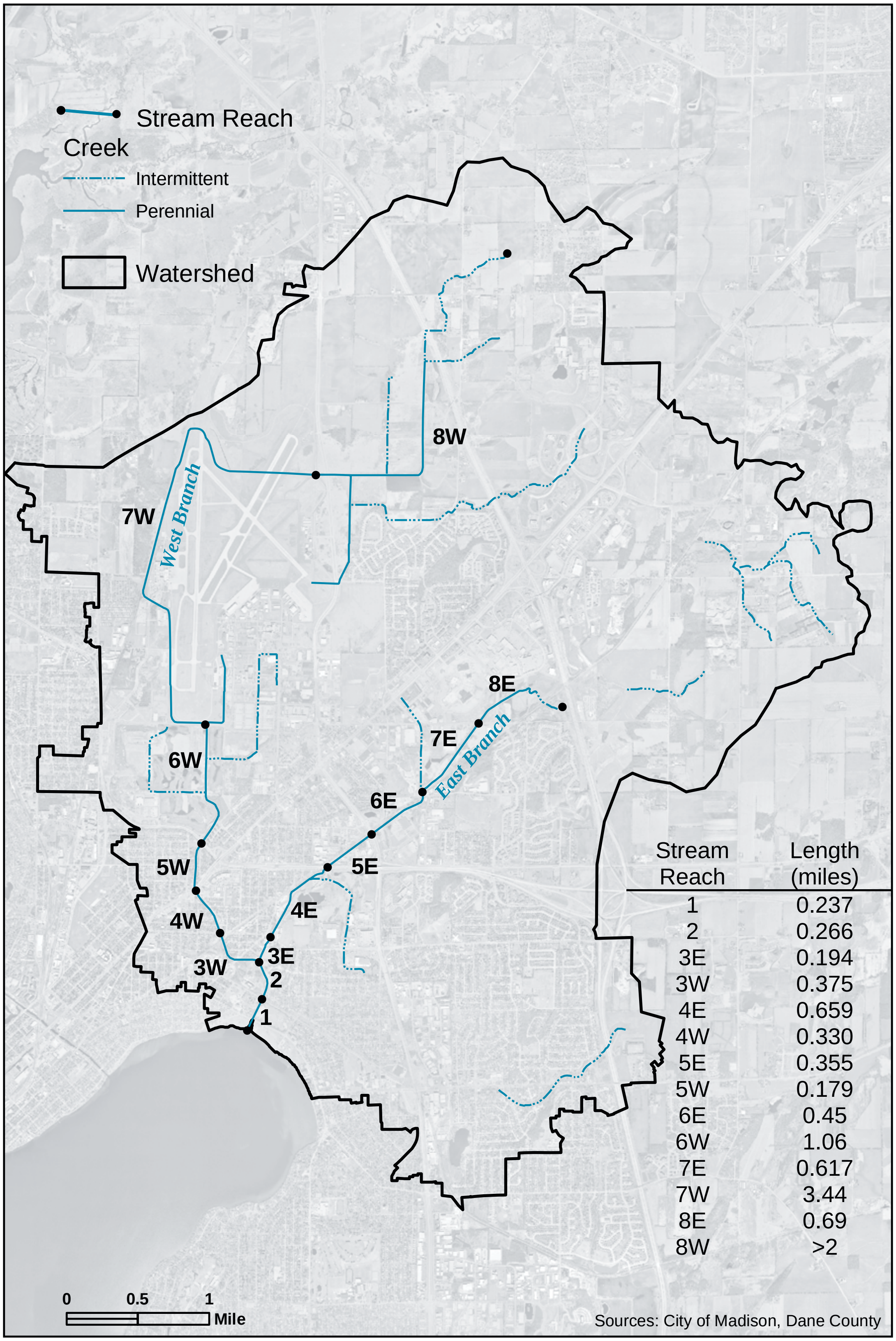
Starkweather Creek has been affected by channelization and urban encroachment, especially in the lower reaches; much of the upper reaches of the creek has not been affected by urbanization and have significant riparian zones. Approximately 45 percent of the creek (9 miles) is within an urbanized part of the watershed and 55 percent is in rural agricultural and natural areas. Most of the creek banks have some kind of vegetation, which can range from 10 to 50 feet wide; much of the lower reaches have streambanks stabilized by materials such as riprap and steel piling, which in many places separate the channel from the riparian zones. Although upper reaches have thick forested areas along the stream, streambank erosion is widespread and some parts have no transitional zones between agricultural areas and the stream channel. As a result, the stream's riparian areas do not perform the full range of functions associated with healthy riparian buffers.

As part of the effort to improve the environmental condition of Starkweather Creek, the stream corridor and the riparian zones are the best places to start. In the summer of 2005, we conducted a stream corridor survey for Starkweather Creek. The survey followed guidance from Kitchell and Schueler (2004), who provided a systematic approach to quickly and effectively document stream corridor conditions. We used this method to identify areas with potential for riparian area improvement.

The Dane County Regional Planning Commission (1983) included a summary of a 1980 survey in the Starkweather Creek Water Quality Plan. The survey divided both branches into reaches and assigned each reach a number or a number and letter combination (fig. 2-2). We used the same reaches and identifiers. In addition, we included an additional reach (7E) to provide additional detail about a significant tributary to Starkweather Creek.

We conducted the survey on foot and by canoe on several occasions in June, July, and August 2005. Rainfall in Madison, Wisconsin, was below average for the summer. Again using guidance from Kitchell and Schueler (2004), we conducted an overall reach assessment to indicate bank, buffer, and vegetation conditions, among other characteristics. In addition, we collected data for unique problem sites on impact assessment forms. This survey focused on the following types of sites: problematic outfalls, severe bank erosion, impacted buffers, channel modification, and trash and debris. Photographs and global positioning system (GPS) points were taken for the beginning and ending points of reaches as well as for problematic sites.

Although some parts of the riparian corridor are relatively healthy, our findings confirmed that Starkweather Creek suffers from bank erosion, reduced water clarity, dis-



Stream Reach	Length (miles)
1	0.237
2	0.266
3E	0.194
3W	0.375
4E	0.659
4W	0.330
5E	0.355
5W	0.179
6E	0.45
6W	1.06
7E	0.617
7W	3.44
8E	0.69
8W	>2

Figure 2-2. *Stream corridor reaches and their lengths. Reaches are identified by number or letter/number combination.*

turbed vegetation in the riparian buffer, algal blooms, and sediment deposition. Table 2-1 provides descriptions of the reaches' conditions. We identified 19 sites as "priority sites," meaning their conditions are highly problematic and in need of prompt attention (fig. 2-3). These are appropriate places to begin addressing the many complex problems facing the stream corridor and riparian areas of the Starkweather Creek watershed. Tables 2-2 to 2-4 describe each site location, the problems identified there, and the possible solutions or actions that can be taken to start the process of improving the environmental condition of Starkweather Creek.

Our survey of the stream corridor allowed us to identify three main areas of concern: stormwater runoff control within the watershed; streambanks and the modification and stabilization of the channel; and vegetation and habitat improvement in the riparian zones.

Table 2-1. *Qualitative and quantitative analysis of the stream corridor of Starkweather Creek, based on the stream corridor assessment survey, by reaches.*

Reach	Grade (%; 160 possible points)	Description
1	55	Habitat availability less than desirable; disturbed substrate; bare soil common; isolated areas of bank erosion; moderate floodplain encroachment
2	68	Mix of stable habitat with potential for colonization; most streambanks covered with vegetation; stable banks; minor floodplain encroachment
3E	59	Habitat less than desirable; disturbed substrate; patches of bare soil; stable banks; minor floodplain encroachment
4E	72	Mix of stable habitat with potential for colonization; isolated areas of bank failure; high flows can enter floodplain; minor floodplain encroachment
5E	43	Habitat availability less than desirable; patches of bare soil; past downcutting evident; active stream widening; significant floodplain encroachment
6E	51	Mix of stable habitat with potential for colonization; patches of bare soil; past downcutting evident; active stream widening; significant floodplain encroachment
7E	49	Lack of habitat obvious; unstable substrate; active downcutting; erosion contributing a significant amount of sediment to stream; minor floodplain encroachment
8E	57	Lack of habitat obvious; streambank and riparian corridor covered in vegetation; downcutting evident; no evidence of floodplain encroachment
3W	44	Lack of habitat obvious; patches of bare soil; isolated areas of bank failure; high flows unable to enter floodplain; significant floodplain encroachment
4W	34	Lack of habitat obvious; very high disruption of streambank vegetation; stable banks; high flows unable to enter floodplain; significant floodplain encroachment
5W	32	Mix of stable habitat suitable for colonization; high disruption of streambank vegetation; active downcutting; significant floodplain encroachment; high flows unable to enter floodplain
6W	57	Mix of stable habitat suitable for colonization; downcutting evident; active stream widening; moderate floodplain encroachment
8W	78	Mix of stable habitat suitable for colonization; isolated areas of bank failure; no evidence of floodplain encroachment

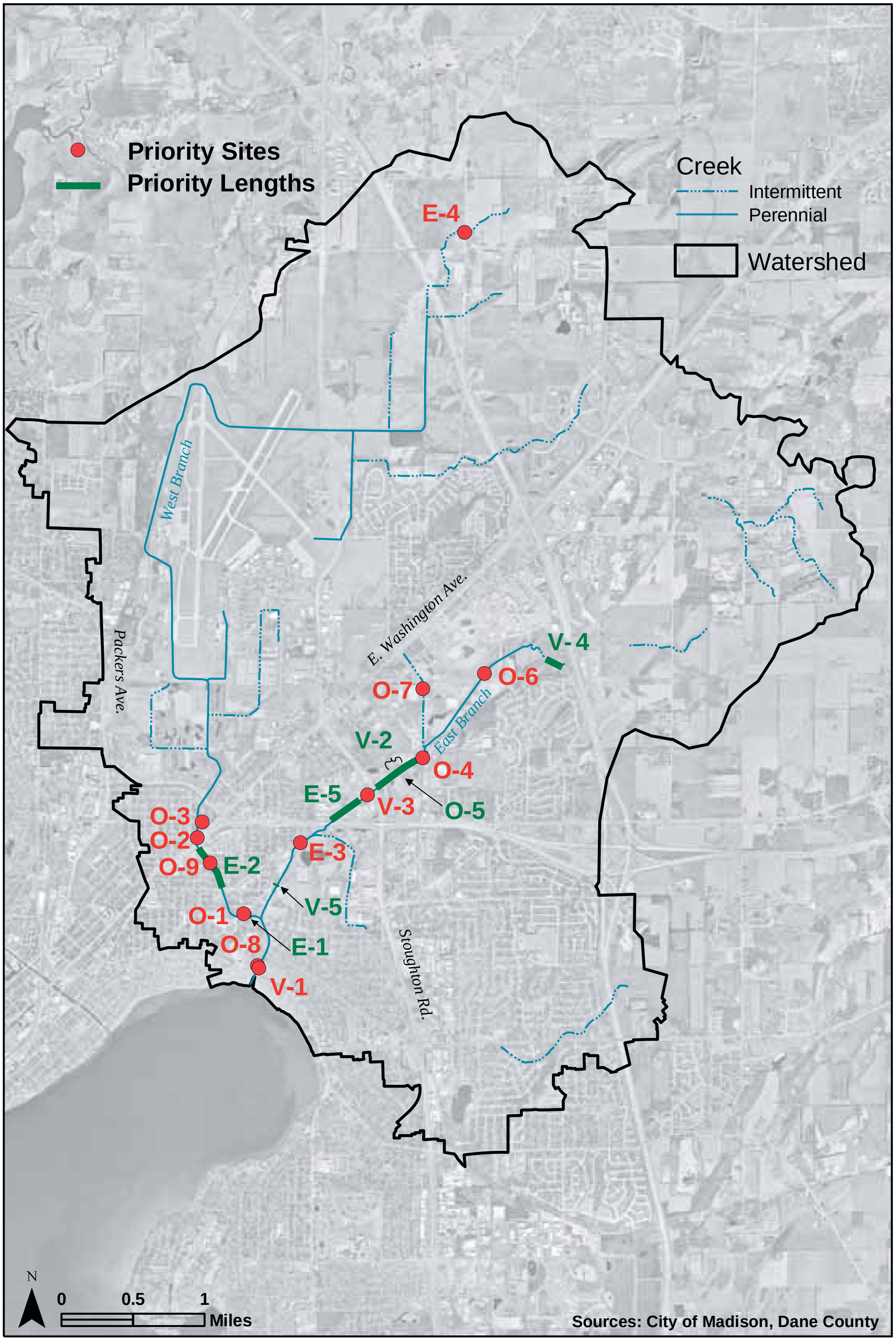


Figure 2-3. *Location of priority sites identified in Starkweather Creek watershed.*

Table 2-2. *Priority sites: Streambanks and channel erosion.*

ID	Reach number	Location and description	Problem identified	Proposed solution
E-1	3W	From Fair Oaks Avenue to the confluence of East and West Branches.	Metal steel piling is slumping, rusted, aesthetically displeasing, and poses a hazard; disconnects channel and riparian areas.	Remove metal armoring; replace it with terracing stabilization that will make it aesthetically pleasing and connect riparian areas with channel (habitat and buffering).
E-2	4W	Clyde Gallagher Street—between Milwaukee Street and East Washington Avenue.	Metal steel piling is slumping, rusted, aesthetically displeasing and poses a hazard; disconnects channel and riparian areas.	Remove metal armoring; replace it with terracing stabilization that will make it aesthetically pleasing and connect riparian areas with channel (habitat and buffering).
E-3	4E	Both banks, downstream from three culverts in the stream adjacent to the railroad (by Jacobson and Webb Avenues).	Bank scouring and undercutting next to the wetlands above the Voit property.	Use bioengineering for bank stabilization; reduce runoff by using pervious and low impact design in the watershed upstream.
E-4	8W	Culvert where intermittent tributary of Starkweather Creek crosses Portage Road.	Severe erosion and scouring by a concrete culvert; 10-foot-deep bowl formed by the base of the culvert; sedimentation, and structural integrity of the road could eventually be compromised.	Fill in the eroded bowl and secure culvert stability; stabilize banks and channel around the culvert using riprap; design for high velocities.
E-5	5E	Stream corridor north of Highway 30.	Concrete slabs used as riprap stabilization on the left bank; steep banks with adjacent industrial and commercial land use, including a semi-truck parking lot. Aesthetically displeasing and erosion apparent.	Remove concrete and replace with more natural stabilization techniques, such as bioengineering; at the very least, replace with riprap.

Stormwater Runoff

Runoff is water that does not infiltrate into the ground during a rain event. Consequently, it flows overland into nearby rivers and lakes, or into urban storm drains, which then route the runoff to surrounding water bodies.

Runoff is problematic in urbanized settings because of the vast amount of impervious surfaces. The Starkweather Creek watershed is 33.5 percent impervious. Other studies have shown similar numbers and have projected 49-percent imperviousness by 2020 (Dane County Regional Planning Commission, 2005). Rain that falls on impervious surfaces is directed toward other impervious areas until it finally reaches the creek. The water seldom has a chance to infiltrate into the ground and it is not treated to reduce the number of toxins. As a result, large volumes of contaminated water are discharged to the creek.

When this untreated water flow directly into the creek, two major problems result. First, sand, trash, and other material from streets, gutters and parking lots are flushed into the creek and build up in the stream corridor when the velocity of the waters subsides.

Table 2-3. *Priority sites: Outfalls, erosion, and scouring.*

ID	Reach number	Location and description	Problem identified	Proposed solution
O-1	3W	West Branch intersection with Fair Oaks Avenue.	Fair Oaks Avenue, 3 blocks of a busy, highly impervious street drains directly into the creek; oily sheen and floating particles in the creek.	Integrate a bioretention facility into a proposed terracing of the bank.
O-2	5W	Outfall under a cul-de-sac on Hoard Street.	Outfall that drains approx. 128 acres, mostly single family residential area, perpendicularly into the creek's channel; severe bank scouring, condemned property across from the outfall; undercutting a nearby bridge.	Little room to work with; adjust discharge angle into the stream; dissipate energy using riprap or other techniques; hard armor adjacent and opposite streambanks.
O-3	5W	Outfall by Commercial Avenue.	Sediment accumulation in streambed from soil erosion on properties between Commercial, McCormick, Aberg, and East Washington Avenues.	Provide community education on soil conservation methods; install sand traps in outfall.
O-4	7E-Trib	Tributary in reach 7E, between Sycamore Avenue, Lien Road, and Parkside Drive.	36-inch outfall with sand and gravel sedimentation downstream; pipe lies parallel to the stream.	Investigate potential for daylighting stormsewer; conduct sediment treatment using bioretention in daylighted channel and/or sediment traps; investigate subsewershed for further analysis.
O-5	6E	Downstream from the East Branch crossing with Sycamore Avenue.	Commercial and residential trash in the stream corridor; plastic, paper, construction material, metal, and yard waste.	Promote cleanup and watershed education initiatives; improve riparian buffers with trash trapping and investigate for sources.
O-6	8E	East Towne Mall stormwater outlet emptying into the stretch between Lien and Zeier Roads.	Runoff from large commercial impervious area with no water-quality treatment directly enters the stream; scouring, erosion, and water quality problems.	Daylight part of the storm sewer; use treatment option, such as detention or energy dissipation, or alternative runoff-management strategies such as rain barrels, green roofs, or pervious pavement.
O-7	7E-Trib	Outfall by Lien and Thierer Road intersection west of Target shopping mall.	Severe erosion by an outfall for a subsewershed of 238 acres of commercial/industrial area (highly impervious); deep scouring by the outfall and sedimentation downstream.	Stabilize around outfall to prevent scouring. Install water-quality treatment, such as detention pond for energy dissipation and sediment removal.
O-8	1	Outfall by Olbrich Gardens on the left bank by the Thai pavilion.	Scouring, erosion, and sedimentation around the outfall.	Stabilize around the outfall and manage runoff in subsewershed.
O-9	4W	Outfall by the intersection of Clyde Gallagher and Worthington Avenues.	Severe trash and litter problems in the stream channel downstream from the outfall.	Investigate sources of the trash and litter problem; conduct neighborhood outreach and education efforts; possibly improve riparian buffer for removal of the litter.

Second, the force of the water as it gushes out of the stormwater-collection systems can erode adjacent streambanks as well as well as create flood conditions and further bank erosion downstream. We have identified several priority sites where direct input from outfalls has created notable erosion and sediment accumulation in the creek (table 2-3).

- Stormsewer outfall from Fair Oaks Avenue (**priority site O-1**).

Table 2-4. *Priority sites: Riparian vegetation.*

ID	Reach number	Location and Description	Problem identified	Proposed solution
V-1	1	Riparian areas in Olbrich Gardens.	Riparian vegetation nonexistent and replaced with mulch down to the stream.	Initiate revegetation program at a high profile location.
V-2	6E	Downstream from Sycamore Avenue and a residential lot adjacent to the stream.	High, artificially amplified streambanks and wholesale streambank erosion with no vegetation for stabilization.	Stabilize bank and revegetate; intiate gentle education program.
V-3	5E	Grassy banks by commercial lots between Stoughton Road and Highway 30.	Grassy banks behind a commercial lot in attempt to beautify the area; no riparian vegetation; grass clippings enter stream and enhance nutrient loading. Lack of biological diversity.	Restore native vegetation and form a riparian buffer, which will result in increased plant and wildlife diversity; could be used as a restoration demonstration site.
V-4	8E	Autumn Wood development area.	Development company used heavy earthmoving equipment to spread topsoil beyond property borders onto riparian buffers; insufficient runoff-management practices on construction site.	Improve runoff management on site; strengthen municipal environmental policies and enforcement capacity; provide continuous environmental education for developers and construction managers.
V-5	4E	Riparian vegetation lacking on private properties adjacent to the creek.	Residents mow down to the creek, eliminating riparian vegetation; Nutrient loading and possible erosion.	Conduct residential education and collaboration.

Figure 2-4. *Priority site O-3, an example of an outlet with erosion problems due to high runoff volumes.*

- Stormsewer outfall underneath Hoard Street (**priority site O-2**).
- Sedimentation by outfall near Commercial Avenue on the West Branch (**priority site O-3,** fig. 2-4).
- Outfall by Lien and Thierer Road intersection west of Target shopping mall (**priority site O-7**).
- Outfall by Olbrich Gardens (**priority site O-8**).

As a result of urbanization in the lower reaches of the creek, little space is available for treatment and detention. It is imperative that stormwater-management methods of treatment and detention be applied if and when redevelopment takes place in the lower reaches of the watershed. Although the solutions proposed for each of the priority sites are intended to significantly reduce the problems associated with these outfalls, they are only patches on a system in need of holistic stormwater management. With limited space, the first and most important step in such an approach to stormwater management is simply to reduce the amount of runoff being drained into the creek.

Mitigating Excessive Runoff Volumes

Pervious Surfaces

Pervious pavement has been engineered to allow water to pass straight through as though it were soil. In some cases, pervious pavements are actually more pervious than the soils that were initially in place. Because of the variations of soil type and geology from site to site, installing pervious pavement requires careful planning and can be quite expensive. This cost is at least partially offset by reduced construction costs because curbs and gutters are not required with pervious pavements.

Another option is to install pavers—concrete blocks that have small, equally spaced gaps between the blocks. Sand and fine gravel can be placed in these gaps to make the surface as level as possible, which maintains the capability of handling car traffic, but also decreases the runoff volumes. To inhibit automotive oils and gasoline from entering the groundwater system, a few pretreatment facilities would be desirable in conjunction with the pervious systems. These treatment areas could be very simple sections of the parking lot or roadway where the water travels over a rough surface, such as gravel, so the hydrocarbons attach to the surface and volatilize, thereby protecting groundwater quality.

Parking lots and roadways make up a large percentage of impervious surfaces in a development, so they are of the highest priority when implementing alternative methods for increasing infiltration and decreasing runoff. Porous pavements or pavers could be retrofitted into areas with good infiltration and expansive parking lots. The Woodman's grocery store and the Olbrich Gardens parking lots, as seen in the Eastmorland and North Platte case studies, are candidates for this practice, as are large parking lots in the watershed.

Low Impact Design

Another effective way of preserving natural permeability and decreasing runoff is through Low Impact Design (LID), which is a means of maintaining predevelopment hydrologic function through innovative design techniques to create "a functionally equivalent hydrologic landscape" (Prince George's County, 1999). It is an effective method of controlling stormwater through on-site mitigation techniques. These techniques can include grassy swales, vegetative roof covers, bioretention ponds, and permeable surfaces. Furthermore, LID attempts to replicate the natural hydrologic functions of storage, infiltration, and groundwater recharge. The U.S. Environmental Protection Agency also advocates LID for the preservation and protection of riparian buffers, wetlands, steep hills, mature trees, floodplains, woodlands, and highly permeable soils (Prince George's County, 1999).

Low impact design practices would be suitable for locations that are being redeveloped or developed for the first time. A few possible locations would be any commercial expansion around East Towne Mall, the Autumn Wood development on the East Branch, or any future Dane County Regional Airport expansions.

Chemical Inputs

With the flow of untreated runoff into the creek, many unwanted chemicals enter the water and decrease the habitat quality. Urban runoff is a main source of chemicals and toxins that are harmful to the creek. Gasoline and oils from automobiles are typical sources, but many other sources can be overlooked. These can include unregulated and illegal waste dumpsites, but they also include contaminants people release unknowingly, such as using cleaning agents for washing the car in the driveway or dumping chemicals like paint thinner down the stormsewer.

To gain a quantitative understanding of Starkweather Creek's water quality, we deployed semi-permeable membrane devices (SPMDs) at six sites twice during the summer of 2005. These inexpensive testing devices mimic fish tissue by accumulating many hydrophobic organic compounds that diffuse from the water column (Huckins and others, 2002). A detailed description of the field procedures and lab results can be seen in appendix B.

Test results showed that the site above the airport contained the best water quality of all the sampled points in the watershed; the sites within the watershed that showed the worst water quality were the golf course ditch and the site immediately downstream of the airport. The remaining three sites had toxicity values ranging between the relatively high quality seen above the airport and the very poor quality seen below the airport and in the golf ditch.

Water quality decreases as the creek flows from East Towne Mall past the Lien Marsh. This may illustrate that the wetland complex within the marsh area does not function to improve water quality or that additional contaminants are entering the creek in this section. Water quality improves farther downstream from the airport and golf ditch

Table 2-5. *A few of the chemicals found in Starkweather Creek and some of their common uses.*

Chemicals found	Commonly used in production of
D-Limonene	Solvents, pesticides, and insecticides
Hexadecanoic acid	Greases, pharmaceuticals, and food additives
Oleic acid	Synthetic butters and cheeses
Propanetricarboxylic acid	Softeners for plasticizers
Diisooctyl adipate	PVC plasticizers
Pyrene	Pigment production
Anthracene	Wood preservatives and coating materials

probably because of the dilution of the pollutants as they travel downstream and mix with more stormwater. The Milwaukee Street site is located farthest downstream of all the locations and is most representative of water leaving Starkweather Creek and entering Lake Monona.

Gas chromatography mass spectrometer tests were also performed on the SPMD extracts. The purpose of this analysis was to gain a general understanding of the types of organic compounds in the creek. Table 2-5 lists a few compounds that we found in Starkweather Creek water samples and examples of some of their possible uses. A complete list of all the organic compounds that were found in the creek can be seen in appendix B.

A limitation to the type of gas chromatography mass spectrometer tests run on the SPMD samples is that the exact concentration of the compounds present is unknown. Without such data, it is not possible to say whether the compounds found were present at levels that exceed regulatory standards.

We therefore suggest that further sampling be done within the watershed at the sites where highest toxicity levels were found, below the airport and at the golf course ditch, to determine whether immediate action needs to be taken.

Nutrient Inputs

In addition to chemical toxins, runoff may also contain harmful loads of nutrients from fertilizers used in agricultural practices or in lawn applications. Excessive nutrient loading in aquatic ecosystems has many adverse effects. In small quantities nitrogen and phosphorus, the most important nutrients, are beneficial because they facilitate the growth of aquatic plants. In excess, however, the nutrients cause eutrophic conditions facilitating massive growth of algae blooms and causing fluctuations in the amount of dissolved oxygen in the water (fig.1-3). As the algae continue to grow, sunlight is blocked from reaching lower levels of the water and the algae itself along with other organisms begin to die. As the decay of organisms progresses, the remaining oxygen in the water is consumed (Wisconsin Department of Natural Resources, 2005). In extreme levels, nitrogen can be highly toxic to animals that use the water body as a drinking source. These toxic levels of nutrients are often the result of poor agricultural practices such as excessive use of fertilizers and manure spills (Wisconsin Department of Natural Resources, 2005).

Agriculture is practiced in the upper reaches of Starkweather Creek watershed, and in most cases there are inadequate riparian buffers between the creek and the fields.

Ways homeowners can help reduce runoff

One of the first steps homeowners can take to reduce runoff from their property is to avoid overwatering their lawn. This limits the amount of water that is available for carrying nutrients. Second, yard waste should be composted or mulched as opposed to swept into a storm drain. Finally, piles of dirt and mulch used in landscaping should be covered. This limits the amount of sediment that will be carried into the stream during the next rainfall (U.S. Environmental Protection Agency, 2003).

Besides nutrients from the lawn, other sources of urban runoff can be found on or near the home. Many of the cleaning agents used when washing a car at home flow directly into the stormsewer. Cars should be washed in a commercial car wash that treats and recycles used water. Otherwise, cars should be washed in the yard so water can infiltrate back into the groundwater. Other easy ways to limit runoff from yards is to install permeable pavement on the driveway, allowing rain and snowmelt to percolate through the pavement. Rain barrels, rain gardens, and grassy swales can also be constructed (U.S. Environmental Protection Agency, 2003).

Algal blooms do take place in the creek, but it is unknown if the agricultural lands are the primary source of these nutrients. If it is found that the source of the nutrient loading is agriculture, best management practices such as reduced tilling and contour plowing along with riparian buffers can be implemented to stop nutrients and sediments, from reaching the creek.

Residential and commercial lawns are another likely source of nutrients in Starkweather Creek. Many homeowners douse their lawns with nutrients, in the form of fertilizer, in an effort to maximize plant growth even though vegetation has a limit of what it can absorb. Any excess nutrients that cannot be used may enter the creek during storm events or after watering a lawn. To mitigate the effect of household nutrients on a watershed, homeowners need to limit the amount of chemicals put on the lawn.

Mitigating Chemical and Nutrient Inputs

Riparian Buffers

One effective way to mitigate the harmful effects of runoff in agricultural setting is to install riparian buffers that can intercept chemicals, nutrients, and sediments before they reach the water body. Riparian buffers have many benefits, such as supporting a great diversity of plant and animal life, geologic and biogeochemical processes, soil production rates, flood regimes, and many other ecological functions (Naiman and Decamps, 1997). Research has shown that installing a grassy strip alone can reduce delivery of agricultural runoff nutrients by 20 to 80 percent and sediments by 60 to 90 percent (Daniels and Gilliam, 1996). Other research has shown that riparian zones can help improve surface-water quality as well as groundwater quality by reducing as much as 100 percent of leaching nitrates (Haycock and Piney, 1993).

In an urban setting, careful planning in the beginning phases of urbanization could be implemented so that riparian buffers are protected for ecological and recreational functions. Ideally, urban buffer strips contain three zones that are a minimum of 100 feet wide on each side. The streamside zone, about 25 feet wide, contains mature trees to provide shade, woody debris, and erosion protection. The middle zone, 50 feet wide, is composed of a mixture of mature trees, shrubs, forbs, and grasses. This area helps to further protect the stream's ecosystem, but it can also be used for recreational purposes, such as for bike paths and walking trails. The third zone, nearest to the developed areas, is 20 to 25 feet wide. This section is ideally grass, such as someone's backyard, and it functions as the main interceptor of sediments and nutrients, thus requiring some maintenance to maximize functionality (Schuler, 1995).

In already developed areas, as in the case of much of Starkweather Creek watershed, much of the urban runoff is channeled through stormsewer piping and other conduits, bypassing riparian buffers and discharging directly into the creek. For the water-quality improvement aspect of riparian buffers to function properly, runoff needs to enter the buffer area as sheet flow and not as a point discharge from a pipe. Also, although riparian buffers can be simple to build, challenges occur when dealing with limited space in an urban setting.

Most of the riparian areas along Starkweather Creek are non-functional or compromised. We identified a few priority sites where the buffering effects of riparian vegetation can be improved by replacing bare spots or non-native grasses with better functioning native vegetation. These include an impacted buffer at the Autumn Wood development **(priority site V-4)** and at some private properties in reach 4E **(priority site V-5).** As a last resort, buffer strips can be helpful in stopping litter from reaching the stream. In Starkweather Creek a riparian buffer can help enormously in two areas with severe litter problems:

- Near the outfall by the intersections of Clyde Gallagher and Worthington Avenues **(priority site O-9).**
- Downstream from the Sycamore Avenue **(priority site O-5).**

Daylighting Stormsewers

Daylighting stormsewers refers to the process of removing storm drains and culverts and replacing them with open channel flow, thereby bringing the drain, literally, into the daylight (U.S. Environmental Protection Agency, 2005). Daylighting provides for further stormwater infiltration and for pretreatment before discharging to a water body.

Improving water quality is one of the benefits of daylighting. Bringing the water above ground and allowing the water to flow over a more natural channel allows runoff to be filtered before it enters the stream and allows for increased infiltration into the groundwater. Daylighting also improves the hydrologic function of stream. By flowing over a natural channel, water velocity slows down, reducing the amount of downstream flooding and channel erosion (U.S. Environmental Protection Agency, 2005). Daylighting storm drains do often require significant land area, which can be limited in urban settings, and it is costly to bring the drains above ground. It is also important to periodically remove sediment accumulated in the daylighted swale because it could be transported downstream in large runoff events.

Daylighting could be implemented in many locations throughout the Starkweather Creek watershed. A storm drain behind East Towne Mall would benefit from daylighting, and there is ample space for the above-ground channel area **(priority site O-6).** At present, a 36-inch pipe discharges directly into the creek and erodes the right bank with the high velocity of water that comes out of the outfall. This creates a large sediment source for the creek, thereby reducing water quality.

The second prime location for daylighting a stormsewer is along the bank of the tributary to reach 7E **(priority site O-4).** This outfall runs parallel to the creek for several hundred feet and contributes a significant amount of flow to the creek between rainfalls. However, this outfall also delivers large amounts of sediment to the creek and is causing erosion during high discharge events. Again, introducing daylighting at this location can help trap sediment before entering the creek and reduce erosion.

Streambanks

The banks of a stream are an integral part of the stream channel as well as the surrounding riparian areas. The geomorphologic changes in the stream constantly modify the meandering channel, creating a dynamic system of physical and biological progression that sustains diverse and healthy life in the stream. When agricultural practices began in the watershed, this natural dynamic system was disrupted by channelization, which drained wetlands and quickly channeled runoff into the lake. As urbanization progressed, high peak runoff into the creek increased, and the vulnerable streambanks suffered erosion and destabilization. This in turn increased sediment loading in the stream and into Lake Monona. As the stormwater-drainage system of the city was expanded, and new land use and construction near the creek prevented natural changes in the stream morphology, the stabilization of the streambanks was necessary and unavoidable.

Stable streambanks are important to the health of wetlands, floodplains, waterways, and lakes. Bank material contributes as much as 80 percent of the total sediment eroded from incised channels (Simon and others, 2000). This percentage will vary from place to place, but is indicative of the importance of streambank stabilization. Moreover, studies suggest bank stabilization can not only lower suspended sediment concentrations, but also reduce lake-sediment accumulation by a significant amount (Chen and others, 2004). However, some bank-stabilization techniques can also have adverse affects on floodplain connectivity to the stream channel, in-stream aquatic habitat, and diverse riparian ecosystems.

Stabilization techniques most commonly used are hard-armoring techniques, such as metal piling, concrete channels and riprap, and softer techniques, such as bioengineering and terracing. Figure 2-5 shows the streambank materials used in Starkweather Creek as identified in the stream corridor survey. Most of the lower reaches in the creek are stabilized using steel piling and low riprap, but much of the upper reaches has not been stabilized and has chronic erosion.

Channelization

The banks of a stream are an integral part of the stream channel as well as the surrounding riparian areas. A natural meandering stream is a dynamic system of physical and biological processes that sustain diverse and healthy life in the stream. Starkweather Creek was channelized to drain the wetlands and enable agricultural development. Subsequent urbanization increased the peak rate and volume of storm runoff, causing bank erosion and greatly increasing the discharge of sediment into Lake Monona. Increased bank erosion led to the need for stabilization of the streambanks by the city.

Starkweather Creek is almost entirely channelized, and channelization is still taking place in the watershed today. The Dane County Regional Airport is currently relocating parts of the West Branch of the Creek using channelization methods to better suit the growing needs of the airport. In Starkweather Creek watershed, there are few opportunities for improvements of channelized stretches within the urban areas due to development close to the stream. However, removing the concrete lining in the side channel to the creek at Eastmorland Park and allowing for stream channel meandering and widening of the floodplain are examples of stream-restoration opportunities in the watershed. As the future unfolds and redevelopment of industrial areas around the creek takes place, it is essential to keep in mind the benefits of naturally meandering stream channel to ecological health of the creek.

Hard Armoring

Hard armoring has been the preferred way to stabilize eroding streambanks for decades. These methods include stone riprap, concrete pavement, rock gabions, bulkheads made of steel, concrete or aluminum, and sack revetments. If done properly, these techniques provide good protection and will work in severe situations where bioengineering methods will not (Tennessee Valley Authority, no date). These techniques are favored because high levels of precision and confidence in design and construction have been developed from research and practical application.

Without proper maintenance, these hard armoring techniques can in fact exacerbate the conditions that they are intended to prevent. One such situation is the use of hard armoring around bridge abutments as well as the sections of streambanks around the bridge (Li and Eddleman, 2002). The formation of a scour hole around the concrete structure is a common occurrence in a stream. An accepted engineering method to deal with such scour problems is to place riprap material around the pier foundation. However, in large rain events, riprap can be flushed downstream, leaving the site even more vulnerable to future scouring.

A severe example of this can be seen in the upper reaches of the West Branch of Starkweather Creek **(priority site E-4).** In reach 8W, where an intermittent part of the creek crosses Portage Road, an extensive scour hole has formed downstream of the culvert, creating an 8-foot drop, eroding sediments downstream (fig. 2-6). This problem could be addressed with riprap rock designed for energy dissipation and erosion prevention or another site-appropriate design determined through careful analysis of the discharge in the ravine. In addition, this location should be carefully monitored and maintained because it is potentially a large source of sediment in the West Branch.

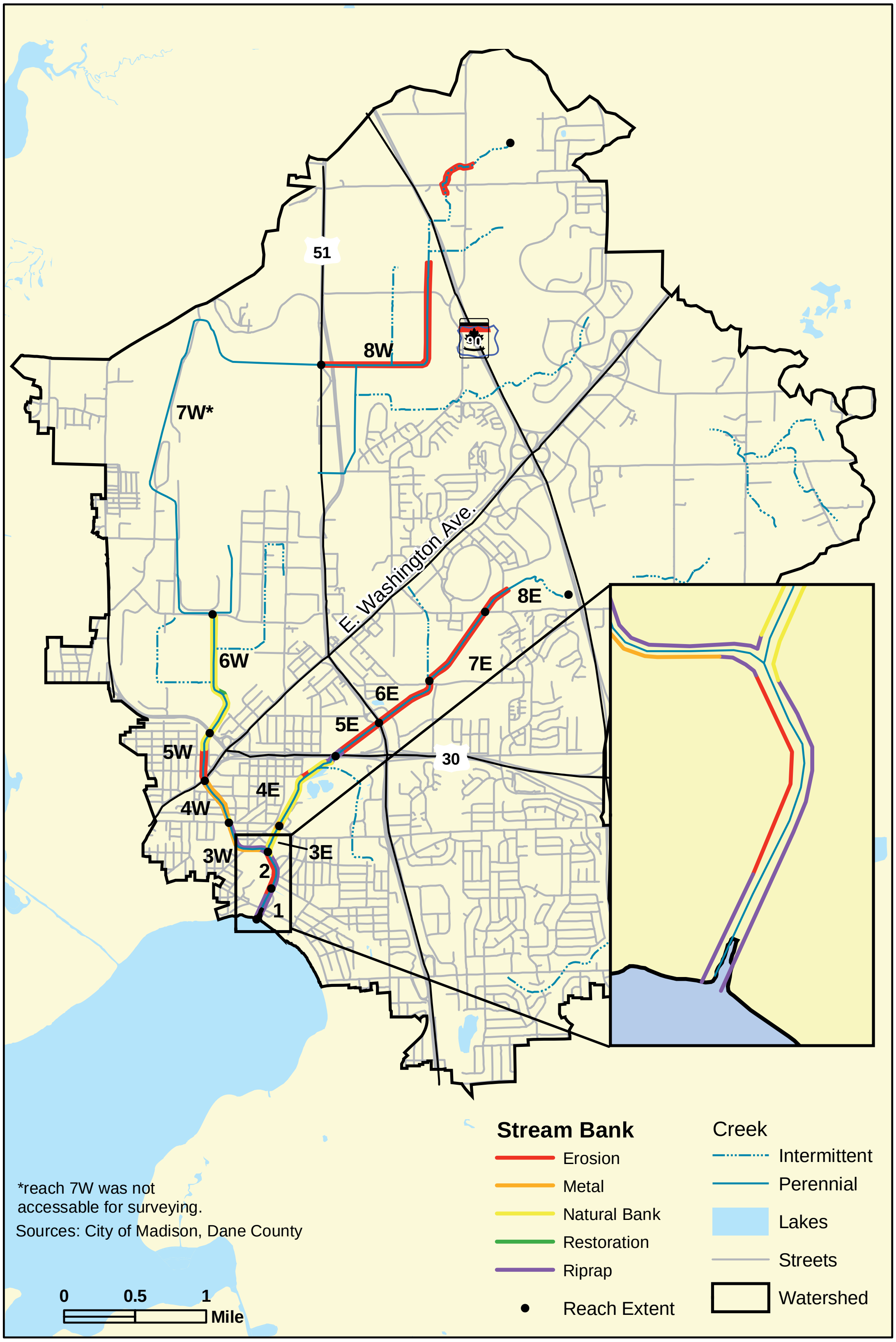


Figure 2-5. *Streambank materials in Starkweather Creek.*

Figure 2-6. *Eight-foot deep scour hole by a culvert in reach 8 of the West Branch (priority site E-4)*

Riprap

Riprap is mainly applied in the lowest reaches of Starkweather Creek watershed, particularly near Lake Monona in reaches 1, 2, 3E, and 3W (fig. 2-2). Although favored and applied with comprehensive design recommendations, riprap stabilization is not necessarily guaranteed to succeed. Installing riprap requires clearance of natural vegetation and results in the loss of existing vegetative cover, a natural means of stream erosion control. Concrete riprap with a smooth surface is prone to accelerate stream flow, which can cause erosion downstream (Li and Eddleman, 2002). However, this does not seem to be a problem in the lower reaches of Starkweather Creek. The integration of low-rise riprap with wetland vegetation and forested riparian areas is an example of successful implementation of riprap in Starkweather Creek.

No places in the stream corridor were identified as being appropriate for new riprap. However, in the stream corridor north of Highway 30 (reach 5E), excessive amounts of concrete slabs seem to be used for the purpose of stabilizing the streambank next to an industrial parking lot **(priority site E-5).** This method for stabilization is not aesthetically pleasing and does not function properly. This would be an appropriate location to recommend alternative stabilization strategies, such as natural stabilization techniques, terracing, or more aesthetically pleasing riprap.

Metal Armoring

Metal armoring is probably the strongest way of stabilizing streambanks (along with concrete channels), and is usually applied under very severe conditions in watersheds with high percentages of impervious areas and where adjacent space is lacking. Metal armoring removes riparian vegetation that can cool water temperature and prevents natural connection between the streambanks and the stream, inhibiting formation of aquatic habitat in the stream. Moreover, these smooth materials reduce bank roughness and eliminate the ability of the natural stream to dissipate flow energy, resulting in more serious erosion downstream (Li and Eddleman, 2002). Techniques such as steel piling create potential hazards for children at play because the steep banks generated using steel piling make easy exit harder if one were to fall into the stream.

The use of metal for bank stabilization is common in Starkweather Creek. A large part of the lower West Branch is armored using corrugated steel sheet piling (fig. 2-7). In addition to the ecological impact and safety issues, the sheet piling in the creek is failing due to erosion behind and under the structure, causing perpetuation of past erosion problems and degradation of structural integrity. The sheet piling is severely rusted in many places and requires immediate maintenance or removal. Reaches 3 and 4 on the West Branch, from East Washington Avenue to the confluence of the East and West Branch, were identified by the stream corridor survey as priority sites in need of action **(priority sites E-1 and E-2).** Because of disruptive localized and stream-wide effects, replacing the metal armoring with a terrace system would be beneficial to these areas in particular and the stream as a whole (see *Terracing* section of this chapter).

Bioengineering

Naturalization, also called bioengineering, involves working with natural materials, such as vegetation and natural flow deflectors (strategically placed rock or root wads from old trees that are placed along the bank) to create a self-repairing bank (Dakota County Soil and Water Conservation District, 2002). Living plants are used as the construction materials and are not employed to decorate civil engineering works (Lachat, 1998). A properly designed, naturalized streambank can offer immediate stabilization while also providing substantial wildlife habitat and water-quality benefits.

Li and Eddleman (2002) presented methods for bioengineering, including an assessment of how effective each method is for the cost required. Bioengineering methods include live stakes, brush layering, vegetated geogrids, log and rootwad revetment, and coconut fiber rolls. It is standard practice to conduct a detailed analysis and design before implementing these bioengineering techniques.

The upper reaches of both branches have been neglected as far as stabilization of the streambanks is concerned. The stream corridor survey has identified two locations **(priority sites E-3 and E-5)** where immediate attention is required to prevent further incisions in the streambanks (fig. 2-8). In these places we recommend bioengineering practices for stabilizing the streambanks while maintaining the natural aesthetics of the sites.

Terracing

Terracing is a method used for streambank stabilization that

Figure 2-7. *Corrugated steel piling sheets serving as armor on the lower West Branch.*

Figure 2-8. *Incisions in streambanks where bioengineering methods are recommended at priority site E-3.*

integrates features of bioengineering and hard armoring. The use of streambank terracing creates more room for large volumes of water, gives flood waters more room to spread out while remaining within defined boundaries, and keeps floodwalls low. Terracing can also hold the soil necessary for plant growth (Napa County Flood Control and Water Conservation District, 2004). The geomorphic design of terraces can reconnect a waterway to its historic floodplain. Rather than using methods that may diminish the character of natural waterways, terracing can maintain natural channel depth and slope. When simple conservation practices are insufficient to stop erosion, particularly on slopes greater than 15 percent, terracing is a recommended management practice. Terracing can be implemented in conjunction with bioengineering methods and hard and natural bank stabilization techniques.

Terracing techniques can be used in several areas within the Starkweather Creek watershed. Terracing at reach 4E, adjacent to Clyde Gallagher Street **(priority site E-2)** is already under consideration by the City of Madison. We propose educational opportunities about terracing for the North Platte of Olbrich Gardens in chapter 5, *Educational Outreach*. Eastmorland Park is also an ideal location for terrace creation. By implementing a terrace system in the park, water that typically inundates the area during rain events can be controlled in a terraced floodplain. (See further discussion in the *Eastmorland Park Case Study* section of this chapter.)

Combination of Stabilization Techniques

It is important not to solve a streambank problem by employing a single perspective. Strengths and weaknesses of different designs should complement each other to create the best solutions (Li and Eddleman, 2002). Abernathy and Rutherfurd (1998) recommended matching vegetation to channel scale to identify zones within a river system where the bank-stabilizing effects of vegetation can prevail over bank-destabilizing processes. By doing so, areas where bank naturalization will be most effective can be identified. Depending on slope, soil type, and other physical and biological factors, armoring and bioengineering techniques should be chosen by site-specific conditions with consideration for upstream and downstream effects.

Vegetation Survey of Riparian Areas

Riparian areas within the stream corridor require specialized plant species that are noteworthy indicators of stream dynamics and riparian zone health. Using vegetative constituents of the riparian ribbon as a parameter for watershed analysis is recommended because plants can serve as clues for inferences and as evidence for findings regarding the watershed. A vegetation survey provides a useful databank of species that tolerate the severity of an irregular flux of environmental conditions within a corridor. It also provides a list of species that survive the ecotonal, or transitional, qualities demanded for growth and sustainability within the corridor between the aquatic system and the upland ecosystem.

Vegetation is dependent on the environmental conditions in the immediate vicinity. Even a small flow of rainwater eroding a bank has an impact on what grows there and how well. The size and shape of vegetated riparian areas are subject to the geologic and geographic determinants that dictate soil and hydric conditions. The vegetation layer changes in size, composition, and quality as it extends throughout the watershed. This pattern can be roughly predicted, easily observed, and employed as a variable to answer questions regarding the watershed basin. Therefore, riparian plants are the vegetation to concentrate on to facilitate a strong understanding and reliable diagnosis of the past, present, and future health of a watershed.

We conducted a vegetation survey of the riparian corridor in the summer of 2005. We found that many original functionalities of the riparian corridor, such as storing flood waters and filtering sediments, have been lost. Therefore, the primary vegetation-enhancement opportunities include habitat and aesthetic restoration of the ecosystem. In a few locations, however, larger tracts of land also provide more significant opportunities for riparian corridor functionality.

Historically, Starkweather Creek watershed was a diverse wilderness that simultaneously relied upon and inherently managed its stream channel and tributaries. Moreover, this watershed had two distinct ecosystems. The first accompanied the rapid flows draining the uplands, creating ideal conditions for the heavily wooded savanna. Downstream, in the second ecosystem, the waters spread across the lower reaches, moving through wetlands. Together, these divergent ecosystems provided a vast composition of species and a fascinating interplay of vegetation types.

The dynamic relationship between these ecosystems is displayed in the following example. It is certain that the lowland forests alongside the lower reaches of the channels hosted mostly mature trees of valuable, late successional species (such as sugar maple, black ash, and elm). It is unusual, however, to have the juxtaposition of oak savanna ecosystems adjacent to several stable lowland forests. Because the savannas required an intermittent fire regime to thrive, the lowland species are fire intolerant and if burned, those areas would reinitiate their cycle with pioneering species until reaching the climax stage of secondary succession again—a process that takes several hundred years without major disturbance to recur. These ecosystems were able to thrive simultaneously in the Starkweather Creek watershed because the adjacent hills of fire-prone savanna existed to the east of the lowland forests. This was downwind of the prevailing westerlies during the fire season. Fires from any other direction were stopped by Lakes Mendota and Monona to the north and south, respectively, and by an extensive and very high water marsh as a fire buffer to the west (T.J. Givnish, verbal communication, October 2005).

Aside from a few wetlands, today there are no exemplary settings of the riparian corridor that have been relatively unaffected by human activity. The impact from human activity primarily began when European Americans settled the region and made demands on the system. Soon after the initial settlement, growth to the east was difficult because of the pervasive marshes and lowland forests that lay along the wet stretch of the isthmus, between the base of the Capitol and the beginning of Sun Prairie. At this early point, the citizens made drastic changes to the landscape by modifying the influence of water as a way to increase land area and spur development. At that time, the watershed ecosystem appeared to maintain a satisfactory supply and quality of water for early Madison.

As Madison became established, however, the development encroached on the riparian corridor. The added pressure to the ecosystem diminished species diversity and quantity, and also lessened their functionality in stabilizing streambanks and storing flood waters. The corridor was broader than what remains today, which explains the occasional presence of unlikely tree species at the outermost breadth of the present buffer zone; the trees would have been located within a riparian woodland rather than constituting the edge of a riparian buffer. Even present physical shapes of observed and recorded trees are evidence that they are remnants of former forests. Additionally, the increased water infiltration and retention in the soil of the watershed's upper reaches supported a comparatively more significant array of terrestrial and aquatic flora and fauna (Dane County Regional Planning Commission, 1983).

The present vegetation conditions within the riparian corridor have been challenged and compromised significantly by urbanization. The lower reaches, which face greater urban pressures, have a larger proportion of nonnative vegetation as compared to the less urbanized upper reaches.

Riparian Vegetation Priority Sites

The entire watershed is in need of at least some attention, but our surveys provided a start toward qualifying current conditions regarding infiltration, erosion control, and elimination of anthropogenic nutrient loading. This facilitated the creation of a list of potential priority sites; after further measurements and observations, we shortened the list to a few sites in need of rehabilitation. The locations most in need of remediation vary in terms of expense and who can provide the vegetation enhancement and maintenance.

The priority sites were drawn from a variety of areas within the watershed, including the following:

- both branches of Starkweather Creek,
- upper and lower reaches,
- new and established developments,

- residential and commercial,
- locations embedded among all natural features and locations affected by engineered structures, and
- locations in close proximity to the creek and relatively distant buffer zones.

At the base of the creek lies a problem stretch along Olbrich Gardens **(priority site V-1**), where mulched botanical specimens line the streambank. Mulch temporarily reduces erosion compared to the loss by runoff over bare soil, but it cannot compete with the thatch and growth of a fully vegetated buffer that stabilizes soil and potentially increases the amount of infiltration of precipitation and nutrients. This is a high profile location for garden visitors and recreational boaters on Lake Monona, who use the boat launch opposite the mulched bank. A revegetation scheme could add to Olbrich's approach to environmental stewardship and encourage the community by demonstrating a successful method of bank stabilization with native riparian species.

Priority site V-2 on the East Branch is suffering extensive erosion, has no vegetation to reduce the forceful impact of precipitation, and has no capillary roots to hold the soil in place during runoff events. The heavy shade and artificially amplified bank height make the long-term success of an exclusively vegetated cover highly improbable. It is better to combine a bank-enhancement strategy with vegetated pockets throughout, which would maintain the tall, steep bank and assure the adjacent homeowner of a reliable foundation. As the vegetated pockets thrive and mature, there will be continuous cover that will be consistent with the adjacent and opposite natural banks. The appropriate and conducive vegetation types to consider are woody shrubs native to streambanks, such as the highbush cranberry (*Viburnum trilobum)*. Additional assets of this species are its ability to resprout when challenged with abusive conditions. Its dense foliage would be similar to that of the opposite streambank.

Priority site V-3 is a part of a commercial lot where a business maintains a lawn touching the water (fig. 2-9). Although a wide buffer of grass reduces erosion and achieves moderate infiltration rates, the lack of plant diversity lost to a lawn is a biological desert for wildlife. In addition, the shallow roots of Kentucky bluegrass do not serve the riparian buffer nearly as well as native plants with deeper root systems. There are also several documented events of grass clippings mechanically broadcast over the creek, resulting in nutrients entering the stream. Because of the damaged riparian buffers and habitats in this watershed, it is preferable to replace grass with native riparian species to encourage the wildlife that depends on this narrow habitat. This could also reduce the nutrient loading of the stream.

During the stream corridor survey, we noted a number of practices that are against current ordinances. One such example is a development project at **priority site V-4.** In this location, topsoil was deposited in the riparian corridor, which then shifted into the stream channel, despite the erosion control and stormwater-management practices typically undertaken at construction sites. Unfortunately, these types of incidents cause a degradation of water clarity and quality and the physical makeup of the natural stream

Figure 2-9. *Lawn touching the creek by a commercial lot.*

corridor. Recently, efforts have been made to improve the risks of runoff and riparian corridor degradation resulting from construction practices (J. Steines, verbal communication, 2005); however, this priority site demonstrates that breakdowns still exist. Therefore, continued efforts, such as project monitoring and a more thorough review of erosion control and stormwater-management plans, could be emphasized (Midwest Environmental Advocates, 2006).

Future Approach to Riparian Vegetation

The results of the vegetation survey for Starkweather Creek watershed provide pertinent data regarding vegetation conditions, but we recommend that more robust analysis of the data, and even additional data collection, be conducted. Successful recommendations and strategies cannot be prepared or implemented without in-depth investigation. Environmental modeling and investigative work can support a recommended plan to reconstruct and tailor site-specific plant communities to the future needs of the Starkweather Creek watershed and the City of Madison.

Eastmorland Park Case Study

We identified Eastmorland Park (fig. 2-10) as a site with the need and potential for stream corridor and riparian area improvements. The park contains a tributary to Starkweather Creek and has characteristics that contribute to the degraded condition of Starkweather Creek. The channel has been straightened, is made of concrete, and lacks a useful riparian buffer. In addition, it is a receptacle for stormwater runoff. Because of its open space, Eastmorland Park potentially has more opportunities than other developed areas in the watershed to make riparian area improvements. Currently, the park is used infrequently, but as a public space, it could serve as a functional, safe, and aesthetically pleasing site.

Figure 2-10. *Current layout of Eastmorland Park.*

Site Analysis

Site Inventory

The park is near the intersection of Milwaukee Street and Stoughton Road–Highway 51. The 14-acre property is owned by the City of Madison (City of Madison Assessor's Office, 2005), and its shape resembles three perpendicular strips of land (fig. 2-10). A land-use map from the year 2000 designates the parkland as open space (Dane County Land Information Office, 2005), and it is zoned as a single-family residence district (City of Madison Assessor's Office, 2005). The Madison zoning code allows a residential district to include recreational facilities that serve residents in that district (City of Madison Department of Planning and Development, 2002).

Neighboring Land Uses. Eastmorland Park is bordered on the west and south by a neighborhood that is also zoned as a single-family residence district (City of Madison Assessor's Office, 2005). The north side of the park is bordered by the back of the Woodman's grocery store and on the east by Head Start, a multi-family residential complex, and a Madison water utility building. Woodman's grocery store is zoned as a general commercial district, and the properties to the east are zoned as general residence districts (City of Madison, Department of Planning and Development, 2002).

Transportation. There are no roads for vehicular traffic in Eastmorland Park. The park has a paved walking trail that parallels the north side of the channel and the parcel boundary. Although there is no official bike trail through Eastmorland Park, bicycles traverse the pedestrian path. In addition, a small section of the pedestrian path is used as a connector for the official bike trail from Dawes Street to Dempsey Road, which is interrupted by the stormwater channel.

Environmental Conditions. The Starkweather Creek tributary that runs through Eastmorland Park is channelized and has a continuous concrete bed from south end of the park to the west side of the park, where it then becomes natural bed. It is common for trash and debris to be seen in the channel. The channel primarily serves as stormwater drainage for approximately 790 acres of the watershed. Storm events drain into the park through five outfalls. The first outfall is located on the south side of the park and drains approximately 50-acre sewershed. A small outfall coming into the west side of the park drains approximately 10-acre sewershed, and flows into the floodplain on the west side of the park. An outfall on the east side of the park and two on the north (for example, the Woodman's parking lot) drain the remaining 730 acres of sewershed (City of Madison Engineering Division, 1993). In addition, three small ditches have been cut in the main floodplain to facilitate drainage into the channel.

Eastmorland Park has a very flat gradient and as a result, stormwater tends to flood the western part of the park during storm events (fig. 2-11). A high water table, less than 10 feet from the surface, exacerbates the situation, as does poorly draining soil. Four soil cores were taken during the spring of 2005 in western parts of the park revealed considerable clay in the area.

Vegetation in the park is very limited in its diversity. The west section of the park, which has the wettest conditions, primarily contains reed canary grass and invasive cattails. The remainder of the park is mowed grass. No study was conducted with respect to wildlife and aquatic biodiversity, such as fish, insects, and macroinvertebrates. However, during several visits in the summer of 2005, we saw a few dead fish in the creek. Ducks were often present, and on one occasion, three sandhill cranes that had been nesting in the vicinity were observed foraging.

Current Maintenance. At present, the City maintains the park by periodically dredging the lowland area on the west side. In addition, the City

Figure 2-11. *Eastmorland Park flooding after a large rain event.*

mows part of the park and maintains the trees adjacent to residential parcels on the south property line.

Park History. Sustained interest and commitment by the residents of Eastmorland neighborhood to provide nearby safe and suitable recreational facilities precipitated every major development of the local drainage ditch into the expanded and engineered Eastmorland Park that exists today. In the 1950s local children used the drainage ditch as a place for exploration and adventure activities. In short time, basic playground equipment was added along the high periphery of the deepening ditch. The popular area quickly became known as Schenk Playground, and local residents began a campaign of repeated requests of the City's Parks Department to mow the grass surrounding the playground and later to replace deteriorating equipment.

The turning point for Schenk Playground was again driven by citizens, when they succeeded in gaining the city's support and approval for a series of substantial resolutions and ordinances. The playground equipment improved and in addition, the city heeded the residents' concerns over the worsening hazards associated with the open ditch. This drainage area within undeveloped city land was expected to accommodate increasing amounts and frequency of high water events, which posed immediate and inherent dangers by the quick onset of urban flooding. The residual dangers worsened each time the water subsided—the ditch was deepened and banks eroded, and increasing numbers of children sustained injuries near the outfalls and steep banks. As storm overflow of the banks became more common, water remained in the low areas of the mostly undeveloped greater Schenk Playground. The local population was quick to declare the site a "mosquito breeding area" and reported a "rat infestation" due to the unkempt nature of the ditch.

In response to these many concerns, the City raised the playground's profile to resemble a managed city park. Through mandated purchases of reapportioned properties, mostly privately owned, and a small area held by another city department, the drainage ditch became an enlarged system to move stormwater through covered culverts and a channelized streambed to north of Milwaukee Street, where the water was expelled. The neighborhood residents enjoyed the new layout that included increased acreage of mowed parkland, expanded recreational space, and an enhanced urban appearance.

This costly fix satisfied the City and local residents for a few decades, until increased urbanization upstream challenged the park's ability to shunt the water downstream. The result has been a cycle of sedimentation and nutrient loading in a poorly functioning marsh, which invites dense monocultures of vegetation to develop. The city's current strategy is to dredge and scrape the wetland periodically to keep the invasive vegetation from clogging the channel.

Opportunities and Constraints

Ecological factors present significant challenges to restoration of the tributary and its riparian area. Most important, the park is used to drain water; it provides no water-quality treatment and offers little storage. The flat topography and clay soils limit natural stormwater functions, such as flow conveyance and groundwater infiltration. The channelization and concrete lining of the channel are unattractive and alter many physical, chemical, and biological aspects of the creek's function.

Features of the current park design have lessened the park's popularity. For example, the park's peculiar shape makes it seem disjointed. High volumes of cars enter and exit the adjacent commercial parking lot. As a result, noise, activity, and pollution detract from the serene, natural surroundings typically desired in a park setting. Although a walking path exists, it is not aesthetically pleasing because of its location adjacent to a fence at the property boundary. In addition, the walking path does not provide direct access from the adjacent neighborhoods to the grocery store. Bike trails are lacking; the one that does exist provides an indirect route through the park to get to the next section of the trail as well as an indirect route to the grocery store. Many complain the bike trail is not clearly marked (M. Rothbart, verbal communication, June 2005). Although some of the space is mowed, it is not conducive to sports activities.

The challenges may seem daunting. Nevertheless, opportunities for riparian restoration do exist. Pheasant Branch Creek in Middleton, Wisconsin, had a similar type of situation: an area of land with a flat gradient, receiving considerable runoff during storm events. In 2003, the City of Middleton and the Wisconsin Department of Natural Resources (WDNR), created a meander, developed a stormwater-detention pond, planted native vegetation in the area and provided walking trails. Several years later, the vegetation is maintaining its diversity and streambanks are stable (K.W. Potter, verbal communication, July 2005). Changes in the Eastmorland Park design could also improve the park's functionality and better serve the local residents. Because of the park's relatively small size, the proposed project improvements are manageable.

Stakeholders

Park users are a primary stakeholder group. Surveys of park users have not been completed; however, adjacent neighbors are likely park users, and many have communicated to the Eastmorland Neighborhood Association what they would like to see in the park. Several particular features that neighbors have requested include a safe park with regular tree maintenance, mowed grass, and low mosquito populations (M. Rothbart, verbal communication, June 2005). The City of Madison Parks and Engineering Departments have been involved with Eastmorland Park: the Parks Department through maintenance activities, and Engineering through previous redesign plans. Both departments have expressed interest in improving park conditions, as has the alderman for this district (L. Palm, verbal communication, June 2005). Because the tributary drains to the East Branch of Starkweather Creek, the Friends of Starkweather Creek would likely welcome any changes to the park that could improve the creek. However, they have not been actively involved in a park redesign. Woodman's grocery store can be considered a primary stakeholder. Although Woodman's has had little involvement with the park to date, their parking lot drains directly to the tributary, and its vehicular traffic has a visible and auditory impact on the park.

Conceptual Design

We created a conceptual design for Eastmorland Park (fig. 2-12) to improve the Starkweather Creek corridor and riparian area and demonstrate that innovative design can also provide a functional, aesthetically pleasing, educational, and safe park in the heart of Madison. We had four goals when we created this design: 1) to present an effective stormwater-management design, 2) to offer a variety of recreational opportunities for park users, 3) to suggest management and maintenance practices, and 4) to promote stakeholder inclusion.

Goal 1: Stormwater Management

Eastmorland Park has been designated for stormwater management by the City of Madison Engineering Department. The area is small compared to the drainage basin (14 acres receiving runoff from about 790 acres); therefore, conventional stormwater-management practices cannot be used to maintain recommended stormwater-quality-treatment functionality. Instead, a series of unconventional options can be applied so that the maximum potential for managing the stormwater runoff in the park is used. Two main purposes for stormwater management need to be addressed in the park: providing a floodplain to detain storm events to prevent flash floods downstream in Starkweather Creek and providing optimal treatment of water quality before water enters the creek.

Floodplain. The designated "stormwater management" area of the park would consist of a natural-looking floodplain surrounding a meandering channel. Wetland vegetation would be planted where ponding would occur most frequently, and meadow-like brush vegetation planted on higher areas of the floodplain. The current concrete bed would be removed and a shallow meandering channel would be formed on the south side of the park. It would eventually enter into an evenly graded wider wet area on the west side of the park (fig. 2-13). Soil removed for the wider floodplain adjacent to the tributary could be used to build a berm between the floodplain and the wooded areas on the west side of the park. The berm could either be a gradual slope or have a more engineered design, such as terracing. This floodplain would contain small flood events, but could possibly flood the recreational part of the park in high flood events. Ponding would not exceed 4 feet and the design of the vegetation and gradient of the area would be such that there are no stagnant water pools. Any ponding in the floodplain would drain within 5 days, so that mosquitoes cannot breed and vegetation will thrive.

Water-Quality Treatment. Given characteristics of the drainage basin, it is expected that the runoff would primarily contain leaves and debris, some municipal trash, and sand and sediment from roads and open areas. Not much nutrient loading is expected. We propose that the treatment of stormwater be divided into two parts: 1) engineered pretreatment facilities that trap trash and settle sand and sediment at three outfalls into the park, and 2) continued treatment within the floodplain, where smaller particles will partially be settled and trapped in the vegetation, and where nutrient uptake in wetland vegetation will take place.

Figure 2-12. *Proposed conceptual plan of Eastmorland Park.*

We recommend three pretreatment facilities that have different functions, depending on their location and the area it is draining:

- *Full treatment in south outfall.* Because the area draining into the current south concrete channel is approximately 50 acres, there is ample space within that channel to fully treat the stormwater for sediment loading. Trash and debris could be trapped immediately when entering the channel. A series of smaller ponds could settle out sediment for all rain events. Another option would be to use more sophisticated engineered solutions, such as sand filters or underground filtration systems.
- *Partial treatment in east outfall.* A stormwater pipe 72 inches in diameter enters the park from the east, draining an area of over 700 acres. Full treatment of the water is not possible due to space constraints, but water from some small rain events entering the park from this outfall could be treated in a small, relatively shallow detention pond. (A detailed site analysis and the preliminary design of the wet detention pond would be required.) Such a wet detention pond would remove sand and coarse sediment loading from small rain events, but large rain events would bypass the detention pond and enter the floodplain after removal of trash and debris. The location at the east part of the park would require modification of the Head Start parking lot.
- *Retrofit of stormwater-management practices to the north.* One of the more noticeable stormwater discharges into the park is from the adjacent commercial property of Woodman's grocery store. The Woodman's property is about 13 acres of impervious parking lots and rooftops, of which an estimated 85 percent drains directly into the park through two outfalls. Because parking lots can be more polluted than residential areas, and given the proximity to the park, Woodman's could proactively engage in retrofitting stormwater-management practices at their property. This would be valuable for improving the water quality of the floodplain and for increasing community efforts to make this park an enjoyable recreational area. Such efforts could include treatment processes at the park outfalls, grassy swales or bioretention in the parking lot along with partial regrading or installation of pervious pavement, and rain barrels.

These ideas are based on a preliminary study of the park and its drainage area, and are only conceptual.

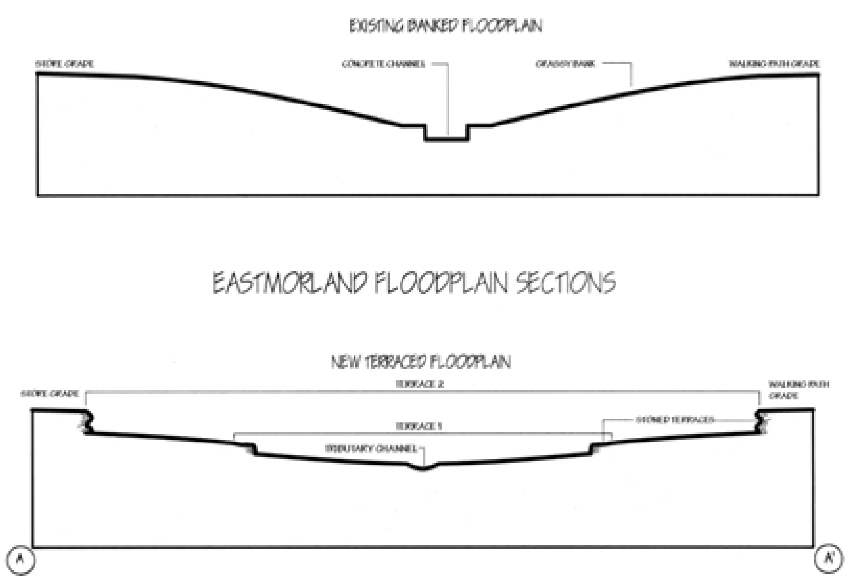


Figure 2-13. *Cross section A–A´ (see fig. 2-12) showing current channel and proposed floodplain.*

Further studies are needed to determine the feasibility of the conceptual framework discussed here. Such studies include detailed site analysis, topography, soils and subsurface geology. Hydraulic analysis is needed to address flood risk issues and water levels, especially when designing the pretreatment facilities. Because of the innovative nature of stormwater management proposed here as well as the nature and shape of the park, research efforts should follow the project to determine the functionality of stormwater quality treatment systems like this.

Goal 2: Recreational Area

Because the area is a public park that is very close to neighboring lots, special consideration needs to be given to a variety of recreational activities and aesthetics. This could be accomplished in three ways: an area shaded by tree plantings, a riparian area, and a mowed area.

- The area *shaded by tree plantings* would focus along the perimeter of the park. To accommodate requests from adjacent neighbors, trees along the south and west sides of the park would remain intact. In addition, parts of the existing trail would be removed and replaced with trees and shrubs. These shaded areas would reduce the visual and auditory impact of the urban surroundings and allow for a more natural setting.
- A *riparian corridor* along the channel would parallel the channel into the wetland area, and would contain native vegetation. Not only could it be aesthetically pleasing, but it could also provide the benefits of bank naturalization. The footpath would be relocated to the southern periphery of the corridor, would have a small circular section near the wetland area, and would continue on the berm between the floodplain and wooded areas along the west side of the park. It is predicted that increased riparian and wetland vegetation in the park will improve wildlife habitat and in turn improve recreational activities such as bird watching.
- A *mowed area* just south of the proposed walking trail and the walking trail itself could serve as the delineator between the mowed and riparian areas. Benches could be placed periodically in the mowed grass alongside the walking trail. It could be used as a dog exercise area or a small, open space for informal sports activities. Bikers could also potentially use the footpath. Parts of the existing walking trail could remain to provide easier pedestrian and bicycle access to the grocery store. However, of greater focus for bikes is the connectivity of the existing bike trail. In this plan, a bridge would be constructed over the south channel, allowing for direct access from Dawes Street to Dempsey Street.

The stormwater design could serve as a demonstration site for how intermittent stormwater drainage can be enhanced by introducing riparian vegetation, thus creating a natural looking environment combined with engineered stormwater-management solutions. Likewise, the vegetation along the riparian corridor can serve as an educational tool about bank stabilization and plant identification.

Finally, safety considerations need to be taken into account, particularly with the stormwater-management and streambank designs. Slopes would be gradual rather than extremely steep to avoid falls, and ponds would be relatively shallow. Other safety measures typical to parks, such as lighting, are also recommended.

Goal 3: Management and Maintenance Plan

For any plan to be successful, continued management and maintenance are necessary; therefore, we suggest management and maintenance practices. Any planted vegetation in the riparian corridor will need to be maintained annually, primarily to weed out aggressive invasive species, such as reed canary grass. As seen in the stream corridor survey, much of the vegetative buffer contains aggressive exotics and invasives. Volunteer efforts could be an excellent way to maintain healthy vegetation. Stormwater-treatment facilities will also need maintenance. The City of Madison Parks Department will need to dredge periodically, and they will also need to continue tree maintenance in the park. Maintaining the mowed areas at a level of upkeep suitable for recreational activities would also be helpful. We recommend that these management and maintenance practices be fully considered before more detailed site design takes place.

Goal 4: Stakeholder Inclusion

This preliminary design has not been through a public participation process or had stakeholder input. Therefore, we recommend stakeholder inclusion in the design of Eastmorland Park. Current planning literature touts public participation, even to the degree of including stakeholders in a plan's design phase. Without inclusion, public resistance may prevent implementation. If implementation does take place, there is a risk the park will not be used if it was not designed to meet the public's needs.

Rather than presenting this conceptual plan in a public meeting, charrettes have been successful as an alternative scenario for stakeholder inclusion. A charrette is an open, group process involving all relevant parties. In it, the parties meet intensively for several consecutive days to create the plan (National Charrette Institute, no date). Because the parties involved in a charrette would create their own design, this conceptual plan could be included in the charrette as an example. It could also serve as a steppingstone for other design alternatives.

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3 BASEFLOW

Decrease of Baseflow

One of the largest concerns facing Starkweather Creek is its overall decrease in baseflow. Urbanization has caused increased groundwater pumping and decreased recharge due to impervious areas; this has resulted in lowering of the water table and reduced baseflow discharged to the creek. Baseflow is a source of clean water at a constant temperature from groundwater discharge to the creek. Streams that rely solely on precipitation or stormwater as their primary water source can suffer from low or nonexistent flows during dry times (Dingman, 2002).

The baseflow reduction has caused many areas of the Starkweather Creek to become stagnant with water that no longer flows at a high enough volume and velocity to dilute pollutants, bring fresh oxygenated water into the system, and prevent rapid temperature fluctuations (Dane County Regional Planning Commission, 1983). The result is a creek that is unable to harbor diverse aquatic life and is much less appealing to the general public, aesthetically and recreationally.

Due to the ecological degradation associated with continuing loss in baseflow, it is important that attempts be made to slow and eventually halt baseflow declines. We present four options that, if implemented, would help mitigate baseflow loss within the creek:

- targeting high recharge locations to increase infiltration and baseflow,
- installation of stormwater-infiltration practices to enhance water penetration in urban areas,
- modification of groundwater-pumping practices to reduce water-table drawdown, and
- artificially increasing baseflow through the addition of treated effluent discharge in the headwaters of the creek.

Baseflow Conditions

During many times of the year, streams carry water resulting from precipitation, including snowmelt and rainfall. However, during periods of little precipitation, many streams have additional sources of water called baseflow. Baseflow can be provided by groundwater discharge from an aquifer, from surface-water storage, as in the case of a river that flows from or through a lake or wetland, or from the melting of glacier ice or of snow that is present throughout most of the year (Dingman, 2002). In the case of Starkweather Creek, baseflow is provided by groundwater discharge (Hunt and others, 2001) and urban sources, such as sump pumpage. Under natural conditions, groundwater is able

Figure 3-1. *The hydrologic cycle and the effect of urbanization on a watershed.*

to reach the stream when the water table intersects the streambed. As the water table rises, groundwater is released to the stream via a series of springs and seeps (Dane County Regional Planning Commission, 1999).

Groundwater discharge is continually replenished by precipitation (fig. 3-1). Precipitation percolates into the ground through pervious surfaces, such as grass or other vegetation, and down through the soil until it reaches the water table, where it recharges the groundwater system. The process of water moving from the soil surface and into the soil is termed infiltration (Dingman, 2002). Infiltration rates (along with evaporation, evapotranspiration, and precipitation) limit the water available for recharge. With all other conditions being equal, the area with the highest infiltration rate is able to recharge the groundwater faster than the area with a lower infiltration rate.

Starkweather Creek has become more urbanized and the surrounding areas have continued to grow in population, causing baseflow to decrease significantly. Groundwater pumping for commercial, industrial, and residential use has lowered the water table (Hunt and others, 2001), and less water is discharged to the creek. The water that is pumped is not returned to the watershed; following treatment, wastewater is directed south of the city to Badfish Creek, where it eventually reaches the Rock River. Increasing urbanization has also decreased the amount of precipitation that is able to infiltrate and replenish the groundwater supplies. Rooftops, pavement, and other urban surfaces are impervious and do not allow precipitation to penetrate and reach the aquifer. Instead, precipitation that falls on impervious surfaces is carried away via storm drains and stormsewers. Much of the stormwater that would normally infiltrate and replenish groundwater supplies is carried directly to Starkweather Creek and surrounding bodies of water (Dane County Regional Planning Commission, 1999). These stormwater flows can be very damaging to ecosystems because of erosion from high water volumes, higher concentrations of contaminants, higher temperatures, low levels of dissolved oxygen, and decreased water clarity.

Historically, the creek was fed by many springs and seeps scattered throughout the watershed. However, we observed that many of these springs and seeps have disappeared and those that remain are greatly diminished. Data collected from 1942 to 1943 at the Milwaukee Street bridge indicated a baseflow of 5 cubic feet per second (cfs) in the East Branch of Starkweather Creek (Sawyer, 1942–44). By the time of Sawyer's study, vast changes had already occurred within the watershed, including dredging of the creek and groundwater pumping (Dane County Regional Planning Commission, 1983). It is likely that original baseflow conditions were higher. Data collected at both Milwaukee Street bridges from 1976 to 1979 indicated that baseflow in the creek had dropped to an average 2 cfs in both branches (Dane County Regional Planning Commission, 1983). According to the 2004 Dane County Regional Hydrologic Study's projections, by 2030 baseflow conditions within the East Branch are expected to drop to zero; the West Branch is expected to drop to 0.57 cfs (Dane County Regional Planning Commission, 1997).

We decided not to measure baseflow in Starkweather Creek because of the difficulties of measuring low flows in low-gradient streams. We focused on the springs that supply Starkweather Creek with its baseflow. Although baseflow is extremely low, there are still functioning springs within Starkweather Creek watershed.

Our spring survey focused on the East Branch of Starkweather Creek (fig. 3-2). The East Branch begins northeast of Interstate 90–94; however, inputs from seeps and springs are not significant until just west of the interstate. A large spring is located approximately 200 yards west of Interstate 90–94 near East Towne Mall; this spring is the largest on the East Branch. Several smaller springs exist on the Blatner property, just south of Highway 30.

One location, thought to be a spring, was actually discovered to be a discharge location for a drainage tile. This tile, in the Triangle Marsh just west of Lien Road, provides a constant source of cool water to the creek (even in the heat of August), and therefore acts very much like a spring, adding to baseflow in the creek. Knowledge of the drainage tiles would be beneficial if wetland-restoration efforts take place on the parcel. (See chapter 4, *Wetlands,* for additional information.)

Several other areas within the Triangle Marsh, originally thought to be spring ponds, may in fact be drainage-tile related as well. However, because of the dense vegetation and overlying sediment, it was not possible make any clear determinations. Our attempts to acquire detailed drainage-tile maps of the area proved unsuccessful.

It is our contention that other springs are feeding the East Branch of Starkweather Creek; however, given the relatively short survey period and extremely dry conditions during the time of our study, our efforts to locate these springs proved futile. At the time of our spring survey, vegetation growth within the watershed likely shielded some springs from view, and drought conditions may have lowered and/or temporarily halted spring discharges. Figure 3-2 displays the locations of the springs we identified, including the drainage-tile discharge area and other questionable sites. This is by no means a comprehensive listing of all springs on the East Branch; these are the springs that we were able to identify at the time of the survey. For further information on possible locations of springs within the watershed, consult *Spring Head Survey of Dane County* (Fish Management Division, 1958–59).

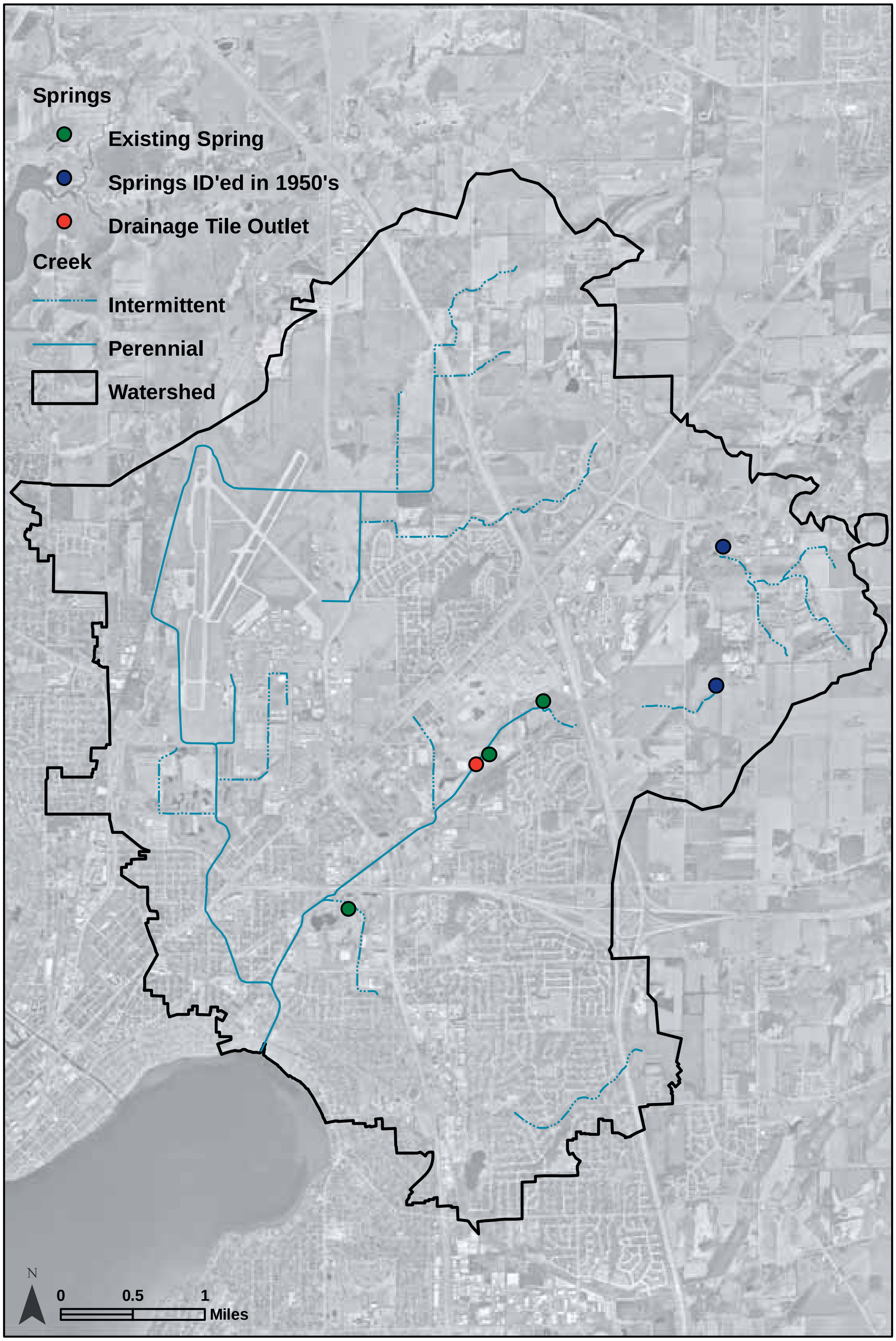

Figure 3-2. *Historic and current springs within the Starkweather Creek watershed.*

Infiltration Practices Currently In Use

Infiltration basins

Infiltrations basins are a large-scale, "end-of-pipe" solution; they capture stormwater in a basin and temporarily store the water while it infiltrates into the ground over a period of days. A typical basin will collect water from a few parcels. To maintain infiltration capacity, basins will typically be planted with deeply rooted plants to keep the soil from clogging with fine sediment. This technique is probably the most common type of infiltration mitigation (Barr Engineering Company, 2001).

Bioretention facilities and rain gardens

Bioretention facilities are shallow vegetated depression areas installed to capture and infiltrate runoff from nearby impervious areas. Simple facilities, called rain gardens, consist of inundation-tolerant plants in a rooting zone that has an approximate depth of 2 feet and a ponding zone of approximately 2 feet (fig. 3-3). In addition, enhanced facilities have a deeper storage zone consisting of sand or gravel, where water is stored to allow for increased infiltration capacity and a perforated underdrain pipe joins the rooting zone and storage zone.

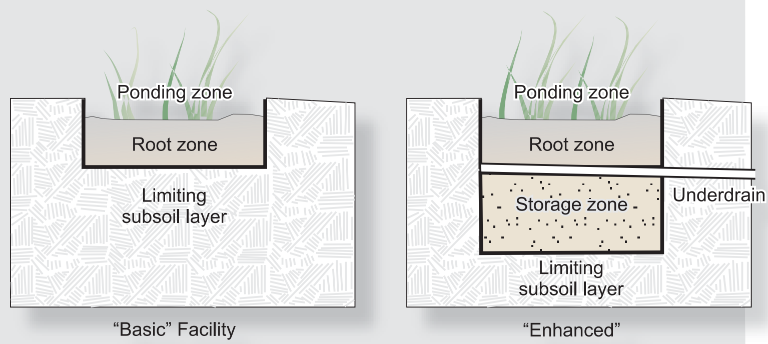

Figure 3-3. *Bioretention facility (modifed from Atchison and others, 2005).*

Infiltration trenches

Infiltration trenches are long, narrow trenches filled with gravel. Runoff is directed into the trench and infiltrates through the gravel into the subsoil. Perforated piping can be installed in the gravel to help direct water from the surface into the infiltration bed (Cahill Associates, 2004). Although gravel in the trench filters some pollutants and sediment from the water prior to infiltration, it is also necessary to install a vegetated buffer adjacent to the trench to allow water to be pretreated, which limits potential clogging of the trench system from soil particles in the water and also facilitates pollution removal (California Stormwater Quality Association, 2003).

Vegetated swales with check dams

Vegetated swales can be installed in place of curb and gutter systems and are generally only used in residential areas that have less concentrated stormwater flow. The swale consists of a broad narrow channel covered with dense vegetation on the sides and bottom. Periodic check dams can be used to dampen the flow of water and enhance infiltration (U.S. Environmental Protection Agency, 1999a).

Porous pavement

Porous pavement is a hard surface that allows water to infiltrate through pores in the material or spaces between sections of impermeable surface like square blocks. Ideal applications of porous pavement are generally installed as parking lots, sidewalks or low traffic density streets (California Stormwater Quality Association, 2003).

Infiltration drainfields

Infiltration drainfields consist of a pretreatment structure, perforated pipe manifold, and a subsurface drainfield. Stormwater flows through the pretreatment structure and is cleaned of particulates and other pollution, conveyed into the manifold, and released into a drainfield. The drainfield consists of a large gravel pit and is commonly placed under large open areas, such as parking lots or athletic fields (U.S. Environmental Protection Agency, 1999b).

Infiltration Assessment and Opportunities

To understand the hydrologic conditions of the watershed for enhancing infiltration, we conducted analyses using geographic information systems (GIS) and simulation modeling. The two methods provided us with an understanding of how infiltration rates could be improved and a means to locate ideal areas for directed infiltration within the watershed.

Our objectives were to

- determine the locations for recharge opportunities within the watershed,
- evaluate the benefits of enhanced infiltration on different geographic scales, and
- discuss opportunities to increase recharge rates with infiltration practices.

Locating Potential Recharge Areas

One way to attempt to increase baseflow is by installing infiltration facilities in areas that have the greatest potential for soil infiltration and groundwater recharge. We conducted a GIS analysis to determine where these areas are located throughout the Starkweather Creek watershed. The key factors that promote groundwater recharge are depth to bedrock, subsoil permeability and water-table depth (Dane County Regional Planning Commission, 1997). Appendix C contains details of our GIS layers and analyses.

The map that we generated of recharge areas shows that a patchy amount of recharge potential within the watershed (fig. 3-4). In general, the recharge areas tend to be concentrated near the creek channel within a distance that allows for an acceptable depth to water table. Because of the significant uncertainty of the soils and water-table data (see appendix C), we recommend that field verification of these two components is conducted prior to any preliminary site assessment or facility planning.

Siting Locations for Infiltration Facilities

We used the recharge-areas GIS layer to attempt to identify some specific locations where infiltration facilities could be installed throughout the watershed. The WDNR has published standards for site evaluation for stormwater infiltration that include subsurface restrictions and other important considerations (table 3-1). As shown in figure 3-5, approximately one-third of the recharge area was impacted by WDNR evaluation criteria and could probably not be used for infiltration facilities.

Many of the WDNR evaluation criteria can be difficult to assess, but are important. For example, step 10 (table 3-5) requires that a site be evaluated for its groundwater-contamination potential. Historically, groundwater flow has been difficult to predict, even for professional hydrogeologists (Schwartz and Zhang, 2003). But careful consideration of groundwater contamination potential should be taken where stormwater could infiltrate aquifers used for municipal drinking water. Figure 3-5 shows that the zones of contribution for municipal high capacity wells encompass a large area of the watershed. These zones of contribution were the result of the modeling and management program

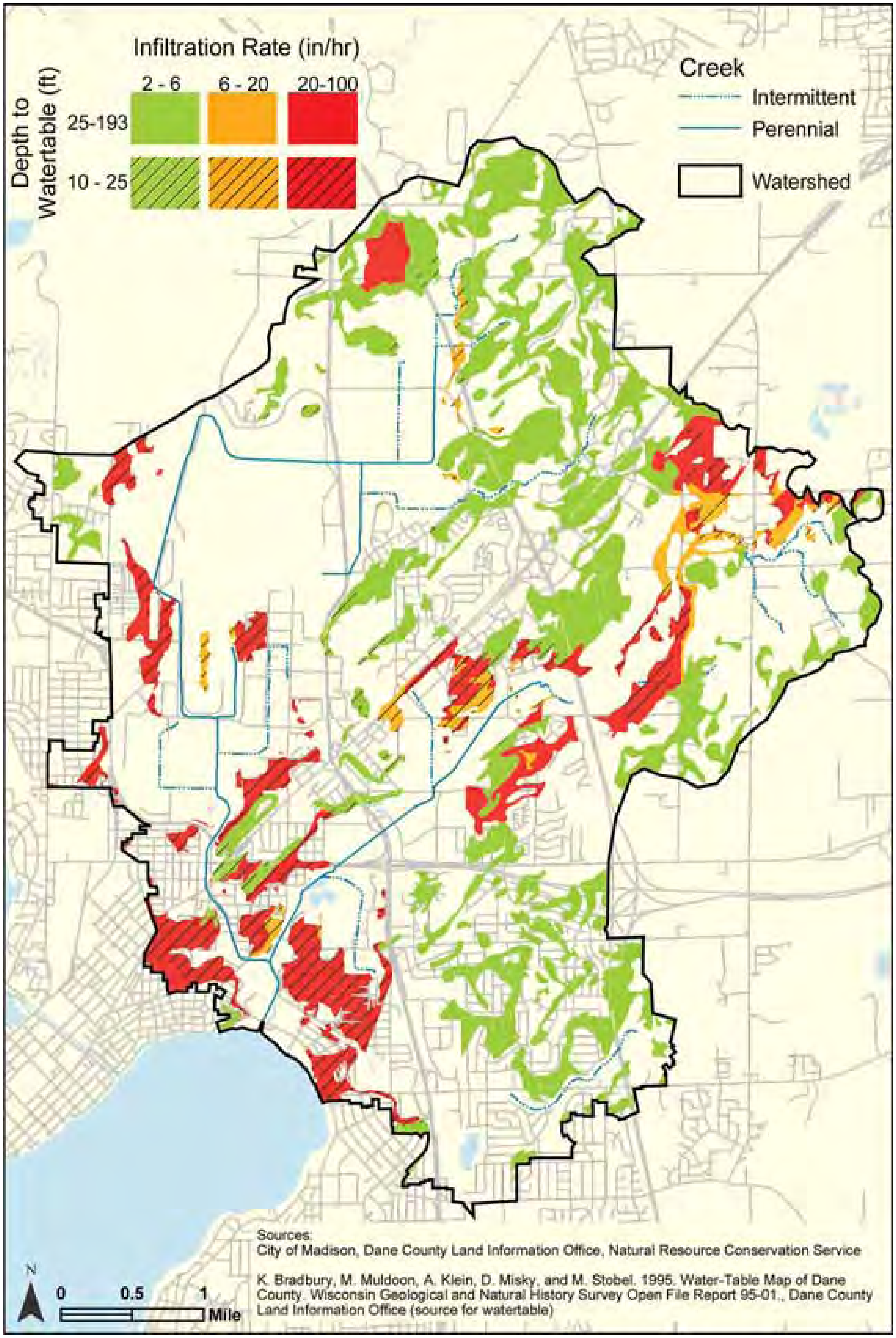

Figure 3-4. *Location of recharge areas within the Starkweather Creek watershed.*

Table 3-1. *Wisconsin Department of Natural Resources standards for site evaluation for stormwater infiltration.*

Site Evaluation Step A: Initial Screening
1. Site topography and slopes greater than 20%.[1]
2. Site soil infiltration capacity characteristics as defined in NRCS County soil surveys.
3. Soil parent material.[2]
4. Regional or local depth to groundwater and bedrock. Use seasonally high groundwater information where available.[2]
5. Distance to sites listed on the GIS Registry of Closed Remediation sites within 500 feet from the perimeter of the development site.[1]
6. Distance to sites listed on the Bureau of Remediation and Redevelopment Tracking System within 500 feet from the perimeter of the development site.
7. Presence of endangered species habitat.
8. Presence of floodplains and flood fringes.[1]
9. Location of hydric soils based on the USDA County Soil Survey and wetlands from the WDNR Wisconsin Wetland Inventory map.[1]
10. Sites where the installation of stormwater infiltration devices is excluded, due to the potential for groundwater contamination, by chapter NR 151 Wis. Adm. Code.[1]
11. Sites exempted by chapter NR 151 Wis. Adm. Code from the requirement to install infiltration devices.
12. Potential impact to adjacent property.

Taken from WDNR Conservation Practice Standard 1002 (Wisconsin Departmen of Natural Resources, 2004)

[1] assessed in GIS (see fig. 3-5)

[2] assessed for recharge-area analysis

conducted by the Dane County Regional Planning Commission (2004). The figure shows 5-, 50-, and 100-year zones of contribution based on expected year 2030 pumping rates; these zones would be useful for planners to use when siting infiltration facilities.

Another challenge of installing infiltration facilities is that in the developed part of the watershed, most parcels are privately owned and have already been built upon, and so only small amounts of land are available for infiltration facilities. Essentially, the only lands available are existing public lands, vacant lands, or lands with private owners who are willing to volunteer their property for public use.

Of the 368 public land parcels within the watershed, 77 overlap with potential recharge area (red parcels, fig. 3-6). In addition, 153 parcels lie within 500 feet of the potential recharge areas (orange parcels, fig. 3-6) and could also be used for infiltration facilities. The most apparent area of overlap, located approximately in the center of the map and surrounded by development, is Sycamore Park. However, because Sycamore Park is a decommissioned and capped landfill, it could not be used. Possible locations are the southeast corner of Reindahl Park, the far north area of the watershed, the northwest corner of the watershed, Schenk Elementary School, and O.B. Sherry Park, and Olbrich Park.

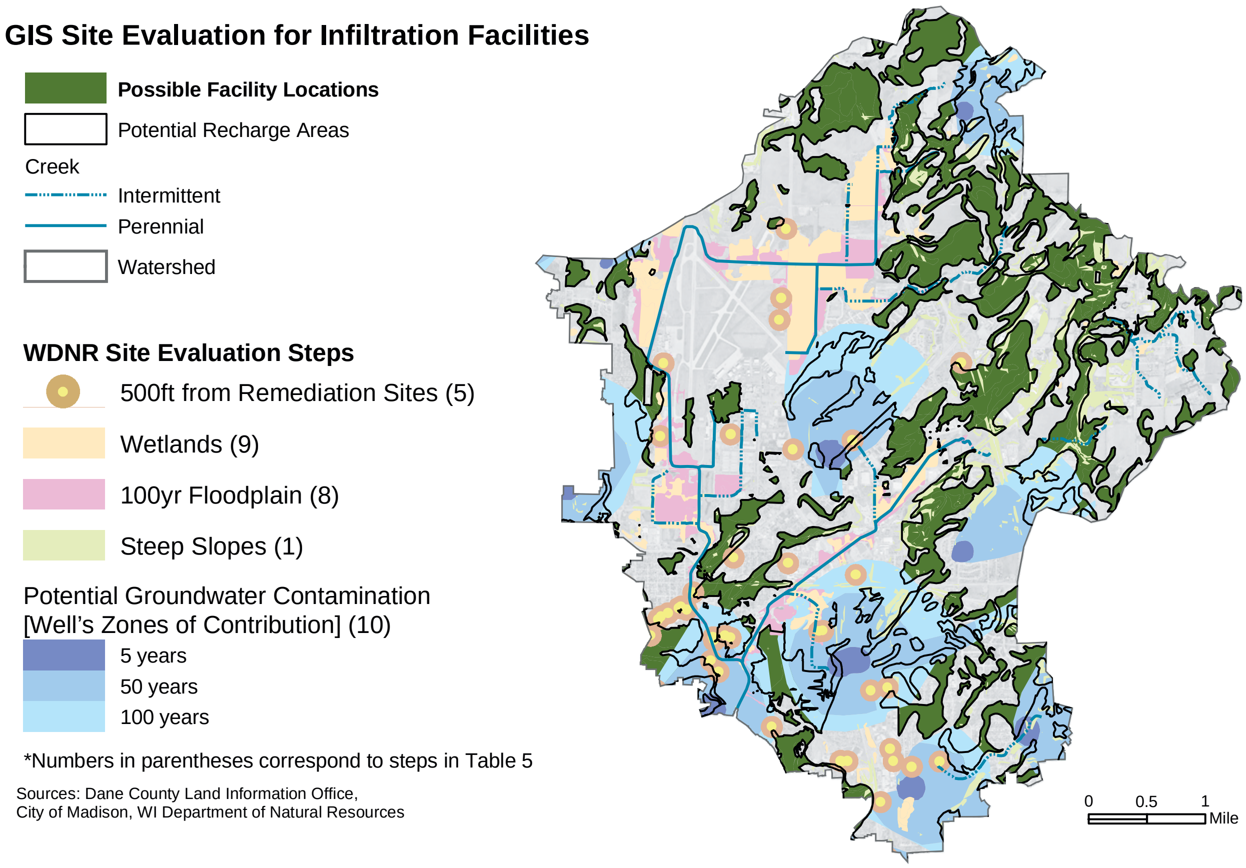

Figure 3-5. *Site evaluation for infiltration facilities.*

Infiltration Modeling

To assess the benefits of implementing of infiltration practices throughout the entire watershed, we used hydrologic simulation models to assess current and predevelopment conditions and analyzed the effect of introduced infiltration practices. We examined the watershed on various geographic scales. We modeled the entire Starkweather Creek watershed, a smaller subwatershed in the Rolling Meadows neighborhood, and an average single family lot. On a broad scale, we attempted to understand the current water budget of the watershed as well as determine the extent that infiltration practices can increase the current depth of recharge. On the subwatershed level, we examined more closely the impacts of different land uses on runoff and infiltration increases with rain gardens. At the smallest scale, we evaluated the impact a rain garden can make for the average single family lot in the watershed.

Watershed Analysis

The objective of the watershed analysis was to estimate the current hydrologic conditions in the Starkweather Creek watershed and determine how infiltration practices could increase recharge rates. Because of the link between recharge and baseflow, increases in recharge can positively impact the health of the creek by increasing baseflow.

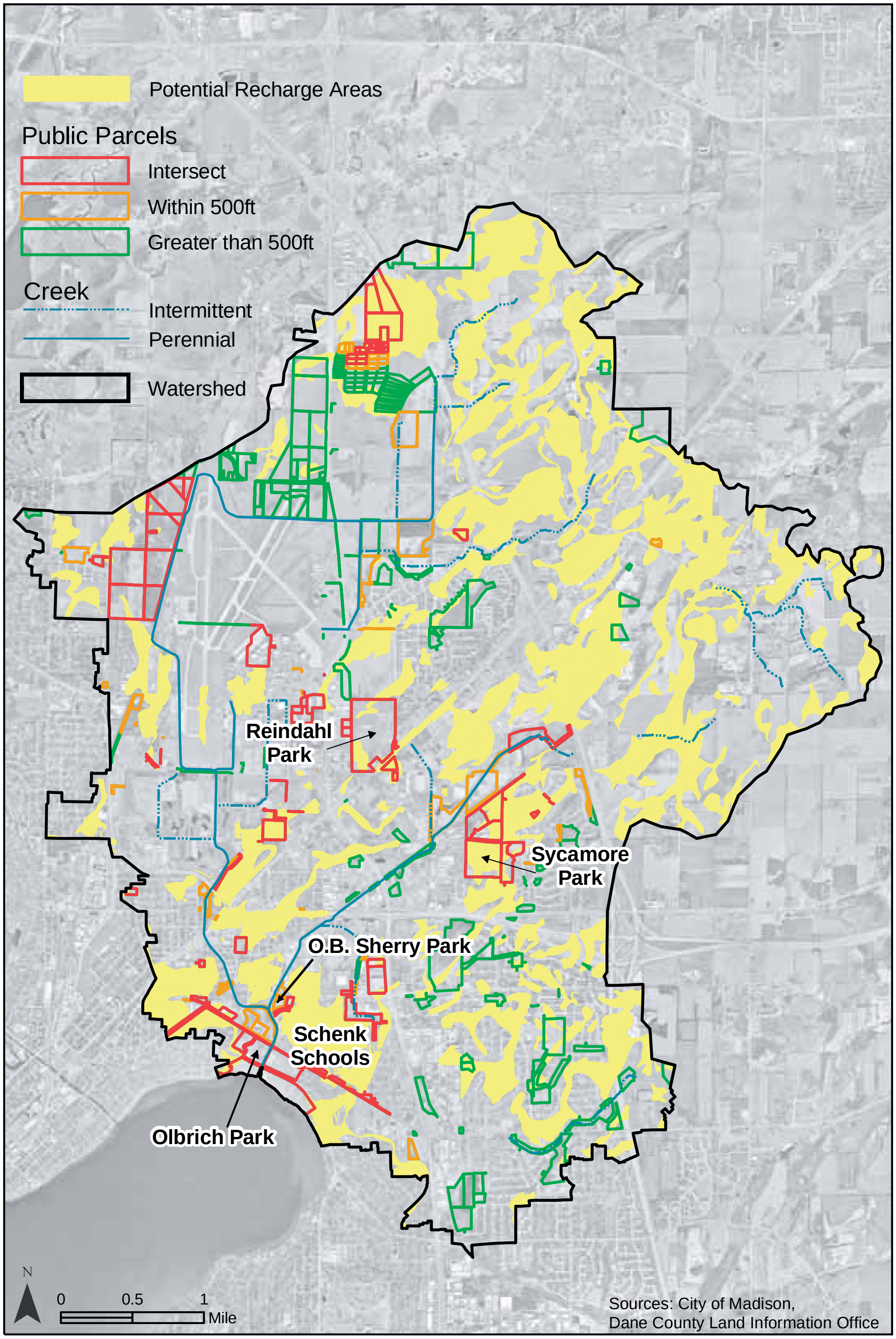

Figure 3-6. *Locations of publicly owned parcels in relation to recharge areas.*

In-depth evaluation of the entire watershed was impossible to achieve with the time and information available to us. Therefore, the results from this model should be seen as preliminary to a more detailed analysis.

To begin the watershed analysis, we assessed current soils and land-use data. Soils in the watershed were distributed into four hydrologic soil groups as classified by the Natural Resources Conservation Service. This classification system ranks soils from A to D, or from least to greatest runoff potential. Soil in the Starkweather Creek watershed is silty loam and predominantly B (78%); A, C, and D soils total less than 3 percent of the watershed, and dual groupings of A/D and B/D make up the remaining 20 percent (5% A/D and 15% B/D). Soils of these dual groups are wet soils that can be drained. The first letter represents how the soil functions if drained properly, and the second if it is not. With the uncertainty for the extent to which soils in the watershed are drained, we acted conservatively by using a classification of B for 90 percent of the watershed and D for the remaining 10 percent. Predevelopment conditions for the watershed were based on the Natural Resources Conservation Service values for good quality forested soil.

The land-use information is based on GIS land-use data from Dane County and the Source Land-Use and Management Model (SLAMM) calibrated for the state of Wisconsin (U.S. Geological Survey, 2005). The type and area of each land use were taken from the land-use data and grouped into fewer land-use types on the basis of the SLAMM land-use descriptions. These groups were closer to land-cover percentages (that is, percentage of parking and roof) than land-use type (such as commercial, industrial, etc.). The SLAMM files provided percentages of land cover within each land use, such as rooftop, driveway, landscaped area, etc. In cases where there were no direct correlations of the GIS land-use files to SLAMM land-use files, estimations were made on the basis of rough calculations from orthophotographs.

Streets, roads, and highways were classified in the land-use data as one group. Streets or rights of way constitute a separate land use within our GIS files, yet a part of other land-use types with the SLAMM files. Rights of way include streets, terraces, and sidewalks. To account for this discrepancy, street areas were split from the land-use information in the SLAMM files and run separately in the model. The remaining other percentages within the SLAMM files were adjusted accordingly. Additionally, an estimate of 80 percent impervious was made for street area and 20 percent pervious for terraces.

The model used for these analyses is Infiltration Patch (IP), Version 3.7, a Microsoft Excel-based model that allows for the incorporation of infiltration practices when modeling stormwater runoff. Infiltration Patch is based on the Natural Resources Conservation Service Technical Release 55 (TR-55) curve-number method using a 50-year warm weather rainfall record (April 15–October 15) for Madison, Wisconsin.

Rain gardens were the only infiltration practices we modeled in these analyses. Rain gardens are small scale, vegetated infiltration practices that can mitigate storm runoff and increase infiltration. The rain garden size was 15 percent of the source area, as supported by previous modeling research for southern Wisconsin (Dussaillant, 2004). Rain gardens were only considered for B soils because they are not feasible at low infiltration rates. Although rain gardens are most commonly used in residential areas to infiltrate runoff from rooftops, rain gardens collecting street runoff are becoming a more common type of stormwater-management practice. Street rain gardens replace the curb, gutter, and terrace with a rain garden into which the runoff from the street is diverted. Our infiltration analyses include both types of rain gardens.

Recharge calculations were also made using RECARGA, a model developed at the University of Wisconsin and accepted by the WDNR for use in the design of infiltration practices. The model used the MAD1981US rainfall file that includes rainfall from 1981, a year when the storm events best represent Madison's precipitation conditions. RECARGA calculated the depth of recharge in B soils for a rain garden of 15 percent of the source (roof) area. With the results from RECARGA and the percentage of rooftops for all buildings within the watershed (as determined from the SLAMM files), we were able to determine the depth of recharge for the entire watershed.

Our watershed-wide modeling with the IP model provided an overview of the water budgets from current and predevelopment conditions. The water budgets represent runoff and stay-on values (values that include evapotranspiration and recharge) for an average year with 19.88 inches of precipitation (from April 15 to October 15). The difference in runoff is the best indication of how changes in the urban landscape impact hydrologic conditions. The runoff depth under current conditions is considerably greater than under predevelopment, forested conditions: from less than 1 inch in predevelopment (0.24 inches), or 1.2 percent of total precipitation, compared with 4.39 inches, or 22.1 percent of precipitation in present-day conditions of the watershed (fig. 3-7).

To calculate recharge rates, evapotranspiration needs to be deducted from the total stay-on depths. Although our modeling allowed for the computation of stay-on depths, determining evapotranspiration without the assistance of a model was challenging under urban conditions. Calculating evapotranspiration for an urban environment has not been studied and is thought to be the "weakest point in the study of urban water balance" (Grimmond and Oke, 1991). Also, the results of our model were limited due to the shortened length of the model year, April to October. Recharge primarily occurs during the coldest months at times of minimal evapotranspiration, so this model greatly underestimates the potential for groundwater recharge. Therefore, recharge values were not calculated with the results from the IP model for current and predevelopment conditions.

However, with the assistance of the RECARGA model, we were able to calculate additional recharge depths from infiltration practices. The model calculated the depth of recharge for a rain garden under B soil conditions to be 13.39 inches/year. Assuming all the rooftops in the watershed (roughly 9% of the total area) were directed to a rain garden that was 15 percent of each rooftop area, recharge rates distributed over the entire watershed would be 1.16 inches. A more realistic approach to this calculation would be

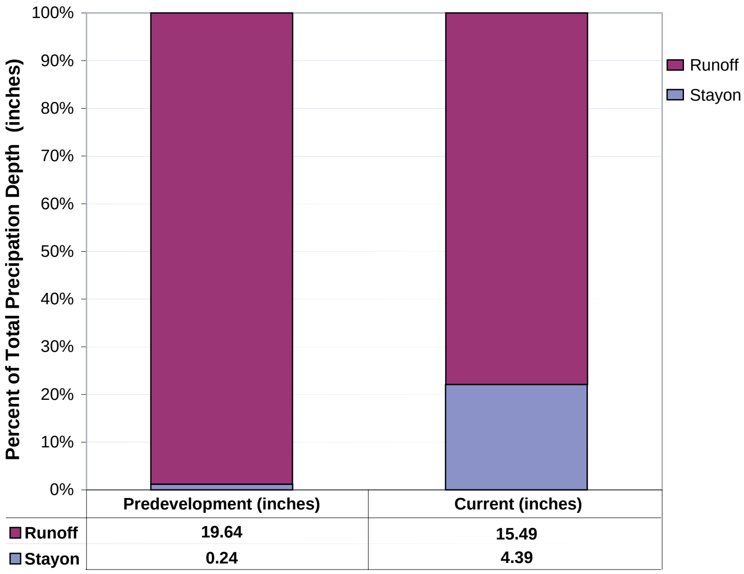

Figure 3-7. *Annual water budgets of current and predevelopment conditions.*

an estimate of 10 or 20 percent of the watershed's rooftops, resulting in a depth of recharge of only 0.12 or 0.24 inches/year.

Another approach to increase infiltration with rain gardens and other bioinfiltration practices is to infiltrate the runoff from street surfaces. Our estimate of land use in the watershed shows that approximately 12 percent of the watershed is roads and more than 13 percent consists of parking lots and driveways. With such large areas of impervious surfaces, infiltration practices located at the edge of streets to infiltrate runoff could be an option for increasing infiltration at more significant rates. By infiltrating all roads within the watershed, 3 inches of additional recharge could occur annually.

We understand that installing a rain garden on every lot and on all curbsides is not practical, economically or logistically. But this analysis does illustrate the extensive actions that would be required to meet the recommended increases to watershed-wide recharge. Additionally, further analysis should be done to identify local benefits of recharge on a smaller scale. For example, recharging the groundwater in proximity to dormant springs may reestablish these springs or increase local baseflow.

Small Watershed Analysis

On a smaller scale, detailed analysis of a subwatershed was conducted to determine the benefits that small-scale infiltration practices can have on runoff and infiltration volumes at a local level. The Rolling Meadows subwatershed (subwatershed ST11-0151), located in the southeast region of the watershed was selected for this analysis (fig. 3-8). This 197-acre subwatershed is primarily residential, consists of hydrologic soil group B, and has a depth to water table ranging from 20 to 40 feet. There are no existing municipal infiltration basins or other stormwater-management practices within the watershed, hence the need for alternative practices. Existing stormwater management conditions in the watershed consist of curb and gutter drainage except for three blocks in the southwestern corner. The stormsewers within the watershed direct the water to the northwest corner off Diamond Drive and eventually enter Starkweather Creek.

Data collection for the subwatershed was conducted through direct measurements of land cover using an orthophoto to determine land-cover percentages. Roofs and driveways were measured manually from orthophotographs for all land uses and averages were made for the residential areas. Field observations were conducted to confirm land

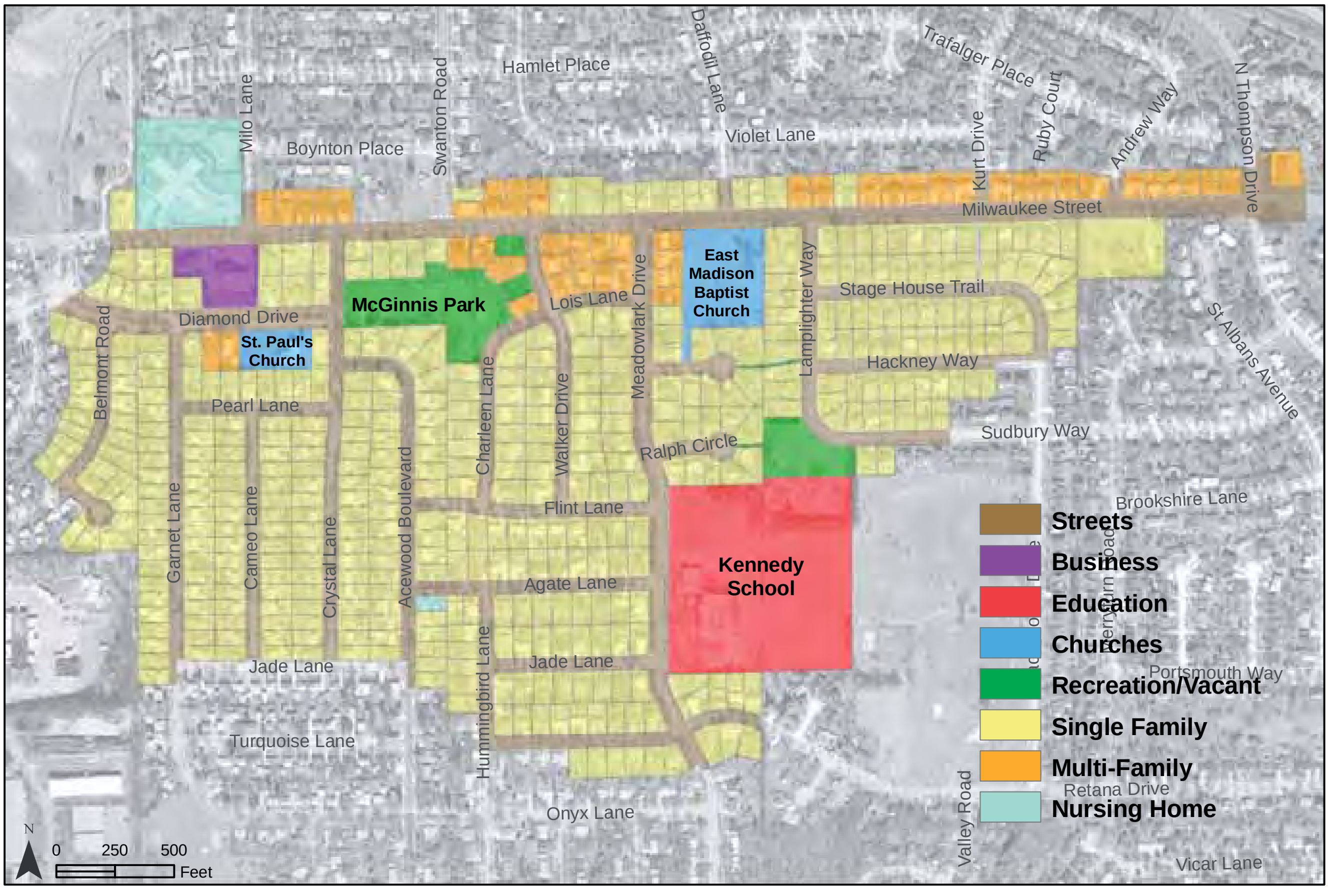

Figure 3-8. *Rolling Meadows subwatershed.*

cover as well as to determine the downspout connectedness. Our survey indicated that 50 percent of the downspouts were disconnected (that is, they flowed to lawns or other pervious area). Due to site constraints, field observations also indicated that realistically most parcels would only have space for rain gardens that infiltrated 50 percent of the total roof area. Therefore, only 50 percent of each roof is directed to a rain garden within the model. The Infiltration Patch hydrologic model was used for this analysis with the data found in appendix C, table C-6.

By comparing land-use ratios in the watershed to the total runoff contribution (fig. 3-9A and B), streets consist of 22.3 percent of the watershed area yet contribute 44.5 percent of the total runoff depth. This data shows that streets are a significant source of runoff that could be infiltrated.

Figure 3-10 displays the water budgets for the Rolling Meadows watershed over the model year with runoff and stay-on values. The scenarios B–E are a range of rooftop percentages in the watershed that direct runoff to rain gardens. As shown from the results, if 10 percent of the rooftops direct runoff to a rain garden, only a 2.5 percent reduction of annual runoff depth would result. Considerable improvements to runoff reduction begin to occur after 50 percent of the roofs are directed to rain gardens, or when street runoff is infiltrated with rain gardens.

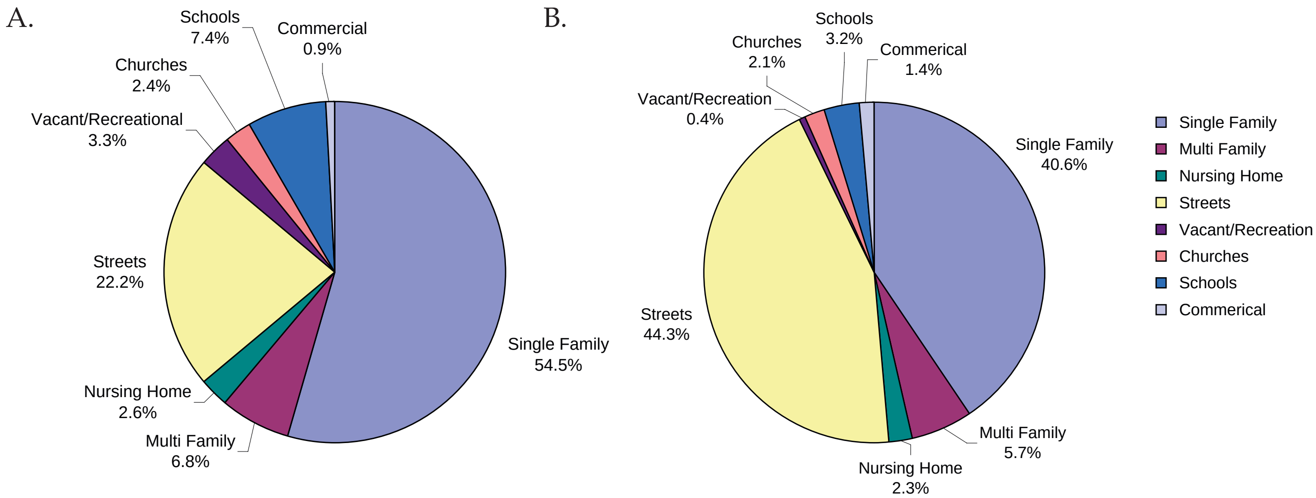

Figure 3-9. *Land-use (A) and runoff contributions (B) for current conditions in Rolling Meadows.*

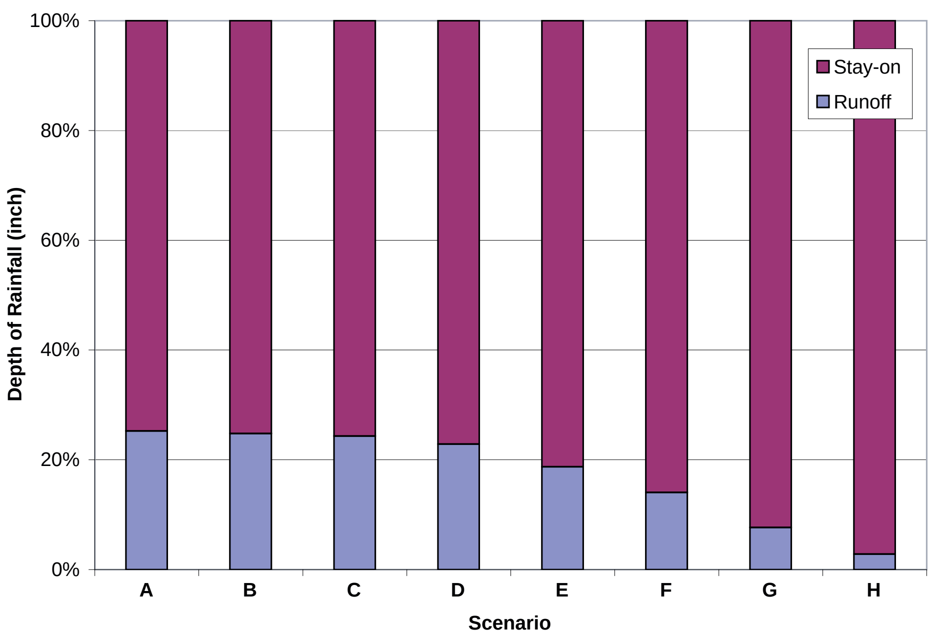

Figure 3-10. *Impacts of rain gardens to runoff and stay-on depths. A: Current conditions with no infiltration practices installed. B: 10% of the roofs directed to rain gardens. C: 20% of the roofs directed to rain gardens. D: 50% of the roofs directed to rain gardens. E: 100% of the roofs directed to rain gardens. F: 100% of the streets directed to rain gardens (no roof rain gardens). G: 100% of the streets and 100% of the roofs directed to rain gardens. H: Predevelopment conditions.*

Single Parcel Evaluation

A closer look at an average single-family residential parcel in the Rolling Meadows watershed better illustrates the impact a rain garden can have on minimizing runoff. Figure 3-11 compares the runoff of a parcel without infiltration practices to a parcel with a rain garden. The results conclude that a rain garden could reduce the surface runoff of a parcel by 54 percent. This reduction supports rain garden effectiveness at minimizing runoff on a single lot, yet due to the large contributions of street runoff, these reductions are difficult to observe on a watershed scale.

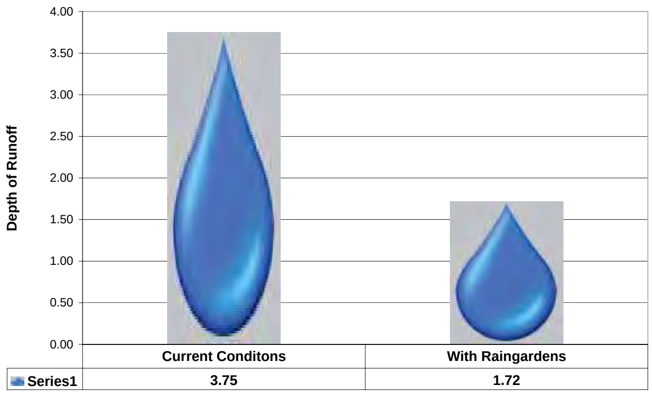

Figure 3-11. *Annual runoff reductions of an average single family house with rain gardens.*

Rain gardens for a single-family home

The average single-family house in the Rolling Meadows subwatershed has approximately 2,200 square feet of roof area and 670 square feet of driveway and walkways. If one were to install a rain garden for an average house, at the effective size of 15 percent of the total roof runoff area (for half the roof), the rain garden would be 165 square feet. To install this rain garden would be approximately $495 to $825 (at $3 to $5/sq ft, which includes no costs for labor and additional support); professional installation would cost approximately $1,650 (at $10/sq ft) (Minnesota Lakes Association, 2005).

Recommendations

Our analyses focused strictly on the hydrologic conditions of the watershed, disregarding the water-quality implications that would be influenced by these infiltration practices. Further analysis should examine the runoff's contributions of nutrients, sediment, and other major water-quality parameters with SLAMM or other water-quality models. Water-quality benefits could significantly support the installation of bioinfiltration practices where runoff reductions or recharge increases alone could not.

At the watershed and subwatershed scales, infiltrating street runoff can make significant reductions in overall runoff volumes and increases in recharge depths. Although the feasibility of broad-scale construction of rain gardens is low, retrofitting these practices on a small scale is the first step. Installation would require a joint effort from the local government and residents for the responsibility of the long-term maintenance. Monitoring data from the Seattle Edge Alternative Project, in which Seattle, Washington, neighborhoods have street rain gardens, have shown success by reducing runoff volume from a 2-year storm by 98 percent (Seattle Public Utilities, 2005). In 2006 a similar project will be implemented in the Lake Wingra neighborhood of Madison to demonstrate the feasibility of street infiltration in southern Wisconsin.

Additional infiltration practices could also be considered for watershed improvements. Models could be used to evaluate other practices, such as infiltration trenches, porous pavement, and swales, that may be more feasible or economical under certain conditions. In addition, rain barrels are an alternative to rain gardens and can be located anywhere, regardless of infiltration conditions, to capture runoff volume and delay peak flow. Simulation modeling of rain barrel effects is becoming more common (such as by SLAMM and RECARGA) and should be done in further analyses to compare to the benefits of rain gardens.

Infiltration practices may not be the most realistic approach to increase baseflow on the broad scale of Starkweather Creek, but small-scale infiltration practices can be moderately effective, whether effectiveness is evaluated on the basis of improved water quality, runoff reductions, or local recharge enhancement.

Groundwater Assessment

Another approach to improving baseflow conditions in the watershed is to focus on groundwater pumping. All water used for municipal purposes in the Madison area comes from groundwater (Public Service Commission of Wisconsin, 2004). In the Starkweather Creek watershed high capacity wells owned and operated by the city of Madison pump more than 4.5 million gallons per day (Krohelski and others, 2000); figure 3-12 shows the pumping rates and locations of these wells. The water table in the upper bedrock formations of the watershed has been drawn down by 10 to 30 feet; in the lower bedrock aquifer, as much as 40 to 60 feet of drawdown has occurred (Hunt and others, 2001). As a result of the drawdown, the water table no longer intersects with the surface, causing the creek to be disconnected from the water table and significantly decreasing baseflow. The obvious solution is to combat the causes of the water-table drawdown by decreasing pumping and/or increasing recharge within the watershed.

Model Design

To obtain a quantitative understanding of the groundwater levels in the Starkweather Creek watershed and to estimate what would be necessary to increase and potentially restore baseflow to Starkweather Creek, we refined a Dane County groundwater model for the watershed. This model is the result of a Telescopic Mesh Refinement (TMR) performed on the Dane County groundwater flow model. The flow modeling project started in 1992 and was constructed through collaboration between the Wisconsin Geological and Natural History Survey, the Dane County Regional Planning Commission, and the U.S. Geological Survey (Krohelski and others, 2000). The Dane County groundwater model and the TMR were constructed with the U.S. Geological Survey groundwater flow model code MODFLOW and manipulated with the graphical user interface GroundWater Vistas.

The cells within the original grid that related to the Starkweather Creek watershed were effectively cut into quarters. After this grid refinement, the river package within the model was further refined to more accurately follow the actual path of Starkweather Creek to obtain more realistic results from the model. The river package was only applied to the East and West Branches of the creek and the confluence area was modeled as if it were part of Lake Monona due to the hydrologic properties of that area of the creek. Through this process, the mass balance and leakance properties of the Dane County model were preserved with less than a 3 percent error.

These refinements resulted in a more detailed model of the Starkweather Creek watershed. This base model represents the current conditions within the watershed. Current pumping rates and physical hydrogeological properties were used. Three simulations were run in the Starkweather Creek model to illustrate how changes in pumping or recharge rates could affect the groundwater levels.

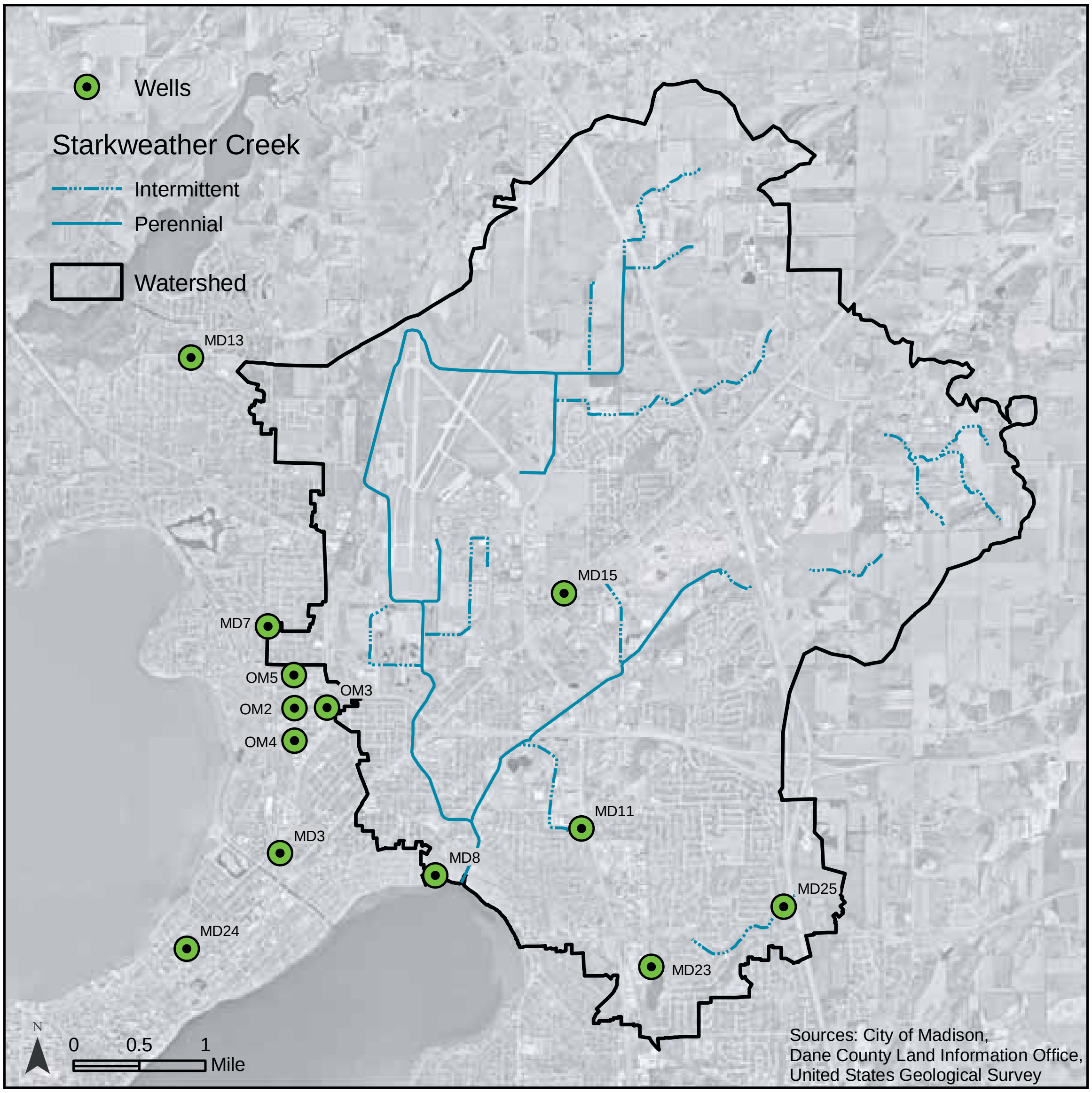

Figure 3-12. *Locations of high capacity municipal wells in Starkweather Creek watershed.*

Recharge Simulations

The first simulation of the Starkweather Creek groundwater model was run to determine how much of an increase in recharge would be needed to bring baseflow back to the earliest recorded measurements in the creek. Studies conducted by Sawyer (1942–1944) indicated that baseflow in the East Branch was around 5 cfs. Because no record of baseflow in the West Branch existed at that time, we assumed it to be equal to that of the East Branch. The current conditions of recharge that were used in the model were previously set in the Dane County model and were based upon the research of Swanson (1996). Her study estimated theoretical recharge rates using parameters such as soil percolation rates, soil moisture storage, temperature, precipitation, and evapotranspiration rates.

Table 3-2. *Modeled baseflow in both branches of Starkweather Creek under current pumping rates and variable recharge scenarios.*

	Recharge (in/yr)	Baseflow (cfs) West Branch	East Branch
Current	6.5	0.8	2.2
+ 4.3	10.8	2.9	4.0
+9.7	16.2	5.0	6.0
+15.1	21.6	7.1	8.1

In the first run of the model, existing pumping rates were maintained; the recharge rates of the watershed were manipulated to determine how much recharge would be needed to increase baseflow to 5 cfs in each branch of the creek. Current recharge rates are modeled to be 6.5 inches per year (in/yr) and give very limited baseflow to the creek. The groundwater model also calculated the current baseflow in the creek to be 0.8 cfs in the West Branch and 2.2 cfs in the East Branch. We ran numerous simulations until a condition close to that of the 1940s was reached. The results from the model showed that a recharge rate of 16.2 in/yr is necessary to produce a baseflow of 5.0 cfs in the West Branch and 6.0 cfs in the East Branch (table 3-2).

The necessary recharge rate of 16.2 in/yr is 9.7 in/yr greater than current recharge. The infiltration analysis results presented in the *Infiltration Modeling* section of this chapter showed that about 1.2 in/yr of recharge could be added to the watershed with homeowner bioinfiltration systems. When comparing this value to the groundwater model's recharge prediction, it becomes clear that enhancing recharge rates while maintaining present pumping rates will not return Starkweather Creek to 1940s conditions. On its own, the enhancement of recharge through infiltration practices will not be the most effective way to bring baseflow back to the creek. High pumping rates are the main cause of groundwater drawdown and the subsequent decrease in baseflow for Starkweather Creek. Thus, changes in pumping rates will likely provide the most benefit when trying to increase baseflow. However, bioinfiltration facilities reduce stormwater runoff, which creates numerous surface-water benefits.

Groundwater Pumping Simulations

The second simulation performed within the Starkweather Creek groundwater model was run to determine the effects that changes in groundwater pumping rates will have on baseflow in Starkweather Creek. The groundwater simulation was run using current recharge rates; pumping rates were varied (fig. 3-13). Head levels (the elevation of the water table seen in the wells) vary throughout the watershed. Under current pumping rates, the average head level is approximately 866 feet. When the pumping rate of each high capacity well within the watershed is doubled, the model produced a decrease in head level to approximately 859 feet, 7 feet lower than current conditions. This simulation was run to determine what head levels are to be expected with increased pumping rates in the future as water demands increase.

In the second pumping simulation, current pumping rates were cut in half. This decreased the drawdown to 870 feet of elevation. Head levels near Lake Monona did not change significantly, but this is to be expected because the lake-water elevation maintains the elevation of the nearby groundwater levels. Throughout the rest of the watershed, head elevations showed a 4-foot increase. Baseflow also increased within the

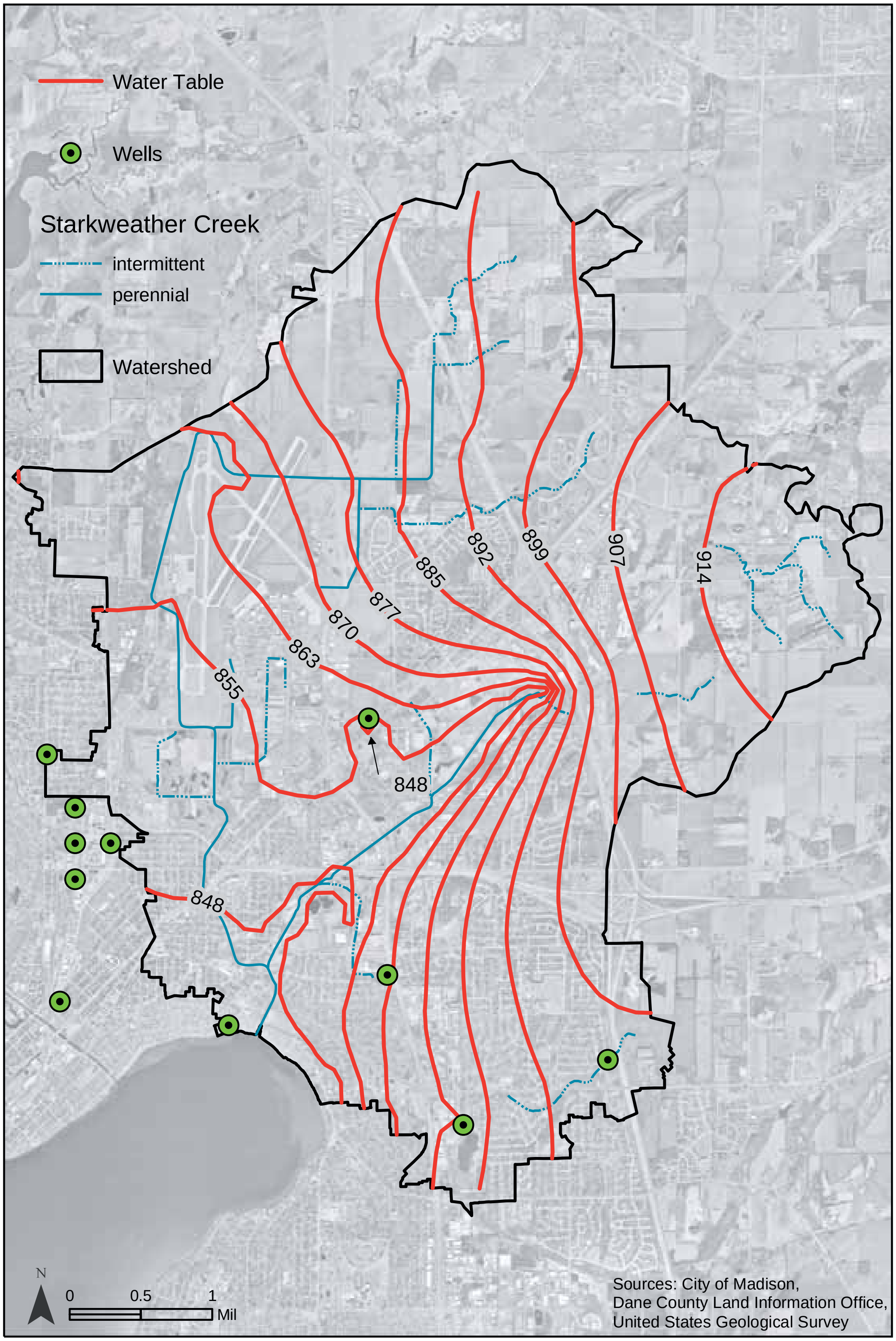

Figure 3-13. *Simulated current groundwater levels in Starkweather Creek watershed.*

watershed to 1.7 cfs in the West Branch and 2.6 cfs in the East Branch, a total respective increase of 0.9 cfs (112%) and 0.4 cfs (18%) per branch.

We ran a third simulation in which all the wells were turned off and no pumping was taking place within the watershed. We found head elevations to be 873 feet, approximately a 7-foot increase when compared to current conditions. Baseflow, however, increased much more than in the simulation in which pumping rates were halved. With no pumping, baseflow was 2.6 cfs in the West Branch and 3.0 cfs in the East Branch, a respective increase of 1.8 cfs (225%) and 0.8 cfs (36%). This baseflow is not equal to the levels from the 1940s because water wells pumping from outside the Starkweather Creek watershed intercept some of the groundwater that would otherwise discharge to the creek.

Comparing the results of the recharge investigation to that of the groundwater pumping, it is evident that only the most extreme in each case shows any significant increase in baseflow for the creek. It would take a significant amount of time, effort, and planning to reach either extreme. Decreased pumping with increased recharge would probably result in the most benefit with the least amount of effort.

Combined Recharge and Pumping Simulations

We ran two scenarios with the groundwater model to see what impact changing recharge and pumping would have on the baseflow in Starkweather Creek. In the first scenario, groundwater pumping rates were cut in half, and recharge rates were increased 50 percent, to a total of 8.6 in/yr. This increased head levels to 878 feet, an average increase of 12 feet when compared to current conditions. Baseflow also increased more than any of the prior simulations, to 2.9 cfs in the West Branch and 3.6 cfs in the East Branch, a total increase of 2.1 cfs and 1.5 cfs, respectively.

A slightly more realistic simulation was run where groundwater pumping was decreased 25 percent and recharge was increased by 25 percent to 7.2 in/yr (fig. 3-14). Head elevations in this case were 873 feet, an increase of 7 feet. As expected, baseflow did not increase as much as it did with the 50-percent decrease in pumping and increase in recharge. In this case, baseflow was 1.9 cfs in the West Branch and 2.9 cfs in the East Branch. The results of these different pumping simulations are tabulated in table 3-3.

While running these different pumping and recharge simulations, we observed that the most response in changing head levels occurred in the upper reaches of the watershed. When pumping increased, head levels showed the greatest decrease in this area; when pumping decreased, head levels showed the greatest increase in this area. A backward particle-tracking simulation done by the U.S. Geological Survey also showed that the upper reaches of Starkweather Creek are the source area for much of the water pumped from wells within the watershed (Hunt and others, 2001). In the case of the Starkweather Creek watershed, the water comes from the upper reaches. This area is also an area of potentially high infiltration rates, according to the analysis discussed in the *Locating*

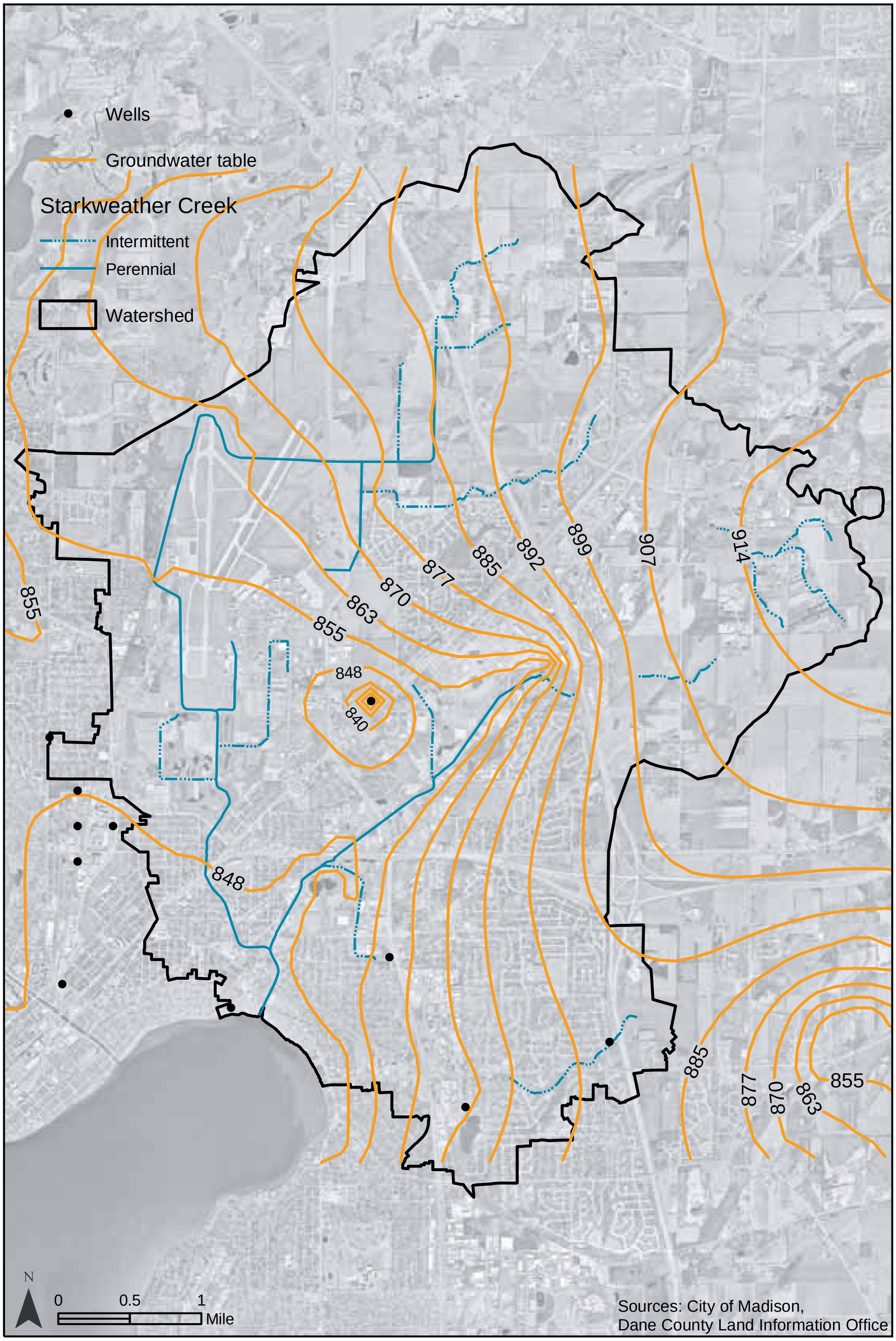

Figure 3-14. *Simulated groundwater levels in Starkweather Creek watershed, using a 25-percent increase in recharge and a 25-percent decrease in pumping.*

Table 3-3. *Baseflow conditions generated by different pumping scenarios, including increases in recharge rates, decreases in groundwater pumping, and maintaining current conditions.*

Pumping scenario	Pumping rate (mgd)	Recharge scenario	Recharge rate (in/yr)	Baseflow (cfs) West Branch	Baseflow (cfs) East Branch
Predevelopment	0.0	Predevelopment		5.0	5.0
Current rates	4.5	Current rates	6.5	0.8	2.2
Decrease pumping (50%)	2.3	Current rates	6.5	1.7	2.6
Current rates	4.5	Increase recharge (66%)	10.8	2.9	4.0
Decrease pumping (25%)	3.4	Increase recharge (25%)	8.1	1.9	2.9
Decrease pumping (50%)	2.3	Increase recharge (50%)	9.7	2.9	3.6

Potential Recharge Areas section of this chapter. The upper areas of the watershed appear to be a prime location to focus infiltration efforts.

Although increasing recharge can have a major effect on increasing baseflow to Starkweather Creek, it is extremely difficult for it to mitigate the large effect that pumping millions of gallons of groundwater has on the watershed. Without decreases in pumping, it is not likely that baseflow will significantly increase in Starkweather Creek. Ideally, conservative and conscientious use of groundwater resources may reduce demands from the wells and allow pumping rates to decrease. Combined efforts of reducing pumping and increasing recharge might allow baseflow to be naturally restored to Starkweather Creek.

Treated Effluent Discharge

Increased impervious surfaces and groundwater pumping are not the only factors influencing baseflow reductions. In the Yahara Lakes system, after pumped groundwater is used for municipal purposes, it is diverted out of the watershed for treatment and eventual discharge. This is primarily done to protect the quality of the Yahara Lakes. Treated effluent contains a higher level of phosphorous than natural water. Introducing phosphorus could cause an increase in eutrophication within the lake system (Richard Lathrop, verbal communication). However, this major diversion of water from the Yahara watershed causes a decrease in baseflow and lake levels (fig. 3-15). This water-quantity problem has been acknowledged by the Madison Metropolitan Sewerage District (MMSD) and other local agencies for more than 30 years (Dane County Regional Planning Commission, 1997).

Several solutions to this problem have been proposed, including the discharge of treated wastewater effluent back into the Yahara River above Lake Mendota. By introducing treated effluent into a degraded urban stream such as Starkweather Creek, several objectives can be achieved, for the health of Starkweather Creek as well as the overall improvement of baseflow conditions in the Yahara River.

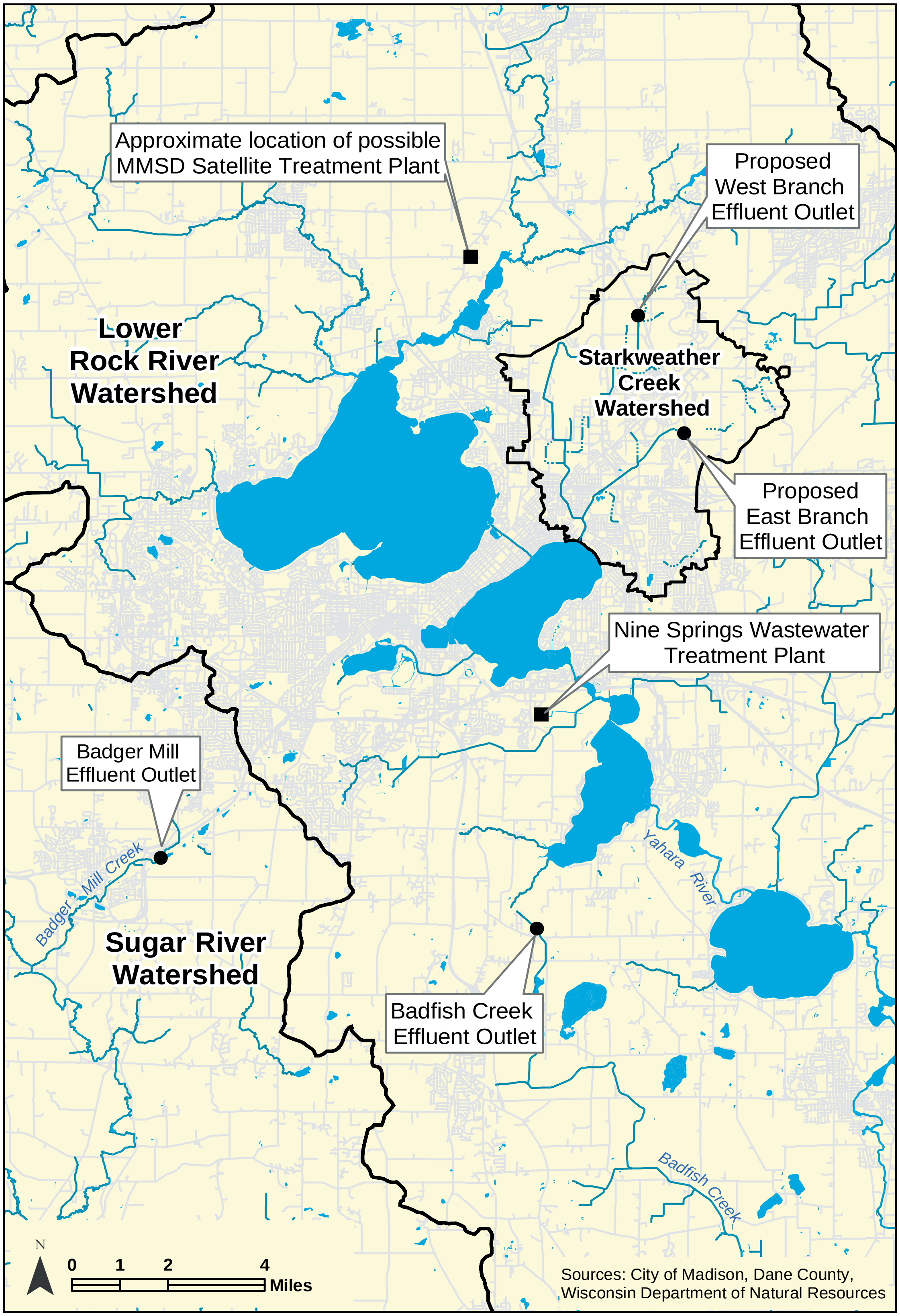

Figure 3-15. *Yahara River system and the groundwater pumping wells in the Madison Metropolitan Sewerage District service area.*

Benefits of Treated Effluent in Starkweather Creek

The Starkweather Creek watershed has been identified by several sources as one of the watersheds most affected by groundwater pumping and diversion (Dane County Regional Planning Commission, 1997). Introducing treated effluent by direct discharge into Starkweather Creek could improve the ecological functions of the stream producing several positive benefits to the watershed.

Increased baseflow improves the hydraulic dynamics in the creek by increasing velocities and elevating water levels. Baseflow was approximately 5 cfs in the East Branch in the early 1940s (Sawyer, 1942–1944). During that same time period, interviews with locals have suggested rich fish life in the creek (Greg Schill, verbal communication, April 2005). By introducing 2 to 5 cfs of treated effluent into each branch of Starkweather Creek (4–10 cfs total discharge), it is expected that aquatic habitat conditions could improve considerably, creating spawning potential and better living conditions for fish and other species.

Low baseflow conditions also cause a buildup of contaminants from sources such as urban runoff, landfill leaching, and industrial discharge. This increase in contaminant concentrations in the water and sediments inhibits of natural ecological functions and the capacity of the stream to sustain life. Introducing treated effluent under dry conditions would dilute and flush contaminants concentrations downstream more quickly.

Another consequence of low baseflow and stream gradient is low flow velocities, which cause frequent stagnation of the water in the creek. Under eutrophic conditions, especially in late summer, dissolved oxygen is depleted. This can result in fish kills and uninhabitable conditions for aerobic life. Dissolved oxygen concentrations have been detected as low as 1 mg/L in Starkweather Creek; the generally accepted threshold for sustaining life in a stream is 5 mg/L (Dane County Regional Planning Commission, 1983; section NR 102.02[3], Wisconsin Administrative Code). Effluent treatment facilities may have aerators that can elevate dissolved oxygen concentrations. Effluent discharge from the MMSD Nine Springs Treatment Facility passes through an aerator, increasing dissolved oxygen concentrations to around 5.5 mg/L (Montgomery Watson, 1995). During late summer, when creek flow and dissolved oxygen are at their lowest, the introduction of treated effluent can be the most beneficial.

Treated Effluent and Badger Mill Creek

Using treated wastewater effluent to augment flow in streams and rivers is not uncommon and is a very efficient use of water resources. A local example is the return of treated effluent from the Nine Springs treatment plant to Badger Mill Creek upstream of the Sugar River. Historically, the Sugar River watershed's wastewater was treated at the Nine Springs treatment plant and released to Badfish Creek, which is outside the Sugar River watershed. However, after the MMSD annexed Verona, a decision was made to return the treated effluent to its original watershed. A pipe was laid from the Nine Springs treatment facility into Badger Mill Creek to return the amount of water taken from the basin for treatment. Prior to diversion of the treated water back into the Sugar River watershed, several considerations were raised, such as the impact on fisheries in the Sugar River, temperature changes, and water-quality concerns. But after thorough study and monitoring, this project has demonstrated success by improving fish habitat in Badger Mill Creek with minimal negative impact (Dave Taylor, MMSD, verbal communication, 2005).

The concerns for Badger Mill Creek differ from the Yahara River and Starkweather Creek for two main reasons. Badger Mill Creek does not have to deal with the complications resulting from phosphorus input into the Yahara Lakes. Badger Mill Creek and Sugar River were and remain in a better ecological condition than Starkweather Creek.

Potential Considerations

The treated effluent discharged into Badger Mill Creek has proven to be a success, but much research was involved, providing the scientific evidence for such extensive and controversial modifications. Prior to discharging treated effluent into Starkweather Creek, extensive analysis of the proposal will also need to be conducted. Several issues need to be taken into consideration when proposing, designing, and implementing new and innovative solutions.

State and federal laws mandate regulations that must be followed for a project of this magnitude to be approved. Many of these regulations are intended to protect the quality of surface waters in the State of Wisconsin. Starkweather Creek is treated as surface water under the category of limited forage fish community in Chapter NR 102, Wisconsin Administrative Code. Because of its degraded state, Starkweather Creek is not considered suitable for the protection and propagation of balanced fish and other aquatic life (section NR 102.04, Wisconsin Administrative Code). Because Starkweather Creek is highly degraded, the addition of treated effluent could have significant positive impacts.

Further studies are needed to understand the water-quality impacts of the introduced effluent. Some questions to consider are: What influences will introduced effluent have on the creek's living conditions in seasons in which the natural dissolved oxygen is higher than the dissolved oxygen of the treated effluent? What happens to the temperature regime in the creek when effluent of a constant warm temperature is discharged into the creek when it might freeze over? How will the physical characteristics of the water affect the recreational opportunities in the creek?

One of the major concerns with urban waterways is the risk of flooding. The longitudinal gradient of Starkweather Creek averages about 1.3 feet per mile, creating a rather flat, flood-prone environment (Dane County Regional Planning Commission, 1983) If 5 cfs of treated effluent is to be discharged into each branch, total baseflow would be increased by a factor of three. However, due to the extent of urbanization in the Starkweather Creek watershed, the increased baseflow levels are minimal compared to flash floods during storm events. Therefore, it is not likely that increased baseflow through treated effluent discharge will affect flood conditions. However, we recommend that hydrologic studies be conducted to ensure that flood risk is not elevated.

One of the more challenging aspects of introducing the treated effluent into Starkweather Creek will undoubtedly be the transportation of the water to the upper reaches of each branch. No infrastructure is currently available in the watershed to transport the effluent. Therefore, extensive engineering design of pipelines and a pumping regime would be necessary for the project to be implemented. One way to minimize costs would be to use existing rights of way, such as current wastewater interceptors.

Lake Monona and Phosphorus Loading Limitations

Although it is important to address the above considerations, the requirements for discharge into Lake Monona will be the determining factor in the success of this alternative. Currently, section 281.47, Wisconsin Statutes, places conditions on when such a discharge may occur into a lake: Generally, the conditions require advanced treatment (that is, beyond secondary treatment) that would "accomplish substantially the same results in eliminating nuisance conditions in the lakes as would be accomplished by diversion." For wastewater to be discharged into Starkweather Creek, it would be necessary for the water to undergo tertiary treatment that reduces phosphorus to an acceptable level. Facilities can reduce the total phosphorus concentrations to 0.02mg/L (Heinzmann and Chorus, 1994).

The surrounding communities strongly support the protection of the Yahara Lakes from nutrient enrichment, specifically from phosphorus loading, which is the limiting nutrient in the eutrophication process. Decades of studies have shown algae, macrophytes, and more recently blue-green algae in the lakes as a result of nutrient runoff from fertilizers and other anthropogenic sources. Restricting the input of phosphorus into the lakes could improve the quality of the lakes for aquatic habitat as well as recreational use.

This lake-protection policy is not likely to be changed, although pressure to improve hydrologic conditions in the area is increasing. It is therefore important to reconcile the two seemingly opposing goals in a solution where wastewater is treated to the degree that will minimize nutrient loading and the management of discharge regimes to minimize impact on the seasonal variations of dissolved phosphorus. Such a solution could serve the purposes of both management goals, to minimize phosphorus loading in the Yahara Lakes and improve the hydrological cycle in the adjacent watersheds to improve water-quantity conditions.

Management and Recommendations

Although more studies are required to evaluate the different challenges facing a project of this magnitude, we have several recommendations on the basis of this preliminary analysis of the feasibility of introducing treated wastewater effluent into Starkweather Creek. These recommendations are based on the assumption that a tertiary treatment facility will be constructed by MMSD north of Lake Mendota and that policy makers for the Yahara Lakes will look at the management of the lakes from a watershed-management perspective. The following scenario is proposed as one alternative:

- Tertiary wastewater-treatment plant designed for ultra phosphorus removal constructed north of Lake Mendota delivers effluent with total phosphorus (TP) concentrations reduced to 0.01 mg/L.
- Transmission lines to transport a maximum of 5 to 10 cfs of treated effluent laid next to the current northeast sewer system interceptor. Discharge of 2 to 5 cfs into the West Branch at the airport, by County Road CV or by Highway 51. Continuation of the transmission line following the existing sewer system pipelines for a discharge of 3 to 5 cfs into the East Branch by the interstate 90/94.
- Each discharge point designed with a natural-looking aerator with capacity of 5 to 6 mg/L of dissolved oxygen.
- Management of the discharge regimes to be conducted in such a way that discharge be reduced or eliminated at times of the year when monitored TP concentrations in Lake Monona are at a maximum. Total discharge to be managed so that TP loading in Lake Monona will not exceed required limits set by the WDNR.

Other alternatives need to be investigated so the best overall solution can be achieved for all concerned, including local citizens, resource agencies, and effected ecosystems. In the future, increased pressure could be placed on local and state authorities to integrate management of the Yahara Lakes and their tributaries. The option of using treated effluent to improve the quality of Starkweather Creek can be implemented if enough political will is available.

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4 WETLANDS

Urban Wetlands: A Delicate Balance

Wetlands within the Starkweather Creek watershed perform different ecosystem functions. One such function is the ability of these wetlands to serve as important habitat for diverse plant and animal species. The wetlands act as breeding grounds, nurseries, feeding areas, and travel corridors for many species, including songbirds, waterfowl, reptiles, amphibians, small mammals, and white-tailed deer. In developed areas where habitat is becoming increasingly scarce, wetlands have increased in importance because they provide a refuge for many species existing on the fringe of urban development (Wisconsin Department of Natural Resources, no date).

Wetlands also have the potential to help mitigate urban runoff. Dense vegetation, coupled with their location within watersheds, allows wetlands connected to stream channels and runoff sources to store large amounts of precipitation and floodwater, thereby reducing downstream effects (Wisconsin Department of Natural Resources, no date). Following storm events, wetlands are able to slowly release stored water to rivers, lakes, and streams. Wetlands are also able to absorb large amounts of nutrients, pollutants, and sediments, filtering these materials from the stormwater before it enters rivers and lakes. Although urban wetlands can trap and store harmful chemicals and nutrients and also transform them to less harmful states, wetlands can suffer from overexposure to contaminants, leading to a decrease in filtering capacities over time (Mitsch and Gosselink, 2000).

Unfortunately, the ability to serve one of these functions can come at the cost of the other. Nutrient- and sediment-rich runoff that enters urban wetlands can result in monotypic stands of nuisance species; preservation of highly biodiverse wetland areas can require a more natural hydrologic regime free of the materials associated with urban runoff. By linking disconnected wetlands back to the stormwater-conveyance systems in an effort to mitigate storm flow, the biotic integrity of these systems is typically jeopardized. One of the greatest challenges is forging a balance between biodiversity and stormwater-runoff control by managing various wetlands within a watershed to serve both functions.

Urban wetlands also provide important opportunities for recreation and education. Hiking, fishing, birding, hunting, canoeing, and exploring are some of the many recreational opportunities provided by wetlands. Additionally, in urban areas where limited exposure to the "outdoors" exists, wetlands are important areas for nature education to take place. Wetlands within the Starkweather Creek watershed play an increasingly important role as recreational lands continue to be replaced by commercial, industrial, and residential uses.

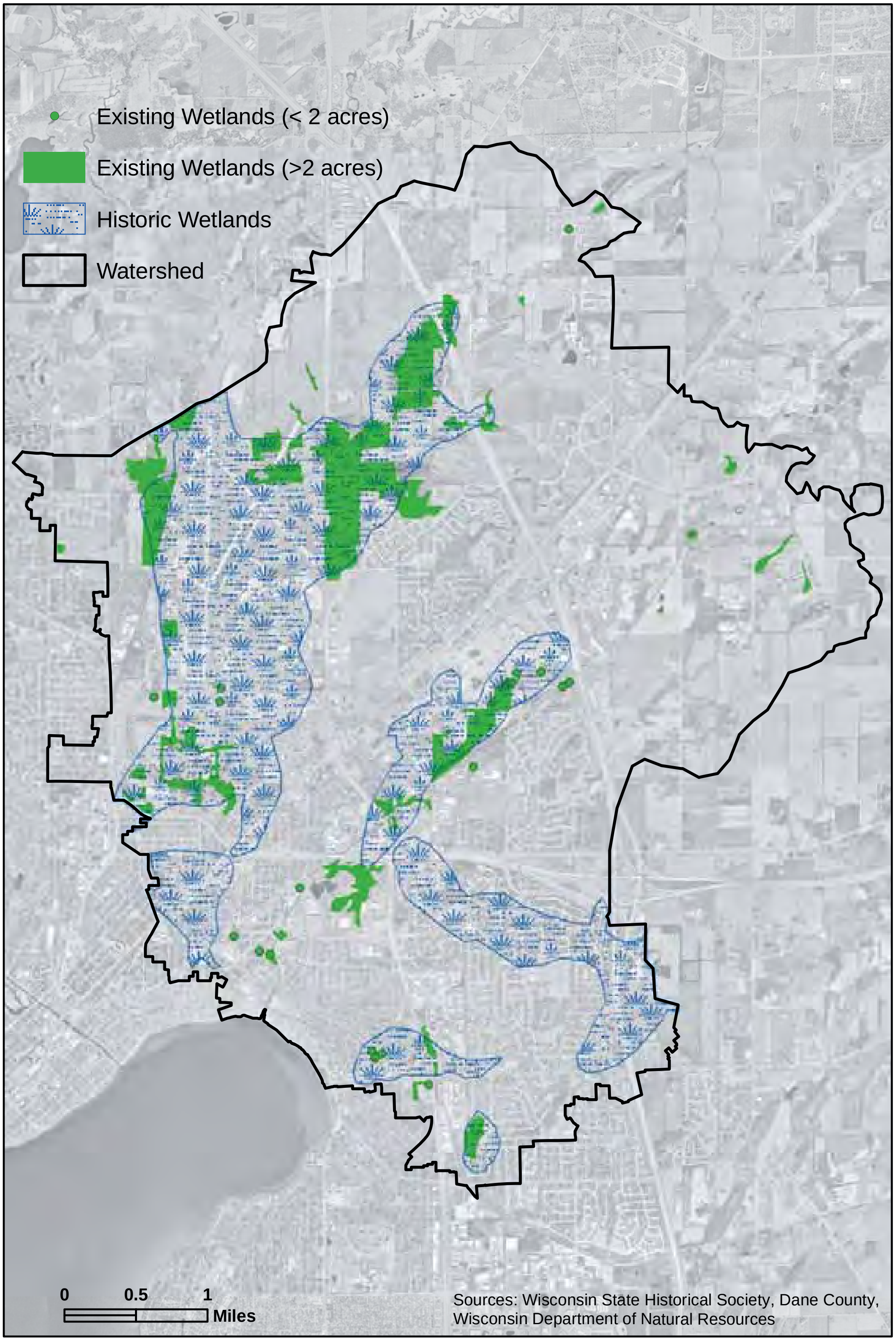

Figure 4-1. *Extent of wetlands loss within Starkweather Creek watershed.*

We sought to identify the most ecologically, logistically, and aesthetically important wetlands within the watershed. Within this group of wetlands, we chose several to be studied in greater detail. Because of the aggressive urbanization that has occurred within the watershed, most wetlands have been so altered that complete restoration is impossible. However, a comprehensive watershed wetlands plan could increase the functionality of many of these areas with respect to their stormwater-retention capabilities or their biotic integrity. By acting now to enhance these areas, present and future generations can enjoy them and reap the ecological benefits that the wetlands might provide.

Watershed Development from a Wetland Perspective

Historical Perspective and Current Issues

Prior to development by European settlers, the Starkweather Creek watershed consisted of approximately 3,000 acres of wetlands (Mollenhoff, 2003). The original federal land survey of the area listed two primary types of wetlands present: "marsh land" and "swamp woods." According to Mollenhoff (2003), the areas the surveyors described as marsh land are what botanists would today refer to as sedge meadow. Although the author did not mention how the surveyors defined "swamp woods," many of the original surveyor's notations for swamp woods also mentioned standing water. We categorized these swamp woods as wetlands. The extent of wetlands within the Starkweather Creek watershed prior to European settlement is illustrated in figure 4-1.

The wetlands existed relatively unaffected by man until almost the middle of the nineteenth century when settlers arrived in the area of what is now Madison. By 1845, Madison was a city of 4,500 residents, with most of the population centered along the isthmus between Lakes Mendota and Monona. In the latter half of the nineteenth century, Madison city officials viewed wetlands as health hazards because the wet conditions provided breeding grounds for insects that carried disease. Many residents considered the marshes to be unattractive and contradictory to the image of Madison they wished to present to visitors (Mollenhoff, 2003). As the population of the Madison area grew so did the demand for land, creating a convenient excuse to eliminate wetlands.

During the 1880s and 1890s, draining was the most cost-effective method of wetland elimination along the Isthmus, but this required the lowering of Lake Monona, which triggered numerous lawsuits (Mollenhoff, 2003). Consequently, all subsequent wetland elimination on the Isthmus had to be accomplished by filling. It has been estimated that between 1836 and 1920, 3,800 acres of Madison area wetlands and more than 200 acres of former Lake Monona frontage were filled in, including a stretch of shoreline more than 0.5-mile long near the mouth of Starkweather Creek. Fill material ranged from dredged lake sediment to household refuse and construction materials. Developers even resorted to hauling in trainloads of sand to augment the limited supply of fill. By 1920, most of the wetlands within the Madison plat had been drained or filled (Mollenhoff, 2003).

Although wetland alteration within the Madison plat occurred throughout the period from 1836 to 1920, the draining and filling of wetlands within the Starkweather Creek watershed did not begin in earnest until nearly 1860. Around this time, H.P. Hall, who owned the land that is now the site of Truax Field, dug nearly 7 miles of drainage ditches on 340 acres of his property (Dane County Regional Planning Commission, 1983). The effectiveness of Hall's drainage ditches in lowering the water table did not go unnoticed by his neighbors. In the years following his ditching project, Hall helped some of his neighbors install drainage ditches on their property, and by 1908 other farmers within the watershed sought, and were granted, a drainage district from the circuit court.

The drainage district carried on the work of Hall by continuing to improve drainage along the West Branch and channelizing nearly the entire East Branch (Dane County Regional Planning Commission, 1983). The success of the drainage district at lowering the water table gradually led to factories and homes displacing farms within the watershed. Today, land use within the watershed is largely a mixture of industrial, commercial, and residential development (Water Resource Management Program, 1990). Figure 4-1 illustrates the extent of wetlands loss within the Starkweather Creek watershed by comparing wetlands distribution from the 1834 land survey to the current extent of wetlands within the watershed.

Challenges for Mitigation and Restoration of Urban Wetlands

In the last two decades, there has been an increasing focus on wetlands as important ecosystems, resulting in considerable research on wetlands and methods of restoration. However, urban wetlands still remain a relatively unstudied subject. Furthermore, most of the results from urban wetland studies are site specific and few findings are suitable for generalization. This lack of information is especially significant because wetlands in urban settings pose more restoration challenges than wetlands in rural areas. The success or failure of a particular restoration or management goal is directly related to how effectively these challenges are addressed.

Ecosystems, such as wetlands, tend to stabilize as a result of homeostatic mechanisms in the form of biological, chemical, and physical reactions that counter external impacts to the system (Beeby, 1995). These responses are dynamic adaptations to the controls to which a particular system evolved. The way a given ecosystem responds to external impacts is determined by its inherent resilience. Resilience can be understood as the ability of a system to persist in the presence of perturbations. Some ecologists also define resilience as the rate at which an ecosystem community returns to its equilibrium level after being moved away from it (Pimm, 1991). Highly resilient ecosystems will almost always return to equilibrium; ecosystems that have little or no resilience will in many cases be fundamentally changed after perturbation, perhaps by losing species or by moving to a new equilibrium.

Resilience of a system depends on many parameters, such as ecosystem size, shape, connectivity, and edge characteristics. Urban wetlands are exposed to the most adversarial combination of these parameters. In contrast to their rural counterparts, urban wetlands tend to be small. The size of a wetland affects all its functions. Many small constructed stormwater-retention wetlands receive such a volume of residues that they require frequent maintenance and replacement. Furthermore, it is assumed that habitat value increases geometrically with area (Willard, 1988). The rationale for this relationship is based on the notion that increased area supports additional species and diversity. When planning a wetland restoration in an urban setting, one should therefore choose the largest site possible if multiple sites are potentially available. Also, one large site is preferable over multiple smaller sites.

Urban wetlands are isolated in many cases, which compromises or inhibits the ability of plants and animals to move during periods of increased ecosystem stress. This isolation also reduces the probability that re-colonization can occur once a species is lost from the system. If multiple small wetlands are anticipated within a restoration plan, the inclusion of environmental corridors can help to enhance connectivity, facilitating movement and exchange between wetland sites while providing a variety of beneficial functions (Turner and others, 2003).

Furthermore, transitions between urban wetlands and surrounding land uses can be sharp. Many wetlands have steep sides from filled areas, removing the potential for adjustment and, therefore, forcing the loss of plant and animal species. Buffers can mitigate some of these ecosystem stresses by allowing for expansion and contraction of the plant community in response to environmental variations (Turner and others, 2003).

External factors that can potentially change the ecology of a wetland are hydrologic regime, sedimentation, water quality, and invasive species—all of which are closely interrelated. Hydrology is the major driving force in a wetland ecosystem. Depth, duration, and frequency of inundation define the wetland environment, and changes in these hydrologic parameters are believed to be far more dramatic than any other impact (Mitsch and Gosselink, 2000). The hydrologic patterns in a wetland, however, are determined by characteristics of the surrounding watershed.

All the wetlands studied within the Starkweather Creek watershed receive stormwater runoff. A wetland's ability to buffer stormwater aids the mitigation of adversarial effects to adjacent water bodies; however, the wetland itself will degrade over time. Many native wetland species are unable to tolerate prolonged stress from ponding water and might eventually face local extinction, creating vegetative gaps that are then readily filled by more tolerant (possibly invasive) species. Soils can become permanently waterlogged, resulting in changes to soil chemistry and bacterial metabolism due to oxygen depletion (Brady and Weil, 2002).

Stormwater inflow into wetlands, either intentional or incidental, can result in the trapping of sediments. Soil particles from upland erosion and other particulate matter from urban processes are introduced into the wetland and settle out when water velocities decrease. This process plugs the pores of spongy wetland soils, obstructing infiltration, increasing soil bulk density, and reducing soil organic matter (Brady and Weil, 2002). It also levels out microtopography, reducing surface area. Microtopography is important for plant diversity because it provides plant species with varying abilities to tolerate flooding ecosystem niches (Werner and Zedler, 2002).

Wetlands also can retain pollutants. The positive and negative charges and extensive surface area of organic matter within a wetland makes them highly suited to pollutant adsorption. Studies have shown, however, that pollutant adsorption and, hence, retention capacities attenuate over time. Continuous input of stormwater or other effluents over prolonged periods of time will ultimately change ambient soil chemistry so that pollutants, especially heavy metals, can be released from storage, turning a sink area into a source area (Kadlec and Knight, 1996). The same concept applies to nutrient retention, especially with respect to phosphorus. Efficient long-term pollutant removal will only be achieved in a system that is building up organic matter or whose plants are harvested, as in phytoremediation. In natural systems, continuous water-quality impairment will eventually threaten the habitat value and biodiversity of the wetland.

The sum of these adverse conditions usually results in a wetland being unable to balance these impacts. Continuous ecosystem stress weakens and ultimately destroys its inherent resilience, providing opportunities for other plant species that are more tolerant of such conditions. Such opportunistic plants tend to be invasive in character, changing a diverse native plant community into monotypic stands. The three most common of these species in Wisconsin wetlands are *Phalaris arundinacea* (reed canary grass), *Lythrum salicaria* L. (purple loosestrife), and species of the *Typhaceae* family (cattails). (See next page for more detailed information on reed canary grass.) Unless the effects of altered wetland hydrology are addressed in a restoration plan, the restoration has little chance of success.

Social factors need to be taken into account as well. Urban residents may regard wetlands as nuisances, citing them as areas harboring vector-borne diseases or habitat for undesirable species, such as raccoons. In addition, urban wetlands may be used for illegal dumping. Fortunately, growing awareness of, and increased interest in, environmental issues in recent years has somewhat changed the perception of wetlands. Manuel (2003) surveyed residents of Halifax, Nova Scotia, with regard to small urban wetlands within their metropolitan area. She found that most residents were aware of the sites, but were not especially observant of or knowledgeable about them; however, the majority of participants regarded the wetlands as assets and important wildlife habitat. Nonetheless, urban wetland-restoration projects require sensitive site selection coupled with public education and citizen involvement to gain people's interest and support.

Even if all these criteria are given adequate consideration in a restoration plan, urban wetlands have built-in ecological deficiencies preventing their restoration to pristine and self-sustaining systems. The restored site will not be in equilibrium with its highly artificial surroundings. Urban wetland managers are therefore facing the options of either continuously managing the system or accepting its reduced functions and degraded

Latest research about reed canary grass and management implications

Reed canary grass, an extremely aggressive perennial grass that forms persistent, monotypic stands on disturbed sites, has invaded many wetlands in the southern Wisconsin. It has been bred and widely planted for erosion control along streambanks and as a forage plant. It is not clear whether it is a native grass, an exotic strain from Europe, or a hybrid strain. At present, more than 40,000 ha of wetlands in Wisconsin are dominated by reed canary grass (Bernthal and Willis, 2004).

Site disturbance has long been known to be the facilitator of invasion, but knowledge of the mechanisms involved is crucial for developing a management strategy. Through simulations, Kercher and Zedler (2004) found that flooding has the most intensive effect on the propagation of reed canary grass and the decrease of species richness. Flooding creates vegetative gaps, increasing light availability. Reed canary grass thrives best under high light conditions. Sediment addition has similar but less intensive effects than flooding. Nutrient additions had no effect on species richness, but did significantly increase reed canary grass frequency and biomass along with resident species biomass. The various combination of treatment regimes resulted mostly in additive effects. However, an interaction of sediments and nutrients with flood conditions synergistically increased invasion in some cases, as did the addition of nutrients coupled with simulated grazing. A field study by Carpenter and others (2004) about hydrologic disturbance confirmed the results. Miller and Zedler (2001) demonstrated that reed canary grass responds to flooding by morphological adaptations expressed as reduced below-ground biomass and increased shoot length.

How can these research results be translated into management options?

- Reed canary grass invades sites that have canopy gaps (gaps in plant cover) that can either result from prolonged flooding or other processes, such as grazing. Hence, any such activities should be avoided if feasible. A continuous, dense canopy cover can hold reed canary grass in check. Planting or maintaining vegetation with early season rapid development can limit reed canary grass shoot growth.

- A loss of microtopography takes place when sediment input into wetlands is increased as a result of excess water inflow. Creating or maintaining a hummocky microtopography promotes species richness and provides a more diverse environment in terms of soil moisture and light conditions. Nutrients alone are not a driving force, but they accelerate invasion if coupled with other disturbances. Therefore, less use of fertilizers in surrounding land uses will limit nutrient influx into wetlands. Vegetative buffers around wetland edges can also mitigate this effect.

- When reed canary grass occurs in small patches of otherwise high quality vegetation, herbicide application can be pursued. Successful long-term methods, however, have not been identified to eradicate reed canary grass once it has converted a diverse wetland into a monotypic stand, and more research is needed. Short-term success has been achieved by a combination of herbicide application followed by burning, disc cultivation, and excavation. More detailed information on conventional reed canary grass treatment is provided in Thompson and Luthin (2000).

habitat values. A few strategic measures, however, are available that can help translate an urban restoration proposal into a viable long-term project.

The first key element is the definition of a restoration goal. To 'restore' something in its literal sense means to reestablish a system to its original condition. Given the constraints of the urban setting, it would be unrealistic to expect to restore a wetland to presettlement conditions. For our purposes, however, restoration can be broken down into more differentiated meanings so that more realistic goals can be defined:

- *Enhancement* is a form of restoration that simply implies site improvement, such as by weeding.
- *Minimization* of an adverse impact can be pursued, such as by reducing stormwater surges into a wetland by installing or upgrading an upland detention area.
- *Compensation* implies the trade-off of an ecological loss for an ecological improvement, for example, by converting part of a wetland into a buffer between a wetland and an upland to improve ecosystem resilience.
- *Replacement*—exchanging a particular resource for another—may be pursued in some situations, for example, mitigating the loss of one riparian area to development by restoring another riparian area into a functional corridor between two existing wetlands.
- *Rehabilitation* can be incorporated by redressing an impaired function, such as restoring a flood buffering capacity by removing accumulated sediment that obstructs soil infiltration.

Restoration or any of its differentiated meanings have to be related to a functional category. Any ecosystem can be looked at from various interrelated perspectives. A wetland can be enhanced in terms of general biodiversity or only for one or several specific desired species, for hydrologic functions, for water-quality functions, or simply for aesthetic values or recreational purposes, and so forth. The more concrete the definition of a restoration goal is, the easier it will be to develop a project plan and to choose appropriate criteria for monitoring project success.

Grayson and others (1999) and Ehrenfeld (2000) provided excellent guidance for how to assess restoration success and how to avoid pitfalls when dealing with urban wetlands. Potential difficulties are associated with the long time commitment required to successfully complete a restoration and minimize the unpredictability of restoration outcomes. An adaptive restoration approach allowing for intermittent project evaluations with feedback loops to incorporate new experiences and insights can help to prevent unforeseen surprises. Zedler and Callaway (2003) gathered information from several years of an experimental adaptive restoration approach in California and arrived at the following recommendations:

- Develop an adaptive management team that meets on a regular basis to review results and discuss future actions.
- Establish priorities for management concerns and information needs.
- Set site-specific goals with appropriate assessment criteria.
- Design the restoration site to facilitate alternative approaches.
- Phase the work so that information gained can be used in subsequent modules.
- Gather data for evaluation and statistical analysis.
- Include research teams of scientists and students and reward them for publishing peer-reviewed research or thesis work.
- Identify outside funding sources for research needs.

We considered the attributes and challenges posed by wetlands while studying those contained within the Starkweather Creek watershed. In many cases, especially with respect to the wetlands that we discuss in greater detail, we tried to identify and address how these processes and phenomena have affected the wetlands in the past and will be a factor in future restoration efforts.

Inventory of Existing Wetland Areas

Distribution and Extent

The total area of wetlands in the Starkweather Creek watershed is approximately 905.5 acres, 67 percent of which lie on or adjacent to the East Branch, 27 percent associated with the West Branch, and the remaining 4 percent lying isolated from direct contact with the creek. Although many of these wetland areas remain as a seemingly disjointed network, it is logical to treat them as larger complexes that are connected by surface and groundwater flow. Studying these areas as "complexes" of smaller wetland fragments will also prove beneficial when discussing future management plans for the watershed. Grouping wetlands together now will facilitate the protection and restoration of larger areas when future management plans are crafted for the watershed.

Qualitative Description of Major Wetland Complexes

Confluence

North Platte/O.B. Sherry Park. Located on the city properties surrounding the confluence of the East and West Branches of the creek, this group of wetlands is approximately 0.5 acre in size and is mostly overgrown by reed canary grass. Despite their current poor quality, these wetlands are an area of high interest because of the planning that is being undertaken for the North Platte, which will include a wetland-restoration project. However, because of the backflow of lake water into the creek past this site, any restoration attempts will have to take into account the compounded effects of poor water quality.

West Branch

Madison Gas & Electric Marsh. Nestled between the East Branch of the Creek, the SOO railroad tracks and the Madison Gas & Electric (MG&E) substation, the MG&E Marsh is a thriving remnant of tussock sedge meadow in the middle of a highly urbanized area. This small yet high quality wetland apparently escaped attention and was not mapped in the Wisconsin wetland inventory. Water flow through the area is assumed to be from a high water table due to groundwater discharge promoted by a sandy subsurface layer that we identified studying the soils in the wetland. The wetland also seems to receive localized runoff from the adjacent concrete pad housing the substation. More than 40 wetland species are located in this small wetland parcel (see table D-1, appendix D). However, *Typha glauca* and *Phalaris arundinacea* are encroaching at the side bordering the electric substation. We therefore hypothesized that surface runoff inflow is disturbing the wetland hydrology, facilitating exotic invasion. To prevent further degradation, we recommend that Madison Gas & Electric initiate a more detailed investigation.

Bridges Golf Course/Carpenter Ridgeway Neigborhood. Bounded by Highway 151, Aberg Avenue, Anderson Street, and Packers Avenue, the Bridges Golf Course contains many small wetland areas. The Carpenter Ridgeway Neighborhood is bounded to the north by the West Branch of Starkweather Creek and a floodplain forest. The floodplain forest is currently undergoing restoration work by the Friends of Starkweather Creek. The wetland areas within the golf course consist mainly of small emergent wetlands associated with detention ponds. One of the major problems facing wetlands at this site is the fact that the area was once used as a landfill.

Dane County Regional Airport/Private Wetlands. Once home to the largest wetland complex in the Starkweather Creek watershed, the wetlands associated with the West Branch are now dominated by the airport and have been reduced to only 42.5 acres in size. The remaining wetlands in this area are mostly along the reconfigured creek channel and in areas that have not been used for airport runways or parking. Many of the mapped wetlands in this area are not readily apparent and are adversely affected by Federal Aviation Administration (FAA) regulations that seek to deter waterfowl that might use open water for breeding and migration purposes. Wetlands that exist outside of the airport proper are affected by many of these regulations as well, which will limit any restoration work that might be planned.

East Branch

Voit Complex. One of the largest undeveloped areas in the city of Madison, the Voit and Blattner Properties lie between Milwaukee Street, Fair Oaks Avenue, and Highway 30. The wetland complex consists of detention ponds, quarry ponds, and natural springs. Although reed canary grass, thistle, and other weedy species dominate, this area is unique in that it remains undeveloped. However, recent discussion between the city and the landowner should raise concern for the wetland's future. The wetlands themselves are protected from development, but surrounding land use might negatively affect the wetlands. Therefore, any future land-use plan concerning this plot should be made with the wetlands in mind.

Wal-Mart area wetlands. Stretching along the creek and the SOO rail line, the wetlands on and near the Highway 51 Wal-Mart location consist of wet meadows and emergent marshes around the detention ponds used to store stormwater runoff from impervious surfaces. The emergent marshes are home to turtles, frogs, waterfowl, deer, foxes, and other wildlife that use the Starkweather corridor for migration and breeding purposes.

Lien Marsh. A wetlands complex behind the East Towne Target store and the Triangle Marsh and wedged between the SOO rail line and the East Branch of Starkweather Creek is home to a peat mound and associated remnant fen, emergent marshes and wet meadows. The multiple water sources in the area and the low likelihood of development make the Lien Marsh an ideal case study in the Starkweather Creek watershed; see Lien Marsh section later in this chapter.

East Towne wetlands complex. Created to mitigate wetlands lost during the construction of the East Towne Mall shopping complex, the East Towne Mall Wetlands accepts runoff from the parking lots and rooftops on the East Towne property. The entire complex, which extends along East Springs Drive, is home to a number of springs as well as one of the more pristine stretches of the creek with a sandy gravel bottom and wooded corridor. The easternmost section of the wetland offers a quality transition from upland to shrub-carr to wet meadow to wooded wetland.

Isolated

Acewood Pond. A small kettle pond located at the southern edge of the watershed, Acewood Pond ranges from open water to shallow emergent marsh at the pond's edge. Unlike other open-water wetlands in the watershed that are little more than ponds ringed by cattails, Acewood Pond has a healthy community of floating hydrophytes as well as other wetland species such as bulrushes, cattails and broad-leaf arrowheads. The pond is well protected by trees and has high scenic value (fig. 4-2).

Atlas Avenue/Highway 51. Northeast of the Cottage Grove/Highway 51 Interchange, a number of small depression-type wetlands lie along Atlas Avenue and the cloverleafs created by highway ramps. These wetland areas are small and isolated because of the many roads that transect the area and most likely receive high volume of runoff from impervious road surfaces and rooftops. In addition, these fragmented wetlands are dominated by invasive species and will most likely offer little functional value outside of runoff storage and sediment retention during periods when the areas contain standing water after storm events.

Restoration Strategy and Management Proposals for Priority Wetlands

Site Selection

We considered carefully all the wetlands within the Starkweather Creek watershed to select the highest priority sites for wetland mitigation, restoration, and preservation. Prior to selection of these priority sites, we explored all the wetlands within the watershed, either by visiting them or communicating with sources knowledgeable about the region's wetlands.

To ensure the best use of our time and resources, we decided to refine our focus and concentrate our efforts on thoroughly investigating several of the larger wetlands. We based our site selection upon size, shape, surrounding land use, hydrology and social components; in addition, our selection was largely based upon a cost-benefit comparison. Constraints regarding time and money mean that the most important areas must be restored and protected first. With these concepts in mind, we made our final selections on basis of recreational use, aesthetic value, and ecological value and function.

One of the larger wetland complexes in the watershed is the wetland immediately east of the Dane County Regional Airport and Highway 51. The area has ecological and recreational importance as well as significant aesthetic value. Unfortunately, its proximity to airport facilities necessitates limited open-water sources to reduce the risk of waterfowl collisions with aircraft in accordance with FAA regulations. Because open water is often a fundamental part of any wetland ecosystem, any attempt at restoration of the Highway 51 wetland complex would likely be complicated by these regulations. Additionally, future airport expansion could jeopardize this wetland area. However, given the extent of the area, we believe it holds potential for enhancement of vegetative diversity and recreational opportunities.

We chose three priority sites: the Wal-Mart wetlands, Acewood Pond, and Lien Marsh. Due to the size, ecology, and proximity to a large number of residents, we selected Lien Marsh was as the primary focus for our research and recommendations.

Figure 4-2. *The open-water wetland of Acewood Pond.*

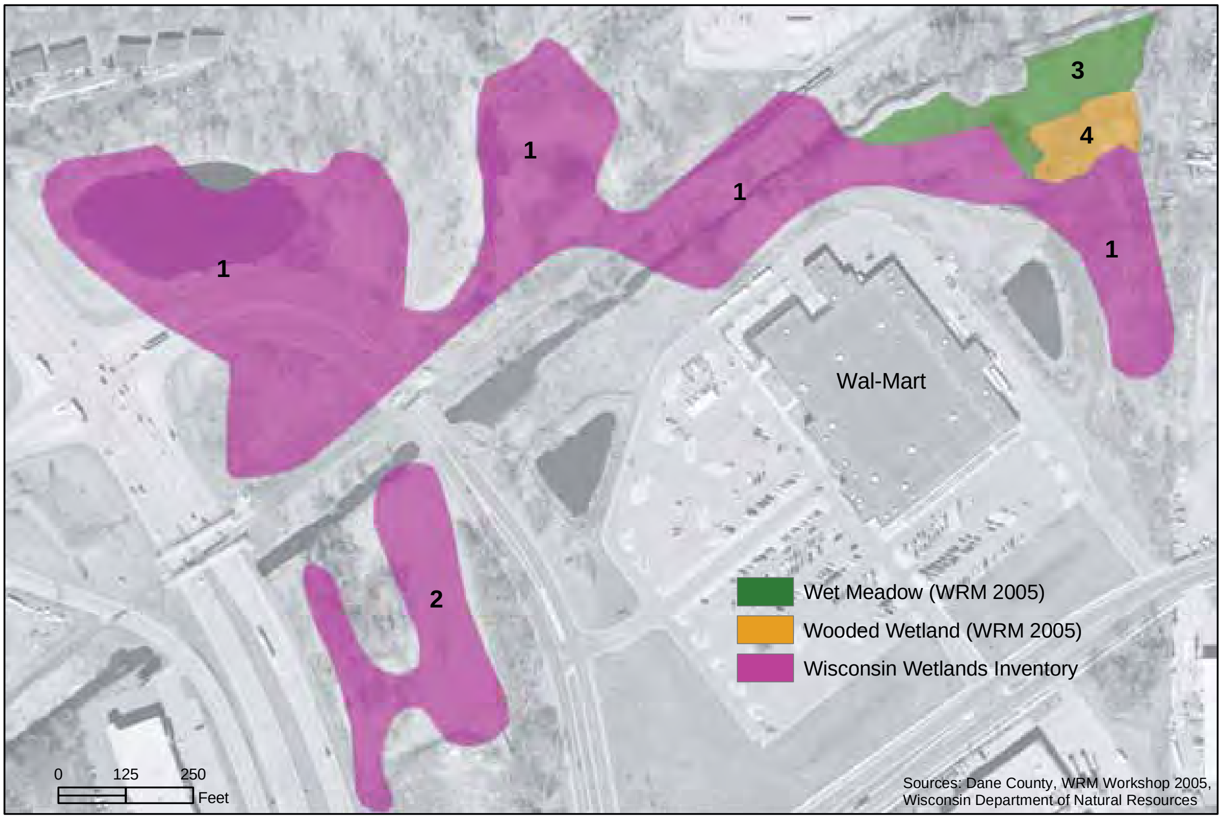

Figure 4-3. *Wal-Mart complex wetland, showing the four distinct management units: 1=stormwater wetland north; 2=stormwater wetland south; 3=wet meadow; 4=wooded wetland.*

Wal-Mart Wetlands

The Wal-Mart wetlands are located adjacent to both sides of the East Branch of Starkweather Creek just 0.5 mile south of Lien Marsh (fig. 4-3).

The Wal-Mart side of the wetland receives stormwater draining the Wal-Mart complex via a stormwater detention basin; however, not all of the wetlands on this side are affected by stormwater input. A larger area nested between the creek and the stormwater-affected part of the wetlands is somewhat higher in elevation and is partly wooded. In fact, that area of the wetland is not mapped as such according to the Wisconsin Wetland Inventory GIS data. However, the soils in this area consist of up to 3 feet of sapric peat overlying sandstone from the Tunnel City Formation (Wisconsin Geological and Natural History Survey, 2003), and we classified this area as wet meadow/wooded wetland. This area of the wetland has the greatest plant diversity, probably due to limited disturbance and better drainage. All other soils in the wetland are peat over silty clay, resulting in poor subsoil infiltration and perched water tables. The stormwater-influenced part of the wetland is mostly reed canary grass in the better drained parts and cattail along with willows in the wetter parts. The higher elevated part of the wetland has a good potential for enhancement of floral species diversity and wildlife habitat. It is spatially protected from developed sites and there is little evidence of hydrologic disturbance. It is not suited for public access and should remain so. A more in-depth assessment of this area is recommended.

The wetland part west of the creek is separated from the Wal-Mart complex by a railway line. It has a basin-like morphology and receives stormwater from Highway 51 and Commercial Avenue on one side and from the Madison Gas & Electric power station on the other. Part of the wetland is an open-water body in spring and early summer, but dries out later in the season. Its vegetation is mostly reed canary grass in the better drained parts and cattail in the more poorly drained parts. This part of the wetland has limited faunal habitat value. We found evidence of wildlife, including white-tailed deer, raccoons, frogs, toads, and turtles. Any enhancement of this area is limited by the presence of hydrologic alterations. The only option for this site would be conversion into a permanently submerged marsh to improve aesthetic values. To accomplish this, a more continuous water influx would have to be introduced to prevent complete drying in the summer months.

Acewood Pond

Acewood Pond is a kettle pond located in the southeast of the watershed. The pond and its surrounding wetlands have significant habitat value for waterfowl. Even though the pond is in a residential neighborhood, there is limited access to the pond because of the great amount of emergent vegetation and wooded edges, resulting in relatively undisturbed waterfowl habitat. At the same time, the area has high aesthetic value for the neighborhood. To further enhance the pond for its wildlife function, waterfowl nesting areas could be introduced. Ducks need undisturbed grassy areas for nesting; it is possible to convert part of the woodlot east of the pond into a duck nesting area. If that plan is too controversial for local residents, the installation of nest boxes might partially accomplish the same objective. At the east side of the pond where the park borders the wetland, a wooden wildlife viewing stand could be built for observing waterfowl and learning about the ecological function of the wetland and the pond.

Lien Marsh

The Lien Marsh wetland complex holds much promise for aesthetic and recreational value and is of great ecological importance. The Lien Marsh is one of the largest remaining wetlands within the city of Madison. The wetland provides a source for recreational use and aesthetic pleasure amidst the otherwise stark, urban background. The wetland also provides habitat for a variety of flora and fauna; it is a refuge for many species within the city.

Lien Marsh is on the East Branch of Starkweather Creek, 1.8 miles upstream from the confluence of the East and West Branches. It is bordered by a shopping complex on Lien Road to the north, the southwest–northeast running SOO railroad line adjacent to Sycamore Park, and a drainage ditch adjacent to a gravel pit to the west. The current wetland extent encompasses the historic R. Lien and F. Boschwitz properties.

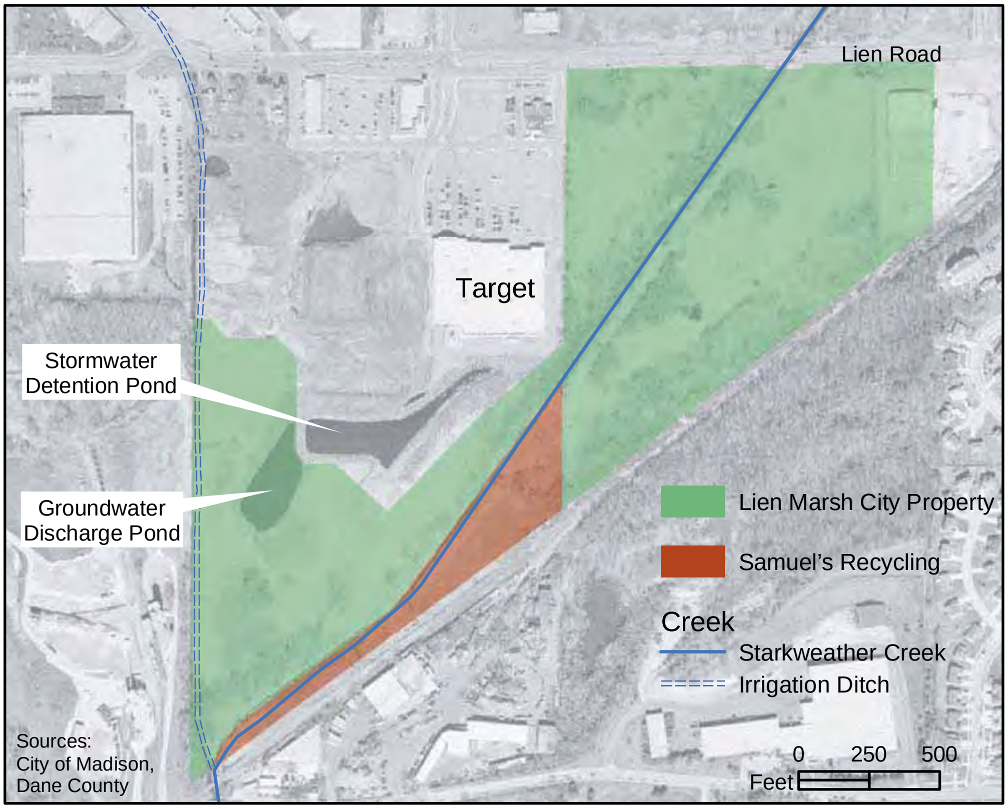

Figure 4-4. *Overview map of the Lien Marsh Complex and environmental corridor.*

An aerial photograph from 1937 shows that the area surrounding the marsh was once dominated by crop agriculture. An aerial photograph from 1995 shows the change in adjacent land use to commercial and light industrial, but also suggests that part of the R. Lien property was still being farmed at that time. The F. Boschwitz property does not appear to have been farmed past 1980.

In the late 1990s, the northern part of the R. Lien property was purchased for commercial development. The City of Madison purchased the southern part of the R. Lien property along with the F. Boschwitz property. These properties now help to strengthen an important wildlife corridor within the city (fig. 4-4).

Physical Setting

Topography. The topography of the Starkweather Creek watershed is characterized by minor differences in elevation. Lien Marsh, however, is adjacent to the highest point in the watershed, resulting in approximately 95 feet of relief between the wetland and nearby uplands. The upland area immediately east of the wetland includes an abandoned landfill, Sycamore Park, and single and multi-family residential units. The part of the wetland west of the creek gently grades into upland areas. The part of the wetland between the creek and the drainage ditch includes a local topographic high formed by a peat mound. Along the wetland edge, there are sharp transitions to human structures due to fill. The creek banks on either side are higher than the wetland interior from dredge spoil dumped when the creek was channelized, creating a bowl-like shape.

We surveyed the wetland with a high resolutions global positioning system (Leica Geosystems, Inc.) to gain better understanding of microtopography.

Geology and Soils. Lien Marsh developed on a glacial lacustrine plain formed by offshore lake sediment. The sediments are highly variable, ranging from cross-bedded and plane-bedded sand, plane-bedded silt and clay, and nearshore gravel (Clayton and Attig, 1997). The eastern part of the wetland bordering the drainage ditch developed on marl, a lacustrine carbonate precipitate from a postglacial period. On its southeastern boundary, where the wetland grades into the steeper upland area, the surficial geology consists of a sandstone outcrop of the Tunnel City Formation (Wisconsin Geological and Natural History Survey, 2003).

According to Glocker and Patzer (1978), the two major soil units are Palms Muck and Dresden Silt Loam. However, on-site soil reconnaissance showed that soil characteristics are more heterogeneous than suggested by the soil survey data (fig. 4-5). We extracted two soil cores using a vibracorer. The first soil core was an organic soil (peat over sandy loam); the second soil core was a mineral soil that was buried by dredge material when the creek was channelized. We also measured soil permeability using a Guelph permeameter at both soil core locations. Permeability at location 1 was one order of magnitude greater than in location 2, which has significance for site hydrology and subsequent ecosystem characteristics.

We also randomly sampled soil throughout the wetland with a hand probe and hand auger. Soils in the southwestern part of the wetland are peat over sandy gravel or marl. Soil reaction to hyperchloric acid indicated strongly alkaline conditions in that area. The soils adjacent in the south are silty clay. In the central part of the wetland, there is eroded silt over peat; the western part is composed of silty clay loam. The soil on the east side of the creek is also mainly silty clay loam accompanied by some silty clay.

Hydrologic Regime. Hydrologic parameters are the major driving force in a wetland ecosystem. The Lien Marsh is controlled by three different hydrologic regimes: groundwater discharge, surface-water inflow and outflow, and fluctuating creek water levels. Water movement through the wetland is controlled by soil characteristics, topography, and minor seasonal fluctuations due to evapotranspiration. At least a part of the wetland east of the creek is tile drained. We found clay tiles discharging water into an open-water pool that directly drains into the creek (see chapter 3, *Baseflow).* Two other small open-water pools in the wetland are not connected to the creek.

Groundwater discharge is visible near the peat mound in the fen and as a groundwater-fed, human-made pond. The fen is west of the creek and is recognizable by the remnants of a peat mound. We installed four piezometers to measure hydraulic gradients with screens at four depths. Throughout the entire monitoring period between April and August, the readings indicated a positive hydraulic gradient, which means groundwater is being discharged continuously. The fen formed due to a sandy gravel layer that may be part of a local or regional groundwater flow system.

Our comparison of aerial photographs from 1995 and 2000 showed that the pond was constructed during this time period. The purpose and functions of the pond are unclear. We measured groundwater seepage out of the pond with a seepage meter and calculated a discharge rate of 8×10^{-4} cm/s. This method is known to

Figure 4-5. *Overview of the Lien Marsh complex showing locations of soil-permeability measurements, water-table loggers, piezometer locations, and soil types.*

yield highly variable results, so the actual value is insignificant. The purpose of this measurement was to confirm that the water levels in the pond are sustained by groundwater discharge. No other means of inflow into the pond could be identified. During spring, when water levels are higher, the pond releases water through a small outlet to the south. The water then seeps through an area dominated by *Scirpus fluviatilis* (river bulrush) and then discharges into the drainage ditch. In the summer, pond levels drop due to increased evaporation and the outlet dries up.

To better understand the groundwater signature in various locations in the wetland, we monitored the water table in three locations with digital water-table data loggers over a period of 24 days in July. The data loggers were set to record every 30 minutes. The locations of these data loggers are indicated in figure 4-5.

Our data showed that all three locations are groundwater influenced. Daytime hours were characterized by water-table drawdown from evapotranspiration, and nighttime, by water-table recovery from groundwater recharge. The amplitude of this daily cycle is more attenuated in the fen area and more pronounced in the mineral soil locations. The total drawdown over the five days displayed in appendix D (figs. D-1 to D-6) was also greatest in the mineral soil (1.5 ft), with only 0.18 feet of drawdown in the fen. The area outside the fen, dominated by *Scirpus fluviatilis*, is

Figure 4-6. *A seepage outlet on the creek bank in early spring. The rust color is iron that oxidizes when the water comes into contact with the atmosphere.*

intermediate in terms of drawdown and recovery.

The water-table response to rainstorm events plays an important role in the type of plant species that can thrive. The mineral soil is more likely to repeatedly develop reducing conditions characterized by oxygen depletion throughout the growing season favoring more water-tolerant plants.

The middle part of the wetland west of the creek receives stormwater from the detention pond. This stormwater probably mixes with groundwater as it moves through that part of the wetland. Because of the basin-like topography within this area, the water becomes ponded and stagnant. However, as a result of the stormwater that the wetland has been receiving since about the year 2000, the hydrology of this area tends to experience fluctuations. During high flows the water has cut a few small outlet channels through which water now discontinuously exits the wetland as surface flow. A number of small seepage outlets along the bank allow water to discharge to the creek (fig. 4-6).

Finally, the creek is hydrologically connected to the wetland. Dredging and channelizing of the creek around the end of the nineteenth century greatly altered the watershed hydrology (Dane County Regional Planning Commission, 1983). The energy gradient became steeper because of a shortened flow path, so water velocities increased; this has resulted in lateral erosion, an increase in peak flows, and a decrease in baseflow. This process has intensified throughout the twentieth century as a result of rapid urbanization within the watershed. Watermarks from the July 20, 2005 rainstorm of 1.17 inches (National Oceanic and Atmospheric Administration, 2005) after a six-week drought period documented a nearly 3-foot difference between peak flow stage and baseflow stage.

Soil probing showed very little evidence of frequent overbank flooding prior to channelization. Presettlement watershed characteristics, such as small elevation gradients, many wetlands, and meandering streams, suggest that the flow regime was characterized by constant high baseflow coupled with an attenuated response to storm events. We therefore believe that the wetland experienced very infrequent overbank flooding prior to development and that floodplain dynamics played a subordinate role to groundwater discharge in presettlement wetland hydrology.

This conclusion is also supported by results from the regional groundwater model, which indicates upward flow along the entire East Branch of Starkweather Creek (Bradbury and others, 1999).

Geochemistry. As a consequence of their low position in a watershed, wetlands are landscape sinks that accumulate chemicals as well as sediment. Hence, wetland geochemical properties are not only controlled by in-situ conditions, but are also strongly influenced by upland processes. We were interested in whether knowledge of chemical parameters would allow conclusions to be drawn about ambient processes. We collected geochemical data using comparator-based colorimetric test kits from CHEMetrics, Inc., and a portable temperature/conductivity meter. The complete data set is listed in appendix D (table D-2).

We tested groundwater by sampling from piezometers in the fen. The groundwater was of intermediate conductivity, indicating moderate electrolyte concentration, probably mostly from dissolved carbonates that are relatively abundant in glacial sediments. Alkalinity was moderately high, indicating a well buffered system. Dissolved oxygen was low, but never completely exhausted, indicating that redox potentials are probably never very high, despite water-saturated conditions.

The soil core from the fen only showed gleyed colors (bluish gray), indicative of reducing conditions, from 5.00 to 5.40 feet in depth. The rest of the sediment core had yellowish-brown hues that would be more typical of an upland soil. The soil showed the most reduction in the top layer, indicated by the absence of nitrate and the presence of 1 ppm dissolved iron. Concentrations varied with increasing soil depth as indicated by a slight increase in nitrate and the absence of dissolved iron. The rate of reduction is higher in the upper part of the soil because of more organic matter, which is the energy source for reducing bacteria. No phosphate was detected in the groundwater.

We tested surface-water chemical characteristics in the groundwater-discharge pond, the stormwater-detention pond, at the wetland outlet, in the creek, and in the drainage ditch. The creek can be characterized as eutrophic. Nitrate levels varied between 2.5 and 4.5 ppm, with values closer to 4.5 ppm during drought conditions, probably due to less dilution. Dissolved or bioavailable phosphate varied between 0.1 ppm in spring, zero during the summer drought period, and 0.4 ppm after a major rainstorm. Nitrate levels in the stormwater-detention pond were negligible.

Phosphate levels varied between 0.1 and 0.2 ppm, which is surprising because the drainage area for the detention pond consists only of rooftops and a large parking lot. One possible source of dissolved phosphate could be fertilized flower beds, but there are no data to substantiate this hypothesis. In contrast to groundwater and stormwater, phosphate levels are higher at the wetland outlet, reaching an average value of 4 ppm. (For comparison, water-quality effluent limitations for facilities permitted by the Wisconsin pollutant discharge elimination system is 1 ppm of total phosphorus as monthly average [Wisconsin Department of Natural Resources, 1997]). Because no significant amounts of phosphate seem to enter the wetland under current conditions, the phosphate seems to be stored there and becomes mobilized by water seeping through it. This is a significant finding because wetlands are generally regarded as nutrient sinks, primarily due to the high amount of organic matter found within them, which has a large capacity for adsorbing nutrients.

To further understand the phosphorus levels within the wetland and surface water, we used the Bray-1 extraction process to quantify available phosphorus at six sites throughout the wetland. Following the extractions, we determined phosphorus levels by using the absorbic acid method. The results showed that available phosphorus levels ranged from 1 ppm to more than 120 ppm. The results indicated significant variability with respect to sample location, which is not completely unexpected. Part of the Lien Marsh and the adjacent upland were actively farmed in the past. The phosphorus levels obtained from the sample sites were similar to levels found in many local agricultural fields. More than one hundred years of active farming and manure application most likely caused the current high phosphorus levels. In addition, the wetland interior has various depths of silt on peat (up to approximately 1 foot), which we interpreted as eroded topsoil from the immediately surrounding area. Many of these areas were also recently farmed.

The results from the phosphorus testing challenged the widespread belief that wetlands can be used for nutrient-treatment functions. Wetlands have only a limited storage capacity and once this storage capacity is reached, wetlands can instead become source areas of nutrients and pollutants, seriously affecting water quality and habitat in connected streams and lakes. Our findings indicated that a clear understanding of site-specific conditions is essential prior to decision making in terms of constructing treatment wetlands.

Flora. Wetland flora are controlled by soil characteristics, hydrology, and land-use history in and around a particular wetland area. The entire wetland complex is infested by the invasive plant *Phalaris arundinacea*. The GIS data allowed a rough estimate of vegetative site conditions, but also revealed major weaknesses resulting from restrictions of resolution and generalization. On-site vegetation mapping revealed greater heterogeneity and ecosystem diversity (fig. 4-7).

The most diverse vegetation is associated with the fen and the groundwater discharge pond. The soil is porous, provides a stable water table in relation to other locations in the wetland, and has a low nutrient content. The local topographic high elevation point also protects it from sediment accumulation. Conversely, finer textured mineral soils are more susceptible to greater water-table fluctuations due to lower bulk densities and stormwater influx, accumulate more sediment, and have a high nutrient content. Overall, the fen seems to have escaped early settlement disturbance better than other parts of the wetland, as expressed by the higher species diversity there.

Nevertheless, the fen shows signs of serious ecosystem stress. The vegetation survey showed that upland plants and *Cornus rademosa* Lam. (gray dogwood) and *Frangula alnus* P. (glossy buckthorn) are mixing in with the native fen vegetation. This suggests that the native fen vegetation is experiencing stress from slow but continuous dessication. The reason may lie in declining water tables resulting from groundwater pumping, but may also be explained by the dredging of the pond.

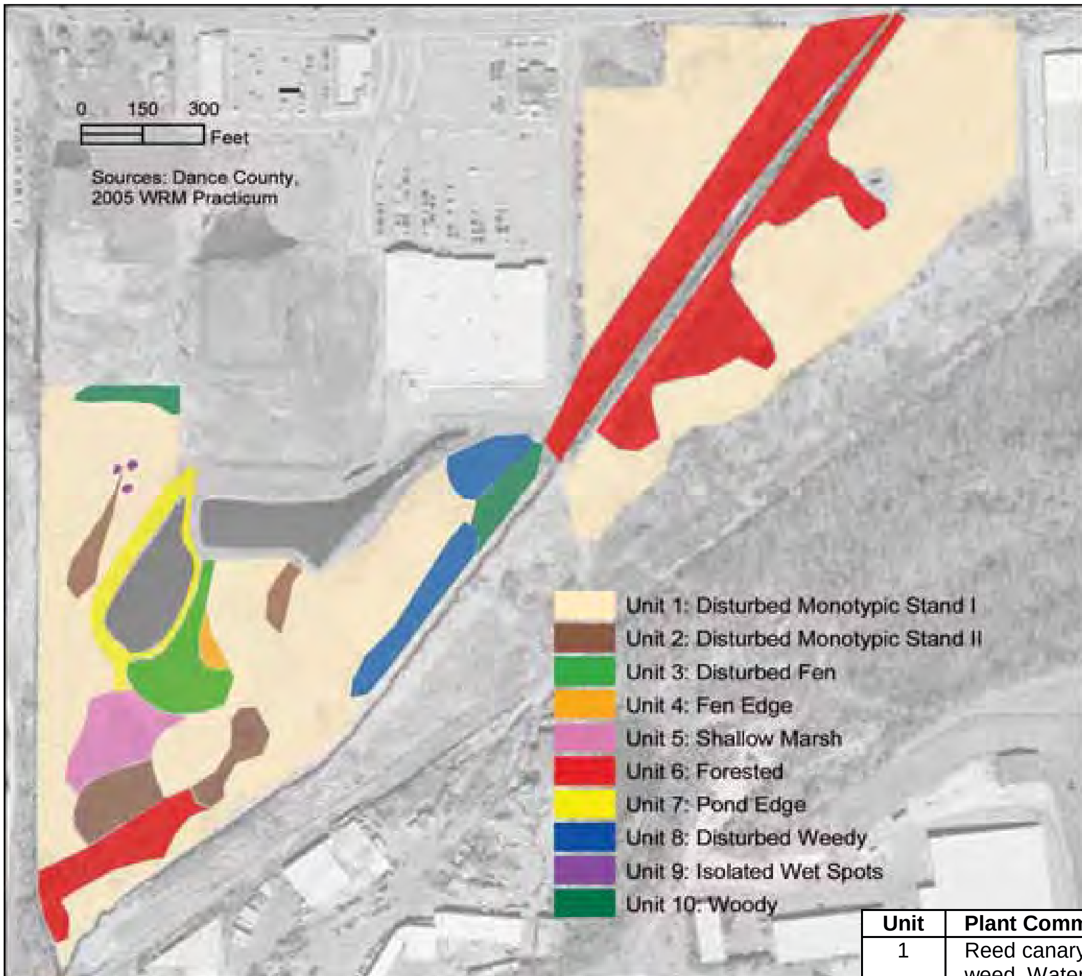

Figure 4-7. *Lien Marsh complex with vegetation communities.*

Unit	Plant Community
1	Reed canary grass (~90%), Jewel weed, Water smartweed
2	Hybrid cattail (~100%)
3	Canada anemone, Angelica, Canada goldenrod, Red top, Marsh milkweed, Gray dogwood, Wild yarrow, Bugleweed, Wooly sedge, Water smartweed, Buckthorn, Kentucky blue grass, Swamp aster, Curly dock, Joe pye weed, Wild mint, Geum, Canada thistle, Cotton grass, Nut sedge, Sterile sedge, Prairie loosestrife, Rag weed, Germander
4	Swamp nettle, Common goldenrod
5	River bulrush (~80%), Broad leaved cattail
6	Cottonwood, Bush honeysuckle, Garlic mustard
7	Green bulrush, Stalk-grain sedge, Slender rush, Blue vervain, Rattlesnake mannagrass, Narrow leaf cattail, Hybrid cattail, Soft stem bulrush, Fox sedge, Tussock sedge, Blunt spikerush
8	Comfrey, Canada goldenrod
9	Blunt spikerush, Broadleaf arrowhead
10	Sandbar willow

The pond draws water from its immediate surroundings, which is then lost to evaporation. A series of aerial photographs between 1980 and 1995 do not show any evidence of brushy vegetation on the fen. Currently, however, there is a large *Frangula alnus* P. (glossy buckthorn) located at the highest point of the fen as well as a few small individuals scattered around the general area. The coincidence of pond construction and buckthorn establishment suggests that the fen has become drier due to water loss to the pond. The vegetation along the pond edge is quite diverse and is mostly bulrushes, grasses, and a few pioneering sedges. The hybrid cattail *(Typha glauca)* has become established as well. We

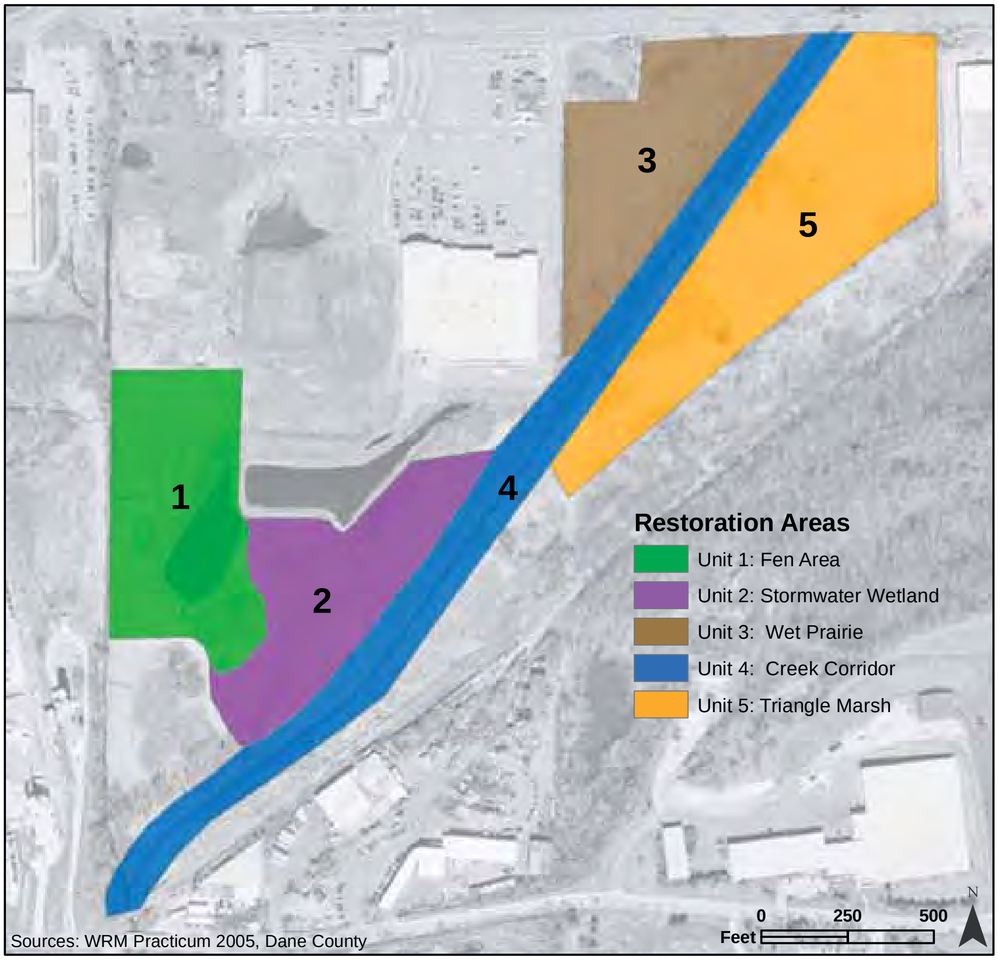

Figure 4-8. *Ecological units within the Lien Marsh wetland complex.*

have no information as to whether or not these plants were seeded intentionally.

The largest part of the wetland is dominated by *Phalaris arundinacea* in mesic to wet areas and *Typha glauca* in areas with standing water. Soil testing around the fen also suggests that those areas with evidence of disturbance from soil compression, possibly from heavy equipment, coupled with accumulated sediments are also infested by *Phalaris arundinacea*. In contrast to that, the soil profile on the peat mound in the center of the fen appears to be undisturbed (Quentin Carpenter, University of Wisconsin–Madison, verbal communication, 2005). Hence, the current vegetative condition of the wetland provides ample evidence of various types of disturbances that stretched the ecosystem resilience to a point where it has adjusted or is in the process of adjusting itself to a new equilibrium characterized by lower plant diversity.

Fauna. Although we did not conduct a systematic survey of the fauna inhabiting the wetlands, it was evident that despite its degraded status, the wetland provides habitat to a diversity of vertebrates and invertebrates. The more obvious animals observed were white-tailed deer, ground hogs, muskrats, great blue heron, breeding sandhill cranes, Canada geese, and mallards. Other smaller birds using the wetland are red-winged blackbirds, swallows, and yellow finches. Several red-tail hawks were observed in the upland transition to Sycamore Park. Among the small vertebrates observed were green frogs, chorus frogs, American toads, and a stocked population of bluegills and largemouth bass in the groundwater discharge pond (verbal communication with an angler). Wildflowers in the fen area provide feeding ground for a variety of butterflies and bumblebees.

Current Status of Lien Marsh

Lien Marsh is a degraded wetland, but has potential for restoration. The wetland offers relatively diverse site conditions resulting from the surficial geology, soil types, microtopography, and microhydrology. This diversity is expressed by various wetland types ranging from fen, shallow marsh, sedge/wet meadow, forested wetland, and small, more diverse plant communities surrounding the small open-water pools. Creek channelization, tile drainage, farming, and urbanization have led to significant changes in hydrology and soil characteristics, which favor conditions for invasive plants. It is especially unfortunate that the fen, although having been preserved throughout the farming period, is now seriously threatened by the pond construction that occurred at a time when protective wetland regulation was in place. Overall, the site seems to represent the typical case for a wetland in an urban area.

Restoration Recommendations

As a result of the varying site conditions in the Lien Marsh, we propose subdividing the area into the following five ecological units (fig. 4-8):

- the fen including the groundwater pond,
- the area receiving stormwater from the detention pond, which we refer to as the stormwater wetland,
- the area bordered by Lien Road and the Target property, which we refer to as the wet prairie,
- the creek corridor, and
- the area east of the creek, which we refer to as the Triangle Marsh.

This will allow different management practices to be applied to each area, depending on its preexisting conditions.

Fen. A fen is the one of the rarest wetland types in Wisconsin because of the unique conditions that contribute to their development. The strongly alkaline reaction of the peat in the fen area suggests that the fen can be classified as calcareous. Calcareous fens are listed as areas of special natural resource interest in section NR 103.04 of the Wisconsin Administrative Code. It therefore seems appropriate to assign the fen the highest priority.

Fens are mainly controlled by internal hydrologic conditions and are therefore less susceptible to disturbance from land-use changes in the surrounding watershed

(Mitsch and Gosselink, 2000). Peat mounds grow and are sustained by a water table that is higher in relation to their surroundings, driven by a high hydraulic conductivity layer that promotes up-welling of groundwater. The fen in the Lien Marsh has experienced water-table decreases from artificial groundwater drainage in the adjacent drainage ditch and the groundwater pond and from regional groundwater pumping. The lowered water table has led to drier soil conditions, and native fen species are now being replaced by upland plants, resulting in lower plant diversity. It is also likely that the actual peat mound has been shrinking because unsaturated peat is subject to oxidation and, hence, mineralization.

Comprehensive Approach to Restoration

- Restore the hydrologic integrity of the fen.
- Reverse reed canary grass and cattail dominance.
- Enhance plant diversity in the fen.

Functional restoration of the fen would require redressing the hydrologic regime alterations. Hydrologic conditions would have to be restored by filling the drainage ditch and the groundwater pond. Both measures are drastic, expensive, and can be disruptive themselves. Arguing for removal of the groundwater pond seems controversial because the plant community around the pond provides relatively good plant diversity compared to other parts of the wetland. The pond also provides habitat for fish, amphibians, waterfowl, and a variety of insect life. Filling the drainage ditch is also problematic because it receives stormwater from upland parcels, so its removal would have to be incorporated into a broader stormwater-mitigation plan. However, both measures—or alternatively only one of the two—are the only way to lessen further degradation of the peat mound or potentially restore the fen to its historic extent. The fen community can then be enhanced by treatment for invasive species, brush removal, prescribed burning, and targeted seeding of fen species if the local seed bank is insufficient.

Minimized Approach to Restoration

- Stop further spread of reed canary grass and cattail.
- Enhance plant diversity in the fen remnant.

Enhancing the diversity of the plant community may be achieved through brush removal, prescribed burning, and additional seeding. However, it will require long-term monitoring, and it is unknown whether these measures alone will suffice to preserve the remaining fen. We recommend continued monitoring of water levels at the installed piezometers to determine whether the average water-table elevation is changing.

Stormwater wetland. The large, artificial banks of Starkweather Creek, created during channelization and dredging of the creek, sometimes force the stormwater from the detention pond to pool within the wetland. The pooling creates an unfavorable environment for many native wetland species, but favors the establishment of reed canary grass and the hybrid cattail; extensive stands of these plants characterize the area. Water and soil samples from this area showed high levels of phosphorus. Fortunately, the stormwater has remained relatively isolated due to the peat mound, which acts like a berm, keeping the stormwater from reaching the fen area.

Comprehensive Approach to Restoration

- Mitigate altered wetland hydrology.
- Minimize nutrient flux.
- Control invasive species and enhance plant diversity.

To foster a more heterogeneous floral population, drainage must be improved within the wetland. However, increased drainage may also flush more phosphorus from the wetland. This phosphorus would then enter Starkweather Creek and eventually Lake Monona, thereby augmenting the present eutrophication problems.

To improve drainage of the wetland, the creek banks could be scraped, allowing the stormwater to reach the creek by non-turbulent flow along the entire wetland instead of becoming channelized, pooling up, and entering the creek at one concentrated point. Scraping the creek banks would also allow the wetland to drain, possibly allowing for conditions that foster increased sedge growth.

Regardless of the approach, care must be taken to ensure that the wetland does not become overloaded with sediments, nutrients, and chemicals, thereby disrupting the wetland ecology and function. Outputs from the detention ponds should be monitored to ensure the future health of the wetland.

The reed canary grass must be brought under control before any successful restoration of flora can be expected. Aggressive burning and herbicide application may be necessary; however, these methods have not been proven to be completely effective. Research is currently under way to discover more effective means of controlling and eradicating reed canary grass, and it is hoped that more effective methods will be discovered. Depending on the area’s seed bank, seeding of native species may be required to jump start the growth of native wetland species.

Minimized Approach to Restoration

- Control invasive species and enhance plant diversity.

This area should be burned and seeded to promote a greater species diversity of flora. However, the success of such efforts is not assured, given the continued stormwater inputs from the detention pond. As is the case in most wetlands within the watershed, the aggressive invasive reed canary grass has taken hold and can be extremely difficult to dislodge.

Wet prairie

Approach to Restoration

- Establish a native wet prairie plant community.

The wet prairie, at Lien Road by the Target store, provides a prime location for restoration. Burning and seeding could greatly increase species diversity within the prairie. However, restoration efforts must be vigilant and may take several years or more to take hold.

Creek Corridor

Approach to Restoration

- Enhance flow conditions.

The banks of Starkweather Creek on the wet meadow site and the Triangle Marsh are heavily clogged with woody debris. The large amount of deadfall and rootwads within the creek greatly slows the velocity of the stream, which has led to increased water temperatures and large accumulations of sediment. Trees within the riparian area should be thinned significantly, and debris should be removed from the creek. In addition, strategically placed erosion-control measures, such as boulders and rocks, should be employed along the banks. Some sediment could be removed from the creek bottoms to prevent this sediment from contributing to sedimentation problems downstream.

Triangle Marsh. The Triangle Marsh has the potential to be a wonderful wildlife area and wetland. The property is diverse in its topography and habitats. However, reed canary grass has aggressively taken over the wetland. During the summer months, thick stands of this plant, 7 to 8 feet tall, have become the dominant, and may be the only floral species present. During our work on the Triangle Marsh, we discovered that an area, previously described as a spring, was in fact drainage-tile discharge pipes (see chapter 3, *Baseflow).* We believe that drainage tiles are extensive in this area, but were unable to determine their exact locations.

Due to the present condition of the wetland and its location, restoration of the Triangle Marsh must be undertaken in an aggressive and dedicated manner.

Comprehensive Approach to Restoration

- Remove hydrologic alterations.
- Suppress invasive species and improve native sedge meadow community.
- Purchase small wetland area connecting to Triangle Marsh.

The first, most important restoration strategy is the removal of the drainage tiles from the wetland. This could be difficult; we were unable to locate their exact positions. Once these tiles are removed, the area will likely become wetter and might foster increased growth of sedge and other native wetland species. The reed canary grass must be brought under control before any restoration success can be expected. As previously mentioned, techniques for eradicating reed canary grass are not presently available; however, future research may yield important clues.

A relatively large amount of wooded area is present within the Triangle Marsh as compared to the other study sites. The wooded areas should be burned to remove the large amount of deadfall and thin the areas. It is possible that following removal of the drainage tiles, the area will become too wet to foster woody growth, and the areas may begin to decrease in size on their own accord. (The riparian area along

Starkweather Creek should be thinned and woody debris removed using the same methods as on the adjacent wet meadow unit.)

The Samuels Recycling Center (SRC) currently owns a small triangle-shaped wetland on the southern end of the Triangle Marsh. This area is bordered by the creek on the western side and the SOO Line train tracks on the east. Much of this area has cattail marsh and sedge meadow. The SRC wetland area is a likely candidate for purchase by the city at some point in the future. The wetland connects to the Triangle Marsh and is adjacent to the fen and stormwater wetland. Furthermore, this property probably is of little significance to SRC due to its location and wetland habitat. Purchasing this area would allow the entire wetland complex to be joined together into one cohesive, city-owned wetland complex.

Integration of the Wetlands Study into the Watershed Perspective

The health and extent of wetlands within the Starkweather Creek watershed will not be determined solely by resource-management choices related to the wetlands. We have illustrated how watershed-related issues such as stormwater runoff, nonpoint-source pollution, flood control, and water supply can impact wetlands. For any wetland preservation or restoration plan to be effective, it must consider the connection between wetlands and the management decisions affecting the surrounding land and water resources (U.S. Environmental Protection Agency, 2005).

In addition, wetland restoration and preservation plans must take into serious consideration the fact that it may be impossible to return these highly complex areas to their presettlement conditions. That is, it cannot be expected that these areas will be able to serve highly conflicting ecosystem functions, such as stormwater retention and habitat for biodiversity preservation. These wetlands need to be managed with the knowledge that urban pressures may necessitate tradeoffs, gaining one ecosystem function at the cost of another. However, by treating these wetlands as a larger watershed complex, more of these functions can be retained over a larger spatial gradient.

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5 EDUCATIONAL OUTREACH

Importance of Public Awareness

A critical component for rehabilitating a degraded urban watershed is educational outreach. Educating the public is crucial for transforming this resource. Although it has been widely suggested and accepted that a formal watershed education plan for Starkweather Creek is needed, a plan has yet to be formulated or implemented (City of Madison, Engineering and Parks Division, 2005; J. Steines, verbal communication, April 2005).

The Dane County Community Stormwater Awareness Assessment was completed in late 2003 by the Dane County Joint Stormwater Permit Group Information and Education Plan Subcommittee. This survey showed a mixed awareness of adverse watershed health in Dane County. Therefore, an educational outreach plan has the potential to promote further understanding and stewardship in this community. Such a program could generate support among residents and spur funding for watershed-enhancement projects; it could also increase motivation of residents to take local action to reduce the impacts of urbanization and stormwater runoff on their own property, in their schools and businesses, and at their places of worship.

As with any natural resource, many stakeholders are involved in use and management. The Friends of Starkweather Creek is one of the leading stakeholders in the watershed. It collaborates with other stakeholders such as the City of Madison, Olbrich Botanical Gardens, Olbrich Community Partnership, neighborhood associations, and other nonprofits as well as county and state agency groups.

Existing Education Plans and Outreach

In designing an educational outreach program for the Starkweather Creek watershed, it is first important to recognize what measures have already been taken or are being taken by other agencies to educate and inform the public about watershed issues at the regional and local level. With respect to the Starkweather Creek watershed, it is appropriate first to look at educational outreach recommendations that have been presented in previous watershed reports and management plans.

Education Plans

Starkweather Creek Reports (1983 and 2005 Update)

The original 1983 management plan did not deal directly with educational outreach in the Starkweather Creek watershed. However, it did take an important first step in the process that could lead to such a program by polling residents of the watershed about their opinions and perceptions of the creek and its immediate corridor. The survey was structured to gauge in what manner and how frequently homeowners in the watershed used the creek, what problems they felt were occurring within the watershed, and what stream-corridor enhancement measures they would support in the future.

By 2005, the Starkweather Creek Master Plan Update had been amended to include an education and outreach section that recognized the efforts put forth by Olbrich Gardens to design a watershed-education program for Starkweather Creek. More specifically, the Olbrich Neighborhood Partnership Committee began to brainstorm methods by which watershed awareness could be fostered in Starkweather Creek communities; this list served as the basis for a number of our educational committee's first concepts (Dane County Regional Planning Commission, 1983; City of Madison, 2005).

Yahara–Monona Priority Watershed Plan (1992)

The Yahara–Monona Priority Watershed Plan was developed in 1992 as a means of addressing worsening water-quality conditions in the watershed's lakes, streams, and groundwater. In addition to management suggestions for the watershed itself, the plan also outlined a proposal called *S.A.V.E the Lakes*, an educational outreach plan designed to inform residents about nonpoint-source pollution and change the behaviors that contribute to this type of pollution. *S.A.V.E. the Lakes* broke the outreach process into four phases:

> 'Sensibility Phase,' wherein activities are designed to develop and promote cultural attitudes conducive to preservation of our water sources. During the 'Awareness Phase,' watershed residents will learn about the threats to watershed resources, the origins of these threats and what they, as citizens, can do to protect their water resource. The 'Volition Phase' is designed to increase feelings of involvement with water resources and to encourage residents to want to do something about water quality. The 'Engagement Phase' provides watershed residents with means and opportunities to actively participate in efforts to preserve and improve water quality.
>
> — Dane County Regional Planning Commission (1992)

A unique attribute of *S.A.V.E. the Lakes* was that it sought to use existing networks of communication to reach watershed residents rather than creating new ones (Dane County Regional Planning Commission, 1992).

Joint Stormwater Permit Group Information and Education Plan (2003)

In accordance with Chapter NR 216, Wisconsin Administrative Code (Stormwater Discharge Permits), the City of Madison and 18 other municipalities in Dane County developed a stormwater-education plan "to improve the quality and reduce the quantity of urban runoff, resulting in area lakes and rivers meeting their designated use." Because stormwater runoff in urban areas is unavoidable, Dane County set out to lessen its effects by educating various urban target audiences about practices that each could undertake. The information and education plan surveyed the watershed awareness of urban audiences, such as the general public, land/homeowners, business owners, developers, contractors, and municipalities, and create a set of objectives and timeline concerning what each would learn or achieve through the outreach plan. In addition, the information and education plan also outlined how the program will be funded and how the progress of the stormwater education will be evaluated.

Outreach Programs

It is important to identify educational outreach that is being employed at the state, county, city, and neighborhood level to gauge what gaps need to be filled in. Although our list in by no means exhaustive, we offer a spectrum of educational outreach examples.

State

The main agency responsible for watershed education at the state level is the Wisconsin Department of Natural Resources (WDNR). The WDNR maintains a Web site devoted to directing visitors to other sources pertaining to various watershed issues, such as hydrologic cycles, stormwater management, water quality, and riparian corridor protection. In addition to giving definitions and descriptions of watershed components, the Web site also offers a "how to" section that instructs citizens about how they can prevent nonpoint pollution, decrease runoff, and start a local water-quality-monitoring program. The site also offers outreach programs geared specifically toward children, with tools that teachers might employ in the classroom to educate children about the importance of the watershed concept. The culmination of this school-oriented outreach is *Project WET* (Water Education for Teachers). *Project WET* depends on local facilitators to introduce interested teachers to the principles and materials necessary to implement the program. The major shortcoming is that programs are not aimed at dealing with problems of a specific watershed, such as that of Starkweather Creek (Wisconsin Department of Natural Resources, 2005).

County

At the county level, the agency responsible for much of the watershed educational outreach is the Dane County Lakes and Watershed Commission. A number of programs run by this agency help encourage Madisonians and Dane County residents to take an active stewardship role in protecting the lakes and watersheds that make up Madison's unique landscape.

One such program is *Yahara Lakes Week*. Taking place in June every year, this event's goal is "to focus public attention on our water resources, raising awareness of the importance of the lakes in our quality of life and the ways in which our lives affect the quality of the lakes." *Yahara Lakes Week* includes a number of prominent events that tackle very specific problems at various levels in the watershed. At the lower end of the watershed, *Take a Stake in the Lakes* was organized as a means to connect residents directly to the lakes. Through cleanup efforts and stenciling campaigns, this program attempts to mobilize watershed residents to realize the environmental issues that are occurring within the lakes they enjoy.

However, effective watershed education must extend beyond just addressing problems within the prominent aquatic features of a landscape. Because many watershed problems stem from land practices far inland, it is also important to educate citizens about how they can positively affect the watershed even if they are far removed from a creek or lake. This is the driving purpose behind the *Better Lawns and Gutters Tour*, which exhibits properties in Madison that are using rain gardens, native planting, and pesticide-free lawns to lessen urban impacts on watersheds, such as that of Starkweather Creek. The *Better Lawns and Garden Tour* also provides information about how property owners can construct a rain garden and where they can go to get further information.

Madison Metropolitan Area

The *My Fair Lakes* campaign has been used by the Madison Area Municipal Stormwater Partnership to create public awareness concerning the connection between stormwater and the quality of the lakes within the City of Madison. Armed with the knowledge that trash, sediments, grease, and fertilizer-based nutrients find their way from streets and lawns into storm drains and creeks, the city has compiled a list of what citizens can do at home, for their lawns, with their cars, and in the community to ensure that only clean water enters Lakes Monona and Mendota. In addition to a Web site and printed materials, the campaign has also made extensive use of television and radio spots to promote the *My Fair Lakes* concept to the people of Madison.

Similar to the *Better Lawns and Gutters Tour* organized by the Dane County Lakes and Watershed Commission, the City of Madison Engineering Department has begun preliminary work on a *1,000 Rain Gardens* campaign. The goal of this campaign is to encourage interested citizens and businesses to undertake the construction of rain gardens by offering information, guidance, and cost sharing for their construction and maintenance.

Citizen and Community Groups

Educational outreach programs organized at a grassroots level are in many cases best suited to manage watershed issues that are specific to a certain watershed. Community and citizen groups are frequently better equipped than a state or federal agency to undertake educational outreach because they are aware of the particular issues that face their watershed and the circumstances that surround the community or neighborhood in which the issues are based. Such was the case when City of Madison Streets Division, Friends of Monona Bay, Friends of Starkweather Creek, and Friends of Lake Wingra partnered in the *Love Your Lakes, Don't Leaf Them* campaign. To address the nutrient-loading problem that many of Madison's lakes face, this partnership launched the movement to educate Madisonians about how leaves can contribute to the growth of unsightly and unhealthy algae and weeds. The program set about to inform residents how autumn leaves should be managed and leaf-disposal methods other than curbside pick-up (such as in-yard mulching and composting).

Educational outreach efforts most specific to the Starkweather Creek watershed have been undertaken by the Friends of Starkweather Creek. The Friends has been visiting different community groups and neighborhood associations and sharing slide presentations concerning the creek and watershed since the group's inception. The Friends has also been instrumental in keeping the Starkweather Creek watershed involved with some of the larger watershed efforts, such as the *Better Lawns and Gutters Tour* and *Take a Stake in the Lakes*. Additionally, the Friends has organized land and water-based tours of the watershed and maintained a presence at local festivals as a means of fostering education and stewardship.

The Need For An Education Plan

As illustrated in the previous section, a number of education programs and plans exist for the greater Madison area. However, none of the plans was designed specifically for Starkweather Creek and as a result, do not include educational goals, objectives, or campaigns unique to this particular urban watershed. If such a plan were developed, implementers would have a framework by which educational outreach could be approached and achieved. Although we could have simply designed and provided such a plan in this report, our goals and objectives might not align with those of the stakeholders. By having those who will execute the plan and its components take an active part in its design, it is more likely that a sense of ownership will surround the process and the plan will be seen through to fruition.

A first step in such a process would involve defining and gathering stakeholders of the watershed and forming a voluntary education-planning committee. The next step for these stakeholders would be to define the overarching goals and objectives that correspond with the mission statements or purposes of the various parties they represent; the goals and objectives would serve as the framework by which the plan and its components would be designed and implemented. The final step would include creating the education plan itself, which would involve developing targeted campaigns, priorities, timelines, and means of evaluating progress.

Numerous resources provide extensive detail about how to create an environmental education plan. The University of Wisconsin–Extension Environmental Resources Center (http://www.uwex.edu/erc/eypaw/) has a set of materials entitled *Educating Young People about Water*. In addition, the Earth Force (http://www.earthforce.org/green) book, *Sourcebook for Watershed Education*, by Sally Cole-Misch, Larry Price, and David Schmidt (1996), provides a structure for creating an education program as well as information about funding and suggested curricula. The Environmental Protection Agency (http://www.epa.gov/watertrain/) offers a publication, *Getting in Step: A Guide to Effective Outreach in Your Watershed.* This publication references many other resources that provide information about topics ranging from curricula to marketing.

Although we believe it is important for the education plan to be developed by those who will see it through to implementation, it is also important for them to have some sort of framework from which to base their own efforts. Therefore, we have included three goal- and objective-specific campaigns that were developed on the basis of the mission statement of and discussions with the Friends of Starkweather Creek. We believe that these three campaigns will fit within any education plan that is developed and highlight some of broader educational outreach needs of the watershed.

Action Points to Achieve Objectives

Many different campaigns could be developed to achieve the goals and objectives that stem from the mission statement of Friends of Starkweather Creek. The campaigns that we present here represent only a fraction of possible campaigns that we discussed and debated. We narrowed the possibilities to the following three campaigns:

- ***Infiltration campaign*—**developed as a direct result of our findings concerning poor baseflow and water-quality conditions and the increased popularity of rain gardens and rain barrels.
- ***North Platte campaign*—**created in response to the city's recent purchase of this unique, highly visible property and as a result of the Friends specific desires to see a plan developed for this area.
- ***Citizen stewardship campaign*—**devised to bring an understanding of the watershed by means of a map and explanatory text.

Infiltration Campaign

As we discussed in the baseflow chapter, municipal groundwater pumping and reduced infiltration are the two largest contributors to the low baseflow and resulting poor water-quality conditions of Starkweather Creek. To address these impacts, an ideal education campaign would motivate the Starkweather community to conserve water and reduce stormwater runoff using rain barrels and rain gardens.

Stormwater management is a broad term that addresses many different elements to managing runoff, pollutants, and infiltration. This campaign addresses only stormwater management focused around these two specific infiltration practices. This campaign can further the education plan proposed by the Madison Area Municipal Storm Water Partnership, yet specifically target the communities within the Starkweather Creek watershed. To supplement this campaign, additional plans could be developed to address other aspects of stormwater management, such as reducing the use of pesticides and road salt, stenciling stormsewers, and encouraging leaf collection, among others. An infiltration campaign would have the following objectives:

- to educate and bring awareness to citizens about stormwater management,
- to encourage hands-on stewardship activities through the installation of rain barrels and rain gardens, and
- to reduce runoff and increase infiltration within the watershed.

There is a growing awareness of rain gardens and rain barrels throughout the country, including Madison, because communities are learning more about the impacts of urban nonpoint source pollution on local waterways. The Dane County Joint Stormwater Permit Group Information and Education Plan Subcommittee (2003) conducted a survey of 19 municipalities, including the municipalities within the Starkweather Creek watershed (City of Madison and Towns of Burke and Blooming Grove). Results from this survey concluded that 34 percent of Madison area citizens are not sure about how stormwater is treated or incorrectly believe that stormwater flows into a municipal sewage-treatment center. Yet only 23 percent declared that they are not willing to implement rain barrels and 77 percent already direct their downspouts to their lawns rather than driveways. These results indicate a general understanding and a willingness to implement these water conservation and infiltration practices that can be built upon with a directed education plan.

This campaign is divided into two components on the basis of the different infiltration practices and audiences. The rain-barrel component is focused on encouraging homeowners to understand stormwater issues, conserve water, and install rain barrels. Installing a rain barrel can be the first step to bringing watershed issues to the average resident. The rain-garden component is not directed at homeowners, but instead at schools, places of worship, and businesses. From our research and discussions, most efforts at rain-garden education in Madison are focused on homeowners, with less emphasis placed on other audiences. Although much work still needs to be done with educating homeowners about rain gardens, our goal was to provide a different angle on rain-garden education and not overlap with current efforts. By focusing on schools, places of worship, and businesses, rain gardens can be demonstration sites for numerous community members, infiltrate large impervious areas, and simultaneously educate homeowners and bring the rain-garden information back to their homes.

Rain Barrels

Installing a rain barrel is a simple first step for homeowners to use to take action in their watershed by conserving water and reducing stormwater runoff. By collecting water from storm events, owners begin to understand the large volumes of water that run off their roofs and how easily this water can be used to irrigate their lawns and gardens. It is calculated that 32 percent of national water usage is from lawn care; reusing rainwater can decrease the demand from municipal water supplies as well as reduce water bills (U.S. Environmental Protection Agency, 1995). A rain barrel is relatively easy to maintain and does not require high quality soils.

Bringing Rain Barrels to Starkweather Creek Watershed

Current efforts in the Madison area to educate communities about rain barrels have been minimal, compounded by the lack of materials available for their installation. However, a few examples of residential rain barrels can be seen within the watershed (see next page). One of the largest challenges with bringing rain barrels to Madison is the lack of local rain-barrel distributors. A common way to distribute rain barrels is for individuals or small community groups to purchase a collection of rain barrels from a national distributor and resell them to local residents because large hardware and gardening stores

What are rain barrels?

Rain barrels harvest rainwater from rooftops; the water can be stored and used on lawns and gardens. Barrels are placed beneath disconnected downspouts, where roof runoff can flow into the barrel and be stored until needed (fig. 5-1). The average rain barrel can store 50 to 90 gallons of water, and additional barrels can be linked for greater storage capacity.

The size and number of rain barrels installed for a building is determined by calculating the volume of runoff that flows into a barrel during a target storm event. This volume is calculated by determining the area of the roof that drains directly to each downspout and estimating the depth of precipitation during an average storm event. In the Madison and Milwaukee areas, more than 75 percent of storm events are less than 0.5 inch (Pitt, 1999); therefore, designing a rain barrel for a 0.5-inch storm event is a reasonable estimation. The volume is calculated by:

rainfall (in.) x roof area (sq ft) x 0.62 (gal/sq ft/sq ft) x 0.85 collection efficiency = total runoff volume (gal)

For example, a 0.5-inch rain event for a 1,000-square-foot roof yields 263.5 gallons of rain. Three 90-gallon rain barrels could capture this entire event. During times of larger events, overflow can be directed to a lawn or garden. Therefore, even if the entire event is not captured, a large amount of the precipitation can be stored and managed. If providing rain barrels for the entire roof is not feasible or economical, directing any part of the roof to a rain barrel is beneficial (Texas Water Development Board, 2005).

in the area do not stock empty barrels and the appropriate materials.

The greatest resource for finding information about rain barrels is through the numerous Web sites that provide information about purchasing and installing rain barrels. Much of this information originates from parts of the country where rain barrels are commonly used, such as Washington, Texas, Oregon, and California as well as locally from the Wisconsin Department of Natural Resources. However, online information is only effective if homeowners take the initiative to do the research. The most tangible and effective resources, such as brochures with local information about rain barrels, cannot be easily found.

In addition to this lack of information, resistance of homeowners to installing rain barrels mainly stems from a fear of mosquitoes breeding within the barrel (Dane County Joint Stormwater Permit Group Information and Education Plan Subcommittee, 2003). Adult mosquitoes can be prevented from en-

Figure 5-1. *Rain barrel. (Courtesy of the River Alliance of Wisconsin.)*

tering the barrel by a screen or filter where the water enters the barrel. Larvae that wash into the barrel can be controlled by regular cleaning of the barrel or the addition of a nontoxic larvacide.

Rain Barrel Action Points

Below is a prioritized list of action points that could be the framework for developing a rain barrel education plan.

Target the Madison audience. A brochure directed at the Madison community could be created with information about the benefits of rain barrels, how to install a rain barrel, where to obtain the needed supplies, and whom to contact locally with questions. By making a direct connection with the benefits of rain barrels to Madison's water issues, the brochure will be more effective than general rain-barrel information. The brochure could be distributed at community events, public events, and at stores where rain-barrel supplies could be sold, such as hardware stores and nurseries.

Develop Distribution Plans. The Friends of Starkweather Creek and other community groups could organize workshops for the distribution and education of rain barrels. Rain barrels can be purchased in bulk through national distributors and distributed to residents at these workshops. Follow-up assistance with installation should also be offered by volunteers from these community groups.

Create Demonstration Sites. Encourage owners of large properties (such as schools, places of worship, businesses, local governments) to install rain barrels as demonstration sites for local communities.

Encourage Local Distribution. Large hardware and home-gardening stores should be encouraged to stock their stores with already-constructed rain barrels and the supplies necessary to build rain barrels. Public interest would encourage these local hardware stores to provide the necessary materials.

Partner with Gutter Services. Throughout the country, gutter services are profiting from installing rain barrels at the request of clients. Gutter services could supply and install rain barrels for residents who need additional assistance.

Encourage Rain-Barrel Discounts. For homeowners to invest in rain barrels, incentives and discounts could be provided by the city or other agencies. (See *Infiltration Campaign Funding* section.)

Rain Gardens

The purpose of the rain-garden campaign is to educate and encourage schools, places of worship, and businesses to build rain gardens as functioning infiltration practices as well as educational demonstration sites for the surrounding communities. As mentioned earlier, much of the current stormwater-management efforts focus on bringing rain gardens to homeowners (Wisconsin Department of Natural Resources, Madison Area Municipal Storm Water Partnership, Dane County Lakes and Watershed Commission, Friends of Lake Wingra), with less focus on other audiences. The action plan pre-

Figure 5-2. *Residential rain garden displayed on the 2005 Better Lawns and Gutter Tour.*

sented here would supplement rain-garden campaigns already in existence and directly target the landowners within the Starkweather Creek watershed who have significant areas of impervious surfaces and potential for influencing large communities.

Rain gardens are becoming increasingly more common within the watershed, as shown through the numerous rain gardens in the 2005 Better Lawns and Gutters Tour (fig. 5-2). Yet some of the resistance to building rain gardens stems from concerns about costs and maintenance (R. Bannerman, June 30, 2005, verbal communication). One way to address these concerns is to construct rain-garden demonstration sites, not simply for viewing, but to demonstrate the issues of building and maintaining a rain garden: the costs of the plants and soil, the types of plants that work best with or without sunlight or water, the demands of maintenance, and the changes the garden makes through seasons and time. Rain-garden demonstration sites can be built and maintained by the community, generating active stewards as well as performing a needed watershed function.

Rain Garden Action Plan

The following action plans provide a new approach to bringing rain gardens to the watershed by addressing schools, places of worship, and businesses.

Schools. The introduction of rain gardens and their use in a formal school setting meets the goals of the infiltration campaign in three ways. First, schools as physical entities generally have expansive areas with high percentages of impervious surfaces, which include roofs, parking lots and asphalt, and concrete play areas. The introduction of rain gardens in such a setting could mitigate the impacts of some of these impervious surfaces. Second, schools would have the opportunity to educate students about they can do to protect and enhance their watershed. This information might trickle back to the parents, who could take action on their own properties. With older, secondary students, a curriculum discussing rain gardens and their uses might influence these future homeowners to think more critically about what measures they can take on their own property to positively influence the watershed as a whole. Finally, schools are inherently community based and can serve as a focal point in a neighborhood. The construction of a rain garden in such an area might encourage other property owners in the community to make similar efforts at home.

Few public schools in Starkweather Creek watershed have any type of environmental restoration or natural areas on their grounds, with the notable exceptions of the Kennedy School Prairie Restoration and the LaFollette High School Native Plant Restoration. Within Starkweather Creek watershed are seven elementary schools, two middle schools, and one high school, but at present, no schools in Starkweather Creek watershed have rain gardens or rain barrels on school grounds. Such projects could be encouraged in an educational setting. For example, Schenk and Hawthorne Elementary Schools are in recharge areas; rain gardens at these schools could mitigate the impacts of their impervious surfaces and increase groundwater recharge. Correspondence with Schenk Elementary School indicated that plans are currently being discussed for a courtyard project that includes a rain garden (Shelia Briggs, Schenk Elementary School, September 2005, verbal communication).

Construction of a rain garden on school grounds could also introduce the watershed concept to students and their parents. Most schools in the Starkweather Creek watershed are far removed from the watershed's prominent bodies of water, making watershed education somewhat difficult. By introducing a rain garden on school property, educators have a physical tool around which they can construct a watershed curriculum, connecting the students to the Starkweather Creek watershed. The rain garden could first be used to teach students about runoff and recharge at the level of the school and could later be used as a jumping-off point to discuss broader watershed ideas, such as stream baseflow, groundwater pumping, wetlands loss, and the health of our water bodies. The curriculum surrounding the rain garden could be correlated with the level of students at that particular school, with primary schools focusing on simple concepts such as the hydrologic cycle, and secondary students being taught higher-level watershed concepts, such as baseflow and water quality.

Table E-1 in appendix E contains the names of the schools located in the watershed, their addresses, and contact information for the principals of each. Each of these schools could be contacted by mail to ascertain if there is interest among the school's faculty in constructing a rain garden and developing a watershed curriculum around it. After it has been determined which schools and faculty might be interested in a rain-garden project, they could be provided with information about the University of Wisconsin–Madison Arboretum Earth Partnership Program and introduced to the curricula developed for the Arboretum as means of getting them started in developing their own watershed-based curriculum (University of Wisconsin–Madison Arboretum, no date).

Places of Worship. The number of faith-based environmental groups is increasing throughout the country, connecting religious faith with environmental stewardship. Religious leaders are speaking out in support of environmental causes (National Religious Partnership for the Environment, 2005). Within Madison, some congregations are involved with collaborations concerning energy and climate change (such as the Wisconsin Interfaith Climate and Energy Campaign). Faith-based groups have been overlooked for environmental outreach, yet they can be very effective at bringing people together to discuss local issues and share information. In addition, places of worship contribute considerable amounts of runoff from their roofs and parking lots; therefore, they are important landowners to target for infiltrating runoff.

We did not identify any faith-based environmental groups or outreach programs focused on watershed issues within the Starkweather Creek watershed. However, outside the watershed on the west side of Madison, Lake Edge Lutheran Church has an outreach program focused on caring for the Earth and plans to build a rain garden at the church in the spring of 2006 (Reverend Dick Blomker, September 13, 2005, verbal communication). This congregation could be a potential model for interested religious groups.

There are many ways to target religious groups. All places of worship could potentially be feasible for the installation of rain gardens, but a few churches are within the identified areas of high infiltration (as determined in the GIS map of recharge areas; see fig. 3-4). These churches include Parkside Presbyterian Church, Moravian Church, Lakeview Christian Church, and St. Bernard's Catholic Church. Infiltration tests could be performed to confirm reasonable infiltration rates and evaluate the feasibility of constructing rain gardens.

Another approach is to identify active congregations, religious leaders, or community members who would be interested in bringing watershed ideas to their places of worship or build an environmental group for the broader religious community. At a single place of worship, leaders could encourage the development of an environmental outreach program that could focus on the health of the watershed. An initial activity for the program could be to evaluate the runoff of the land and install a rain garden to attract community interest and discuss environmental stewardship. Depending upon the desires and interests of the community, many different environmental issues could be addressed with this program.

Developing an environmental group or task force for many places of worship and potentially many faiths can initiate environmental interest with the broader community. This concept may have more success with smaller congregations that might not have the size to develop their own outreach program directed solely at environmental causes. An example of a faith-based environmental group is The Religious Partnership for the Anacostia River, with a mission to heal Washington, D.C.'s Anacostia River and surrounding communities. The partnership focuses on encouraging "restorative landscaping" with practices such as green roofs, rain barrels, and rain gardens to reduce the pollution of the river. The Anacostia suffers from similar stormwater problems as Starkweather Creek, and this organization is reaching out to people of all faiths to work toward improving the health of the ailing river (Religious Partnership for the Anacostia River, 2004). A similar group formed for Starkweather Creek could assist homeowners or places of worship within the watershed with building rain gardens, or simply be an avenue to communicate information to communities throughout the watershed.

Businesses. Although ongoing stormwater-management efforts in the Madison area do target businesses, their use of rain gardens as an infiltration technique seems minimal. Similar to schools and places of worship, a major contribution by businesses could be the installation of rain gardens on their properties. Businesses with smaller lots and rooftops could construct rain gardens having a design similar to ones typically installed by homeowners. Additionally, the rain-garden installation could be an excellent occasion to engage local residents in a community activity, further educating them on the purpose and function of rain gardens; Willy Street Coop is such an example.

Business owners may not be inclined to install rain gardens or other infiltration techniques on their own, so developing an outreach program for business owners can be an effective way to educate them about the benefits of installing these systems. An outreach program could identify and provide support to those business owners who are interested in installation, either now or during future parking-lot resurfacing or reconstruction activities. Because businesses on larger lots are likely to have larger rooftops and parking lots, bioinfiltration facilities, as described in the infiltration chapter, would be better suited to these types of properties. Bioinfiltration design is more complex than a rain garden; the outreach program could also provide resources about who can perform infiltration tests and evaluate the feasibility of various infiltration techniques.

As mentioned previously, businesses could supply rain-garden products and educational materials. Hardware stores, nurseries, and gardening stores would be effective places to distribute rain-garden resources, in particular plants and materials for rain-garden installation, and educational materials. Several gardening stores already sell native plants with an adjacent display describing rain gardens. An outreach program could focus on expanding the number of stores that promote rain gardens. In addition, the rain-garden displays could be enhanced with flyers that include design principles as well as a listing of further resources and Web sites. This effort by businesses might target otherwise uninterested homeowners and inspire them to install rain gardens on their properties.

Many businesses take part in community service, either through participation in community activities or donations to projects. An environmental education program in Grand Rapids, Michigan, entitled "Rain Gardens of West Michigan" (Rain Gardens, 2000–2004) encourages businesses to partner with schools in developing rain gardens. They suggest businesses could not only donate money for materials, but could also join students in maintaining the gardens (http://www.rain gardens.org/Opportunities.php). This type of approach would complement the recommendation of introducing rain gardens into the schools. Given the rain-garden education efforts that have taken place in Madison to date, organizations such as Madison Area Municipal Storm Water Partnership, the Lakes and Watershed Commission, and the WDNR likely have numerous projects to which businesses could contribute or even actively participate.

Knowing their efforts would be acknowledged might further inspire businesses to become involved in rain garden efforts. One watershed group, The Anacostia River

Business Coalition in Rockville, Maryland, gave recognition to those businesses that have installed rain gardens (Anacostia River Business Coalition, no date.). Again, this is an approach that could be considered for the Starkweather Creek watershed.

Infiltration Campaign Funding

A crucial component of promoting infiltration practices among homeowners, schools, places of worship, and businesses is sustained funding. As efforts among some municipalities have shown, encouraging the use of rain gardens and rain barrels can be contingent on formal programs, which include cost-shares, discounts, and even rainwater-harvesting rebates to homeowners. The benefits for a homeowner may lie in reduced water bills. Water utilities may see reduced demand on stormwater systems, which may lower overall production costs for providing water (Gertson and others, 2002).

Cost-sharing and grants for rain-garden projects have gained in popularity across North America. However, only a few cities in the United States are beginning to offer rain barrels to its citizens at a reduced rate; many regions of Canada have been implementing such programs since 2000 (Regional Municipality of Waterloo, 2001).

A key aspect for successfully promoting the widespread use of infiltration practices within a community is funding support administered by a local entity. Because the City of Madison is already making attempts to increase rain gardens through the 1000 Rain Gardens Project, identifying funding for rain-garden projects may not be as constructive as funding recommendations for increasing the usage of rain barrels. Another major local effort includes the Graham–Martin Prairie Foundation's gift to Dane County and the City of Madison in 2005 to support the establishment of rain gardens and the use of native seeds and plants (Dane County Executive Office, 2005). It may be more advantageous to pursue rain barrels because the City of Madison and Dane County are making serious efforts to promote community infiltration, and the establishment of successful rain-barrel programs has already been demonstrated in some United States and Canadian cities. Many grants identified to promote rain gardens may serve a dual purpose for promoting rain barrels, especially because much of the available grant money is to control nonpoint source pollution (appendix E, tables E-2 to E-4).

Rain barrels and rain gardens can vary in cost, depending on supplies and installation. Some estimates of the costs for implementing a rain garden range "from about three to five dollars per square foot when designed and built by the landowner," versus "about ten dollars per square foot if constructed by a professional landscaper" (Minnesota Lakes Association, 2005). The average cost of a rain barrel for a "low-density residential lot in a subdivision" is $120, excluding accessory components (Low-Impact Development Center, 2003). These accessories, which are generally required to capture rooftop runoff, can push the total cost to more than $200. However, as square footage of rooftops increase so too does the size and cost of the rain-barrel system.

Encouraging the use of rain barrels within a watershed or municipality may initially require the use of federal, state, and/or local funds. Outside of regional or municipal programs, no grants or cost-sharing programs are available to individual homeowners for rain barrels. However, many funds are available to states, cities, and nonprofits to reduce nonpoint source pollution. At present, the residents of the Starkweather Creek watershed are not offered subsidies for the installation of a rain-barrel system.

Some of the most successful infiltration programs are Seattle's RainCatchers Pilot program; the City of Austin, Texas, rain-barrel sales, rebate, and harvesting rebate programs; the City of Olympia, Washington, rain-barrel sales program; and the Christina Basin rain-barrel survey in Pennsylvania and Delaware. These programs have had a very good response; most rain-barrel sales events run out of supplies. For example, the City of Olympia, Washington, had to turn away people who wanted rain barrels during one of their sales events due to limited supplies (City of Olympia, 2005). Homeowner experience using rain barrels has also been very good in most cases, with participants in the Christina Basin reporting 100-percent satisfaction (Kaufman and others, 2003). In Canada, rain barrels have gained popularity among residents, especially in towns like Waterloo, Ontario, which has a population of almost 80,000 residents. The Water Services Division of Waterloo planned to distribute 25,000 rain barrels from 2001 to 2005, as part of their long-term water strategy. In 2001, 6,000 rain barrels were distributed to Waterloo residents at the reduced rate of $30 per barrel; the city allocated $225,000 of the capital budget for cost-sharing in this effort (Regional Municipality of Waterloo, 2001). The cities of Edmonton, Vancouver, Thunder Bay, and Halton also similar programs.

Federal, state, local, and private funds are available to support a rain-barrel rebate or cost-sharing program. Some potential funding sources are described in appendix E (tables E-2 to E-4).

North Platte Campaign

The North Platte, adjacent to Olbrich Botanical Gardens, is a relatively undeveloped plot of land within the Starkweather Creek watershed. In 1999, Olbrich Botanical Gardens completed their master plan, which included only a broad, conceptual plan for the North Platte. Olbrich is updating their master plan, and they intend to revamp the design for North Platte (Hinkfuss, 2002). Planning efforts provide a unique opportunity for providing substantial watershed education about human impacts upon the landscape.

Site Analysis

The North Platte is within the Starkweather Creek watershed near the mouth of Starkweather Creek (Olbrich Botanical Gardens, no date). The confluence of Starkweather Creek forms its northern and eastern boundaries; Olbrich Botanical Gardens. its western and southern ones. It is close to two major arterials, Atwood Avenue and Fair Oaks Avenue (fig. 5-3). "Olbrich Botanical Gardens is actually owned and operated by the City of Madison Parks Division, in partnership with the nonprofit Olbrich Botanical Society" (Olbrich Botanical Gardens, no date). Given its location, the North Platte has high visibility and extremely good public access.

The North Platte has a rich and varied history. At one time, the North Platte was pre-

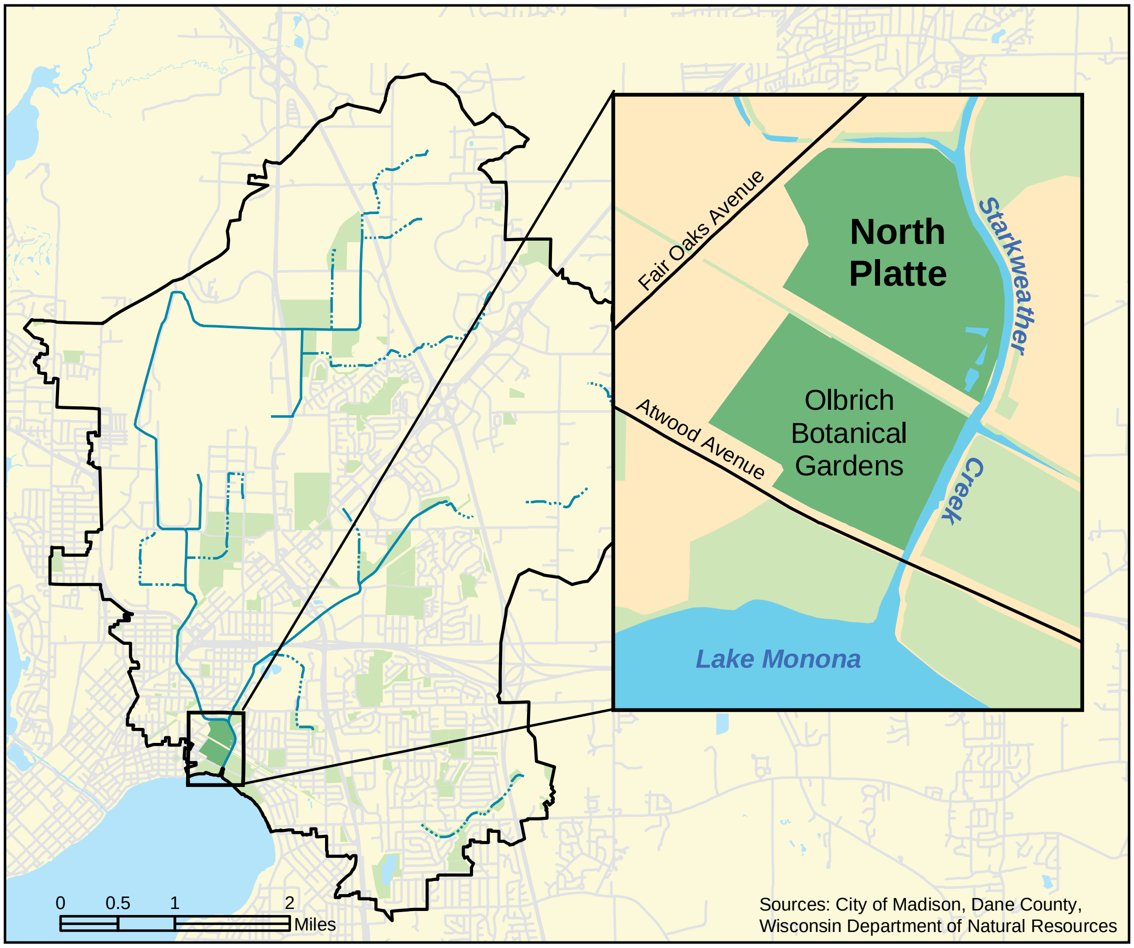

Figure 5-3. *Location of the North Platte in relation to Olbrich Botanical Gardens and Starkweather Creek.*

dominantly wetlands. Given its proximity to the confluence and the influence of seasonal flooding, the exact size of these wetlands is difficult to quantify. The wetlands were drained and subsequently filled for development, and today they are less than 0.5 acre in size. From 1906 to 1924, the site contained a factory used by U.S. Sugar Company to produce sugar from sugar beets. The factory was sold in 1926 and again in 1929, when it became a feed mill and warehouse under the ownership of the Wisconsin Sales and Storage Company. In 1975 the property changed hands and was renamed Garver Feed and Supply Company; it continued to operate until 1997 (Hasbrouck Peterson Zimoch Sirirattumrong, 2005).

In 1997, the Madison Community Development Authority sold two parcels totaling 17 acres to the Madison Parks Division. At the same time a nonprofit organization, Olbrich Botanical Society, in partnership with the City of Madison, acquired a 5-acre parcel known as the Garver Property. Olbrich Botanical Society transferred this parcel to the City of Madison. The three parcels, totaling 22.9 acres, make up the North Platte, which is dedicated to future expansion of the botanical gardens and parks (Hinkfuss, 2002).

Physical Structures

Two buildings are on the North Platte, the Garver Building and the Garver Cottage (Olbrich Botanical Gardens, no date). As seen on figure 5-4, the Garver Building is on the southern part of the North Platte and faces the existing bike trail. The Garver Cottage is east of the Garver Building.

Although the Garver Building is somewhat dilapidated (a fire in 2001 exacerbated the deteriorating conditions), numerous structural evaluations and feasibility studies show that the building was well constructed and still has some structural integrity. It has been designated as an historic landmark, and planning processes are underway to determine its reuse. Approximately 35,000 square feet will be available (Hinkfuss, 2002). The Garver Cottage was used as an office building for the factory. In 2001, the Cottage was renovated in a way that preserved its historic design; it is used as office space for the Olbrich Gardens horticultural staff (Madison Trust for Historic Preservation, no date).

Previously Studied Site Conditions

In 2004, a class in the Department of Urban and Regional Planning, University of Wisconsin–Madison, conducted a site analysis and prepared conceptual plans for the renovation of the Garver Feed Mill building. As part of their site analysis, they collected information on many conditions at the North Platte, some of which include the following:

- deed restrictions,
- land uses,
- zoning regulations,
- utilities, including stormwater, sanitary sewer, and water lines,
- transportation, including roads, recreation trails, and rail corridors, and
- environmental corridors and open space.

Appendix F contains the part of their report that synthesizes these site conditions.

Environmental Conditions

Soil conditions throughout the North Platte are varied. Soil cores collected near the Garver Building revealed a shallow layer of topsoil over compact fill, as did the outer edges of the forested area on the west side of the North Platte. However, several soil cores taken toward the center of the forested area showed little evidence of gravel fill. The cores showed layers of peat, sand, silt, and clay, not necessarily in that order. Infiltration studies demonstrated little to no infiltration capacity (0.0 – 0.1 cm/hr) near the Garver Building; the outer edge of the forested area had significantly greater infiltration rates (8 cm/hr).

The forested area primarily contains stands of cottonwood. The downstreambank vegetation consists of early successional woody species and some native forbs. Vegetation in the remaining areas tends to be heavily disturbed; the upstream part of the streambank

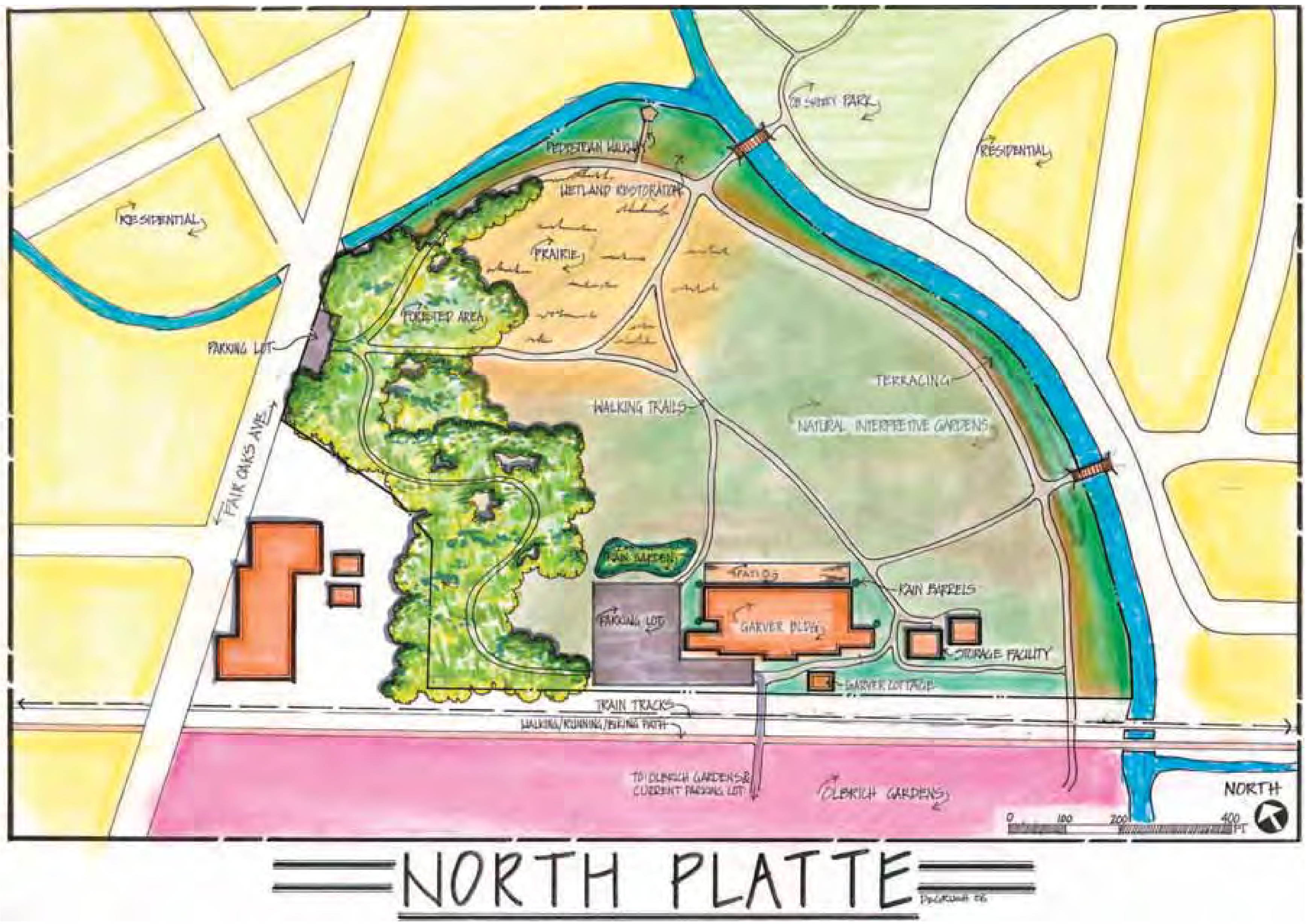

Figure 5-4. *North Platte conceptual plan.*

is a near monoculture of reed canary grass. The remaining open space throughout the North Platte is either void of vegetation or contains predominantly of reed canary grass. Wildlife observed at the North Platte was typical to an urban setting.

Stakeholders

Primary stakeholders for the North Platte design include the Olbrich Gardens board and staff and several departments of the City of Madison, including the Parks and Planning Divisions. Mayor Dave Cieslewicz provided the "impetus for moving forward with restoring the Garver Building" (Urban and Regional Planning, 2004, p. 40) and therefore, is another key stakeholder. Friends of Starkweather Creek, adjacent neighborhood residents, and current and potential users of the site (for example, local residents and visitors of Olbrich Gardens) are also stakeholders. Olbrich Gardens and the City have been leading current planning processes for the North Platte, and Friends of Starkweather Creek and local residents have been active in having their thoughts and ideas included in the process.

Opportunities and Constraints

The North Platte faces formidable obstacles for preservation and enhancement of natural areas and for watershed education. Soil conditions are primarily compacted fill material, which makes native plant restoration and creation of formal botanical gardens difficult and costly. The compacted fill also limits groundwater recharge; precipitation ponds on the North Platte or is discharged directly into Starkweather Creek through overland flow, contributing to its poor water quality. Vegetation species are less than ideal, with reed canary grass dominating parts of the area.

Because the site is quite large and relatively undeveloped, there are many possibilities for what the site should become. Reaching an agreement on a final design will require an ample amount of time and effective collaboration. In addition, renovation of the historic Garver Building and any other ecological restoration could be costly.

Nevertheless, the North Platte has tremendous opportunities. Because of its rich history—one that includes human influence and disturbance—the North Platte offers an excellent on-the-ground location to educate citizens about human impacts on the landscape. It can be used as a laboratory to show how humans have caused degradation with previous land uses and how we can make positive changes in the future. In addition, the North Platte is a rare plot of open, undeveloped land in the City of Madison. It is centrally located and could easily connect to Olbrich Botanical Gardens, Olbrich Park, and O.B. Sherry Park (Urban and Regional Planning, 2004). The North Platte also has a high community value. Many local residents use the space for walking and would like to see its accessibility for recreational activities maintained and even enhanced (J. Steines, verbal communication, April 2005).

Conceptual Plan

Vision and Conceptual Design Goals

Given the opportunities at the North Platte, this conceptual plan strives to achieve the following goals:

- to provide opportunities for watershed education throughout the site,
- to maintain and enhance community value of the area, and
- to restore wetland, prairie, and forested areas throughout the site to enhance aesthetics and ecological functions, such as stormwater filtering and wildlife habitat.

By achieving these goals, the North Platte could become a model for fostering knowledge and appreciation of watersheds. It would demonstrate how an undeveloped parcel might look with watershed enhancement, protection, and restoration as a design priority, while still providing revenue-generating activities.

Precedence

Existing educational exhibits can serve as a starting point for generating ideas applicable to the North Platte. Exhibits that educate the public about watersheds are beginning to have greater prominence across the United States. For example, the Academy of Natural Sciences Museum in Philadelphia (http://www.acnatsci.org/museum/) has an indoor exhibit entitled *Living Downstream*, created in 2001. It explores how human activities degrade water quality and what people can do to help watersheds and the aquatic environment. The Seattle Aquarium (no date) has a watershed activity center as part of their exhibits. Although the exhibit is impressive, all its components are replicas, not displays in a natural setting. The City of Boise, in partnership with corporate and citizen funding, is in the process of building an environmental education center, entitled *Boise WaterShed* (http://www.cityofboise.org/BoiseWaterShed/). It will be certified as a Leadership in Energy and Environmental Design and will have exhibits that focus on issues affecting watersheds, ranging from water quality and wastewater treatment to stormwater recycling.

Many outdoor nature centers include human impacts upon the environment as a component in their educational programs. The University of Wisconsin–Madison Arboretum Earth Focus Day Camp (http://uwarboretum.org/education/efdc/) is such an example. Some nature centers have even been built around former industrial sites. For example, the Eden Mill Nature Center and Historic Grist Mill Museum (http://www.edenmill.org/) in Pylesville, Maryland, developed a nature center around a former grist mill. The educational exhibit proposed for the North Platte will build upon these and other watershed-exhibit concepts.

Features of the Conceptual Plan

Building Recommendations. Currently, the Garver Building rehabilitation has been identified as the first step in the North Platte planning process, of which the city is taking the lead. This includes not only construction activities, but uses for the building. Once that has been established, the planning process would proceed to the remaining North Platte property (E. Komosa, verbal communication, July 26, 2005). Ideally, the Garver Feed Mill Building renovation would be addressed in conjunction with the entire North Platte design. Because this is not the case, we suggest looking at any building proposals with the following questions in mind, "What uses will help to improve the physical, chemical, and biological quality of the Starkweather Creek watershed? What uses can help educate and promote stewardship of the watershed?"

The Urban and Regional Planning (2004) conceptual plan for the Garver Feed Mill put forth many proposals for the building. Of these, we feel the following would best answer these two questions: an interactive nature museum and a green building demonstrating sustainability techniques (for example, solar energy and stormwater management through rain barrels and a vegetated rooftop, among others). We also support uses that generate income such as a café or facilities for weddings and other large events. Rooms could be available to the public for smaller meetings; this could help promote a sense of community.

Interpretive Displays of Watershed History. The North Platte has a history of development that is characteristic of much of the watershed. Therefore, this area and its landscape features could be used as a means of educating the public about this typical development pattern. Interpretive displays could be created and used to bring visitors through the years spanning from the first settlement of the area for agricultural processes to current degraded watershed conditions. Specifically, these displays could highlight the following events:

- draining of wetlands by tiles for agricultural purposes,
- filling of wetlands for urban development,
- channelization of streams to quickly convey urban runoff once stored by lost wetlands,
- armoring of streambanks to protect from erosion caused by runoff-dominated streams,
- decrease in water quality because of loss of wetlands and increased urban runoff, and
- establishment of invasive species in areas where habitat is degraded and poor quality runoff adversely affects native species.

These interpretive displays could be located on the North Platte, close to the features that they are describing. For example, a display discussing channelization could be located on the stream in a straightened area.

Because a sense of history can lead to residents developing a connection with an area of environmental interest, another set of interpretive signs should be developed in a similar fashion to describe the specific history of the North Platte. The displays could discuss the following features:

- U.S. Sugar Company and sugar beet production.
- Garver Grain Company.
- history of the railroad in relation to Madison, and
- history of Olbrich Gardens.

Other features of the North Platte could also be marked with interpretive displays as they relate to watershed issues or features of the watershed that are worth highlighting. To give visitors a synoptic view of the North Platte as well as the interpretive displays located throughout, a brochure, physical model, or map of the North Platte could be also be made available.

Rain-Barrel and Rain-Garden Educational Displays. Multiple demonstration sites located throughout the North Platte could educate visitors about the different infiltration practices that homeowners can perform in their own backyards. These sites could display rain gardens and rain barrels with a self-guided tour of interpretive signs about how to install them and their benefits to the watershed. Demonstrating these practices would help educate the community about how people can reduce their own stormwater runoff as well as understand the hydrologic and water-quality benefits of these practices for managing runoff and enhancing infiltration. These displays would be of interest to horticulturalists who visit Olbrich to learn more about native plant species and root function. Most important, these demonstration sites could encourage stewardship among community members to engage in activities that not only enhance the beauty of their backyards, but benefit the health of the watershed.

Ideal locations for rain barrels in the North Platte are beneath a selected number of downspouts of the Garver Building (fig. 5-4). Because we do not know what the gutter configurations of the building will be, we are unable to calculate rainwater volume and rain-barrel size. The roof area directed to each downspout is required for calculation of roof runoff volume. In addition to rain barrels, a cistern could be installed on the northwest corner of the Garver Building as a part of a green building design and used as a non-potable water source.

The design of rain gardens within the North Platte can allow for many variations. The size and shape of the gardens can be designed to best fit the other elements of the landscape. The types of plants used in rain gardens could include grassy prairie species as well as colorful, flowering plants that would attract birds and butterflies. The gardens can be noted for their design and aesthetics, but still have the functionality of deep root systems that stabilize soils and increase infiltration.

The location of the rain gardens would best be found along the edge of the Garver Building for the directed water to enter the gardens. They should be at least 10 feet from the base of the building to prevent water damage to the structural foundation.

As a result of the industry in this area, the soil has been significantly disturbed and the current soil conditions have low infiltration rates that may not be ideal for a rain garden. An infiltration test should be conducted to ensure a rain garden would function properly. It is likely that the soil conditions on the North Platte are not ideal. Nonetheless, we recommend the installation of rain gardens solely for educational purposes. For an enhanced educational exhibit, experiments could be conducted to demonstrate the infiltration capabilities of various plant communities.

Wetlands Restoration. The wetland on the southwest corner of the East and West Branch convergence would benefit from restoration. The main goal of the wetland restoration would be to remove the highly invasive reed canary grass that grows along the creek and promote the reestablishment of native wetland species. An additional goal in this effort is to promote awareness of the impacts that urban stormwater runoff has on wetland aquatic habitats. After most of the wetland restoration work has been done, a number of interpretive signs describing natural and degraded wetlands as well as the restoration process could be erected along the walking trail that skirts this wetland area. These interpretive signs could include a description of the ecosystem functions that wetlands serve in a watershed. Wetland areas directly across the stream could be used as a comparison to this newly restored area. Although a more powerful comparison could be made by leaving a part of the North Platte wetlands degraded, this might encourage the reestablishment of reed canary grass in the restored area by plants remaining in the degraded plot.

The wetland restoration at the North Platte could also make mention of the nearby MG&E Marsh located across Fair Oaks Avenue on the West Branch of the creek. This area is an excellent example of a wetland that has survived the urbanization of the watershed. The interpretive signs at the North Platte wetlands could direct visitors to the MG&E Marsh and describe some of the shortcomings of restored wetlands at the North Platte compared to their natural counterparts. Interpretive signs could also be placed at the MG&E Marsh to describe the type of wetland it is and some of the plant species found within it, and asking visitors to observe the wetland from the trail to help protect it from degradation. These components of the education campaign would educate the public about the processes, values, and issues facing wetlands on the North Platte as an illustration of the processes, values, and issues facing wetlands located in the watershed as a whole.

Riparian Corridor Improvements: Terracing and Buffer Zone. Terracing can be an effective method of streambank stabilization: It can improve the connectivity between the channel and the floodplain, thereby reducing erosion problems and promoting stable vegetation along the banks. We propose riverbank terracing along a part of the North Platte, beginning at the southeast corner, where the streambank intersects the railroad crossing, and extending upstream to the proposed wetland restoration.

Although this part of the stream corridor is not severely eroded, a terrace system on public lands would provide a readily accessible hands-on experience with terraces. Similar to the wetland-restoration project, interpretive signs placed along the walking trail where it passes the terraced banks would serve as a tool to communicate information. The displays could also encourage visitors to apply their knowledge and to watch for signs of erosion as well as streambank-stabilization techniques at other locations along the creek.

Also important to overall stream and corridor health is a riparian buffer zone. Because the North Platte is a relatively undeveloped public space, it provides a rare opportunity within the watershed to provide a substantial buffer between the creek and adjacent land uses. A specific width would need to be determined during the site-design phase because many factors are involved in determining such a width: sufficient floodplains, stream-corridor regulations, trail design, and even streambank construction. However, in consideration of high flows passing by this location, and the fact that some streambank stabilizations extend 30 feet beyond the channel (Schueler and Brown, 2004), we recommend a buffer no less than 75 to 100 feet.

Forest Protection and Restoration. Given that few wooded areas are in the urban locality of the North Platte, we recommend preserving all forested sections in an effort to preserve this rare and unique resource. Preserving this forested area would provide a number of benefits to the local community. The area provides a reprieve from the urban environment and serves as an educational tool as well an environmental buffer for the creek. The soil conditions, infiltration rates, and vegetation are the least disturbed of the entire site. Removing the cottonwood stands or otherwise altering this area would likely result in impervious surfaces, runoff, or lower infiltration rates, thus degrading Starkweather Creek even further. Some forest-management techniques, including additional plantings, may be necessary to fully restore and preserve the site, and a detailed study could be conducted. However, this type of study would take lower precedence to other recommendations in this conceptual plan.

Prairie Restoration and Natural Interpretive Gardens. Prairie ecosystems are unique landscape features that were once dominant and now exist in small fragments scattered across the Midwest. Restoring an area of prairie ecosystem would expand upon the educational experience of visitors to the North Platte. Most of the North Platte is removed far enough from Starkweather Creek that soils are sufficiently dry to facilitate a prairie restoration in non-forested areas. Removal of fill material in the southern part of this area could create conditions conducive to such an undertaking. A prairie restoration on the North Platte would serve as a complement to Madison's west side prairie restoration at the Arboretum and would allow Olbrich Gardens to display another distinct botanical exhibit.

The undeveloped land east of the proposed prairie restoration could be used as natural interpretive gardens. These gardens could have a somewhat structured layout and be used for native plant information and identification. The area could also include additional exhibits, such as historical interpretive displays and interactive watershed and soils exhibits.

Driveway and Parking Recommendations. Additional parking and vehicle access necessary for the development of the North Platte should be placed and installed only on an as-needed, low-impact basis. Prior to construction of additional paved areas, a proposed-use study could be conducted to determine the daily and special event parking and vehicle access needs of the North Platte and Olbrich Gardens. If additional parking is determined necessary, other parking lots located within walking distance could be considered prior to construction of any new parking facilities. Three parking lots, consisting of approximately 330 total parking spaces, are adjacent to Olbrich Park and the boat-launch facilities, all within approximately 1,000 to 2,500 feet from the existing main entrance of Olbrich Gardens. As noted on the North Platte conceptual plan (fig. 5-4), existing parking for Olbrich Park and the Olbrich boat launches could be used during special events when additional parking is occasionally needed.

If future gardens are placed where proposed in figure 5-4, proposed parking locations will be very close to the new garden areas. If distance from the garden entrance is still a concern, a shuttle service could be established for special occasions. Using existing parking facilities would limit the impact of building additional parking as well as save limited construction funds for other garden projects.

Low-impact development criteria could be implemented when determining the appropriate size, location, and type of materials for constructing any new parking lot. To minimize impacts to existing natural areas, new parking facilities should be positioned outside of any established creek buffer area and away from other environmentally sensitive areas, such as wetlands, woodlands, or prairies (Schueler and Brown, 2004). A few possible appropriate locations for new parking have been noted on the North Platte site plan (fig. 5-5).

Because parking facilities constitute such expansive areas, constructing additional parking using pervious pavement or porous concrete should be strongly considered. A number of studies have shown that pervious pavement significantly reduces runoff volumes and pollutant loading when compared to traditional installations of impervious surfaces (Construction Industry Research and Information Association, 2002; California Stormwater Quality Association, 2003; Pratt, 1995; U.S. Environmental Agency, 2000; Brattebo and Booth, 2003). In Tampa, Florida, porous pavement was installed for a section of the parking lot built for the Florida Aquarium. A comparison of pervious sections to adjacent impervious sections of cement and asphalt showed that the porous pavement successfully reduced runoff flows from the parking lot as well as reduced concentrations of metals within the runoff (U.S. Environmental Agency, 2000).

Construction of a parking lot using porous material does cost somewhat more than traditional impervious applications (U.S. Environmental Agency, 2002); however, the net environmental benefit received by adjacent waterways, in particular Starkweather Creek, and the reduced need for additional stormwater-control systems, could significantly offset installation and annual maintenance costs (Daley, 2003; Pervious Pavement specialist, 2003). Construction design manuals should be used to determine whether the proposed site is suitable for porous pavement, how to properly install and maintain porous pavement, and what the estimated cost will be (California Stormwater Quality Association, 2003; U.S. Environmental Agency, 1999; New Jersey Department of Environmental Protection, 2004; City of Portland, 2004; King County, 1998). Interpretive signs discussing the benefits of pervious pavement and other low impact parking measures could be located adjacent to these areas in an effort to further educate the public.

Additional North Platte Vehicle Access. We understand that, in accordance with the Olbrich Gardens master plan, a drive connecting the Garver Building with Fair

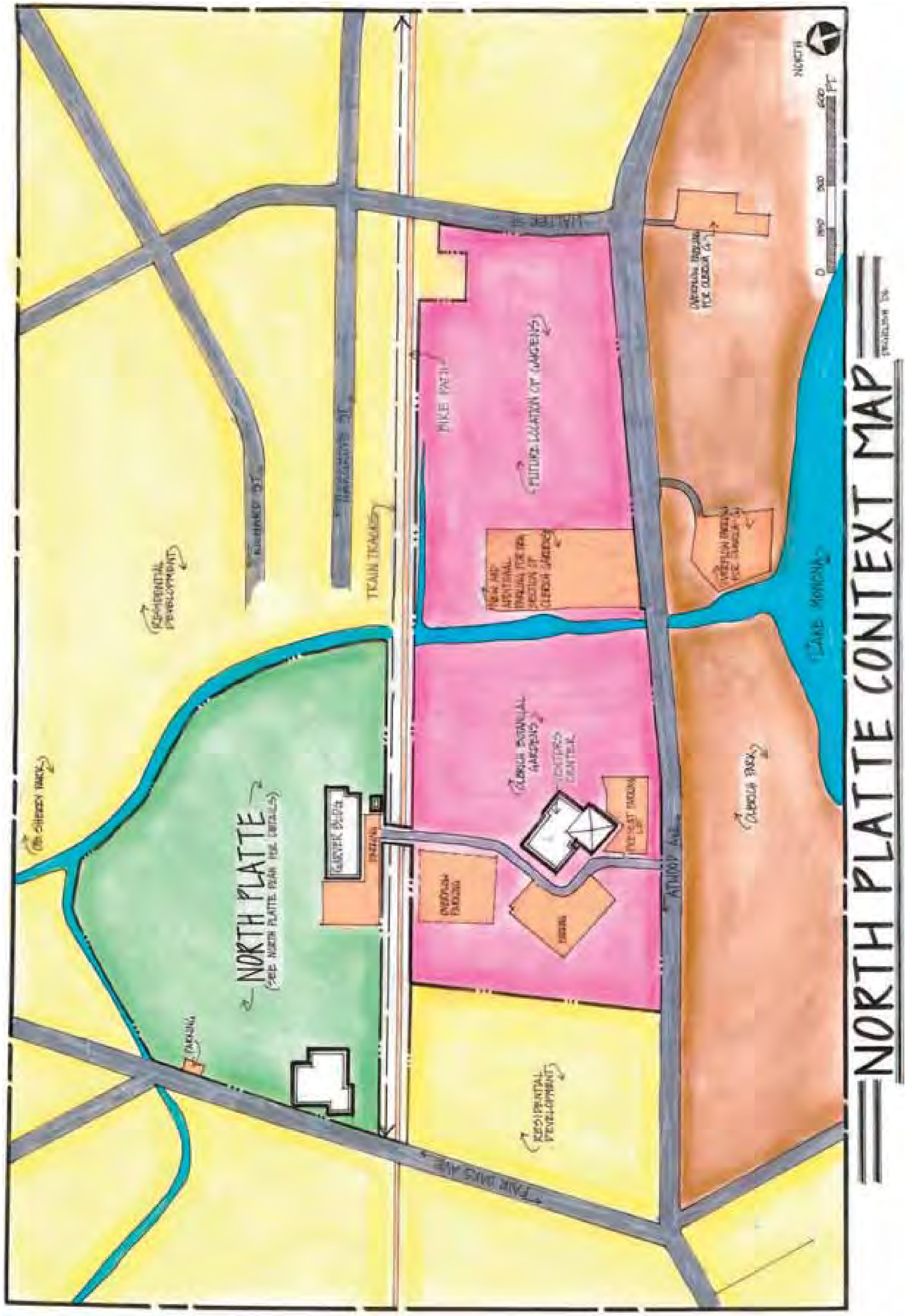

Figure 5-5. *North Platte context map.*

Oaks Avenue is desired (Urban and Regional Planning, 2004). If constructed, the drive would be approximately 900 feet long and add a minimum of 18,000 square feet of impervious space to the North Platte (fig. 5-5). This estimate is based on the assumption that the road would have very low traffic volume and no curbside parking, allowing a narrow street width of 20 feet to be sufficient (Dane County Planning and Development and Better Urban Infill Development Program, 2004). As with the additional parking areas, installation of this impervious surface would have a significant impact to the North Platte resources. However, it does make sense to have an additional access point to the Garver Building to allow vehicular access for emergency services and the physically disabled. As with the proposed parking areas, pervious pavement is a viable option for construction of the drive and would mitigate impacts to surface-water quality.

Walking Trails. In the Starkweather Creek Master Plan 2005 update, the City of Madison Parks Division outlined a concept for the Garver Area and North Platte that included a number of walking trails that would connect Olbrich Gardens, O.B. Sherry Park, and the Dixon Greenway and serve as a framework for native restoration. On the basis of that recommendation, we propose that a walking-trail system be developed to guide North Platte visitors through the educational interpretive displays that we propose in this report. These trails could also highlight the various natural vegetation communities present on the North Platte (wetlands, riparian corridors, and forest stands). The conceptual plan (fig. 5-4) and perspective (fig. 5-6) illustrate the recommended placement of these trails. The proposed trail system consists of three loops: 1) one that has interpretive stations dealing with the "typical" development patterns of a watershed (tiling, channelization, and dredging) 2) another that showcases the unique historical features of the North Platte (the U.S. Sugar Company Plant/Garver Building and railroad yards) and 3) one that contains descriptions of various restoration efforts undertaken in the area (streambank terracing and wetland restoration). (A more detailed description of these interpretive stations can be found in the previous section, *Interpretive Displays of Watershed History*.)

The three trails would begin at or near the Garver Building, interconnect in the North Platte, and be equipped with adequate signage. In addition, at least one of the trails should meet the American Disability Act's recommendations for pedestrian paths. This will create a trail of required width, composed of a hard-packed material with ample area for turnarounds. The remaining trails will be more primitive and preserve one of the last undeveloped areas in an already highly urbanized Starkweather Creek watershed. The trail that extends into the wetland would connect to boardwalks within this area to facilitate access during the periods of high and low water that are characteristic of wetlands. Finally, the entire trail system would be accented with more secluded spots in accordance with the Starkweather Creek Master Plan 2005 update to offer visitors locales for "nature study and contemplation." After the establishment of this trail system, the segment nearest Fair Oaks Avenue could be extended northwest to connect the North Platte to one of Starkweather Creek watershed's best wetlands, the MG&E Marsh. This will require additional signage at the Fair Oaks crossing and at the marsh to ensure that visitors

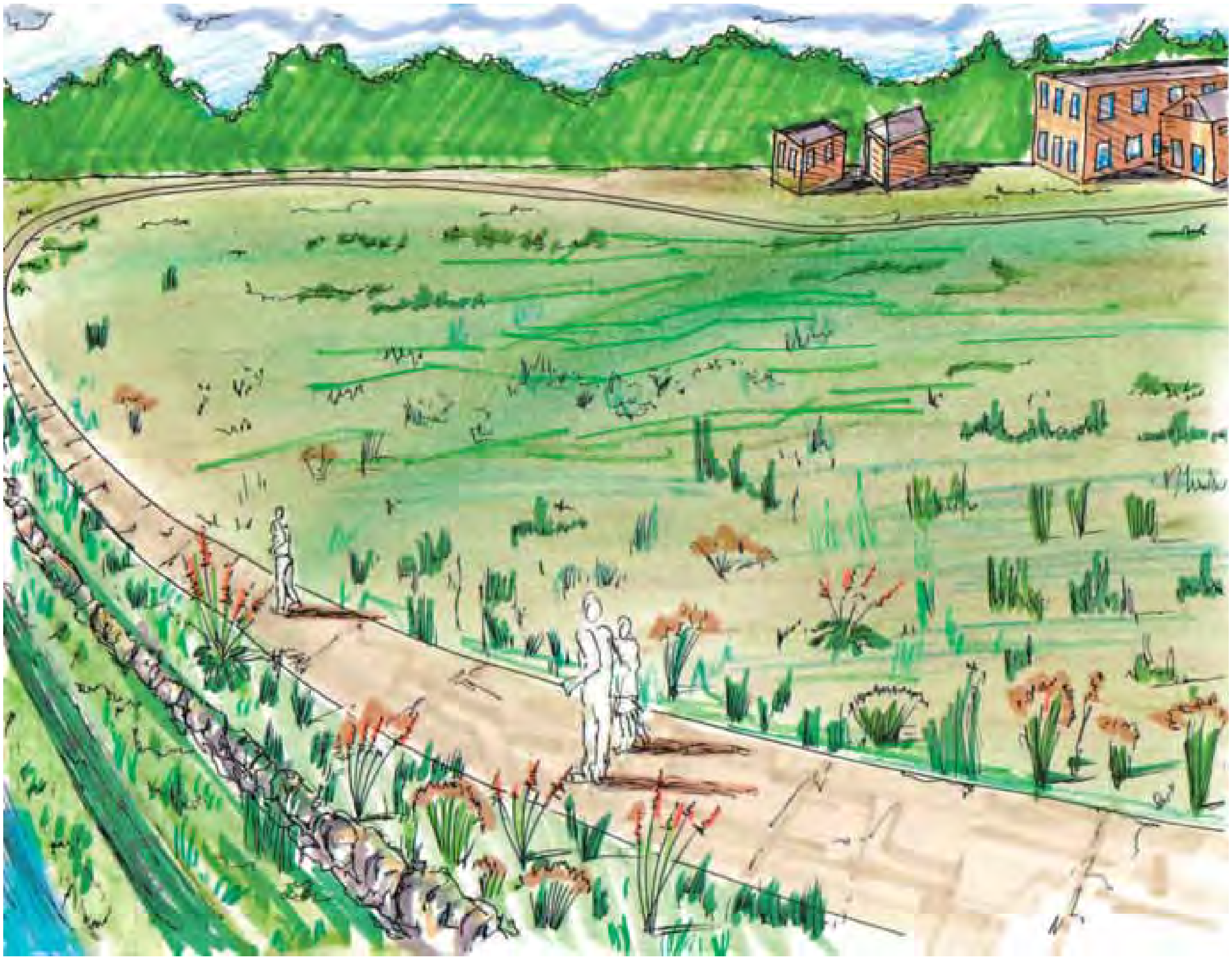

Figure 5-6. *Perspective illustration of the North Platte.*

reach the site safely and interact with it in a manner conducive to its continued survival. Finally, the Olbrich Gardens Board of Directors and the City of Madison could further explore the possibility of connecting the North Platte to O.B. Sherry Park via a footbridge between these two areas and another between the North Platte and the neighborhood on the east side of the creek.

To better facilitate the connection of these walking trails to other biking and walking trails surrounding the North Platte, fences should be kept to a minimum. Because the North Platte has been used by local residents for years without access prohibition, it should remain as open as possible to allow for their continued use of the area. Creating a few small picnic areas throughout the North Platte could also enhance use.

Recommended Locations of Botanical Gardens, Nurseries, and Equipment. Olbrich Botanical Gardens (no date) uses the American Association of Botanical Gardens and Arboreta's definition, which states that botanical gardens are "a scientific and education institution, whose purpose is the advancement and diffusion of a knowledge and love of plants." The exhibits and restoration sites proposed for the North Platte could serve as nontraditional botanical gardens where visitors can learn and appreciate native plants and the critical role they play in a watershed ecosystem.

Because many visitors appreciate and enjoy the specialty gardens that currently exist at Olbrich, an effort could be made to expand the specialty gardens. Several local residents have stated that the ballparks located east of Starkweather Creek are underutilized and have suggested converting them into specialty gardens (J. Steines, verbal communication, September 7, 2005). Expanding gardens in this location would allow for connectivity to the Thai Pavilion, and a fully accessible bridge could connect them to the other specialty gardens. A large parking lot in the vicinity could service the expanded gardens.

As seen on the conceptual plan (fig. 5-4), the recommended location for nurseries and maintenance equipment is behind the Garver Cottage. This location would allow for vehicular access and would be close to the Garver Building, offices in the Garver Cottage, and the existing garden displays. In addition, it would be relatively easy to block public access to the nurseries and equipment and still allow open access to the remainder of the North Platte.

Need for Funding and Fiscal Analysis

Neither economic nor fiscal analyses have been included in this conceptual plan. However, it is likely that any projects on the site would have economic and fiscal impacts on the City, given the property's size, cost for improvements, and the potential uses. Therefore, these analyses would be necessary.

However, we have researched possible funding sources for preservation, natural resource enhancement, and watershed education. Funding restoration projects and community watershed education on the North Platte is largely contingent on the efforts of the City of Madison and the Olbrich Botanical Society. Some of the funding sources identified in the *Infiltration Campaign Funding* section of this chapter may be applicable to projects on the North Platte; this area is of significant community value and would benefit watershed awareness among Starkweather Creek residents. Many funds are available for wetland restoration projects, so this type of project may be easily funded. A few grants of interest are the Five Star Restoration Matching Grants Program, National Corporate Wetlands Restoration Partnership, and Water Quality Cooperative Agreements of the U.S. Environmental Protection Agency Region 5 National Pollutant Discharge Elimination System. Many of these grants stipulate a collaborative approach between multiple stakeholders in the watershed, including private businesses, municipal and state agencies, and nonprofits. Another major requirement of the grants is the ability of a project to increase community awareness of watershed protection through educational outreach.

Stakeholder Involvement

This conceptual plan has not been through a public participation process or had stakeholder input. Many parties, including local residents, care deeply about the North Platte and how its development will affect the adjacent neighborhoods, gardens, and the Starkweather Creek watershed. Having all the stakeholders come together, especially during the early planning and design phases, can help make the North Platte a story of success.

Citizen Stewardship Campaign

Purpose

The overarching purpose of the citizen stewardship campaign is twofold. First and foremost, the campaign aims to increase the community's awareness of watersheds and the problems that can face these features of our urban landscape. Because the Starkweather Creek watershed is the largest watershed in Madison, increasing its residents' knowledge of the watershed concept would affect a large segment of Madison's population. A second goal is to promote watershed stewardship by citizens who live within and outside of the watershed's boundaries. Increasing awareness of watershed issues is a first step in encouraging citizens to take action and positively affect the state of Starkweather Creek watershed. A map and explanatory text have been designed to achieve these two goals.

Product

The map of the Starkweather Creek watershed (which measures 11 x 17 inches) illustrates the creek, roads, walking trails, biking trails, and canoe trails as well as some of the major physical and cultural landmarks found in the watershed. The explanatory text describes many of these landmarks. It also presents some of the problems facing the watershed, gives suggestions as to what citizens can do to help, and provides contact information for parties and agencies involved in the protection of the watershed.

Distribution

The distribution of the Starkweather Creek watershed map could be the responsibility of three parties. Initially, we will take the lead in placing the map and brochure at appropriate locations. After the workshop dissolves, the primary responsibility could shift to the City of Madison and the Friends of Starkweather Creek. Because the City of Madison has been a major partner in this workshop and will probably be responsible for the implementation of many of the suggestions found in this report, it is logical that they become one of the principal distributor of the map, especially at municipal buildings that fall within the watershed. In addition, the City of Madison could also be responsible for placing the map in schools so that it can be used as a curriculum tool and primer for further watershed restoration programs. The Friends of Starkweather Creek could take responsibility for establishing distribution points in places of worship and institutions that are involved in community education and cleanup efforts. Supportive business, especially those that impose a large footprint on the watershed, such as the Dane County Regional Airport and East Towne Mall, could also be approached by the Friends as a means of increasing awareness in areas that affect the watershed most. Finally, the Friends could distribute the map to neighborhood associations, community gathering locations, and festivals/clean-up events that are located within and near the watershed. The Nelson Institute for Environmental Studies at the University of Wisconsin–Madison will serve as a permanent distribution point for the map.

An initial printing of the map and brochure will be funded by the 2005 Water Resources Management Practicum. An electronic copy will be housed at the Nelson Institute for Environmental Studies at the University of Wisconsin–Madison and will also be passed on to the Friends of Starkweather Creek, the City of Madison, and Olbrich Botanical Gardens. This electronic copy can then be taken to any printing company to be printed.

Potential Use and Extensions of Map and Text

One major use of the map and explanatory text could be its promotion as a guided tour of the watershed as a means of inducing stewardship. By guiding citizens and visitors through the watershed, the map and brochure will illustrate how the entire watershed is connected and how individuals can positively affect the whole watershed by their actions.

The map could also be directly tied to the development and restoration that will be taking place on the North Platte. Olbrich Botanical Gardens already serves as one of the focal points of the watershed and the restoration of the North Platte will be underlain with educational components. Therefore, the map and text could be distributed to encourage Olbrich and North Platte visitors to travel farther into the watershed and explore its features and the problems that it faces.

Primary and secondary schools should also consider using the map and brochure as a component of curricula at different grade levels. For example, primary schools could use the map as a means of teaching map orientation skills to children on a local level. Secondary school curriculums could be developed to teach the watershed concept to science classes or could be used as a basis for developing a wetland or prairie restoration project within the watershed.

The map could be updated as an exercise in proactive watershed awareness. The City of Madison and the Friends of Starkweather Creek could review the map and text annually as a means of reevaluating the status of the watershed and prioritizing what should be done within it to continue in the direction of the improvements that have already been made.

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A

APPENDIX A

Studies and Plans Relevant to Starkweather Creek

Plans specifically addressing Starkweather Creek Watershed

- Starkweather Creek Master Plan 2005 Update (City of Madison—Engineering and Parks Divisions, 2005)
- Starkweather Creek Master Plan 2004 Update (City of Madison—Engineering and Parks Divisions, 2004)
- Starkweather Action Program (Dane County Regional Planning Commission, 1987)
- Starkweather Creek Water Quality Plan (Dane County Regional Planning Commission, 1983)

Additional plans relevant to Starkweather Creek Watershed

- City of Madison Comprehensive Plan Public Hearing Draft (City of Madison, DRAFT 2005)
- Dane County Comprehensive Draft Plan (Dane County Department of Planning and Development, DRAFT 2005)
- Dane County Water Body Classification Study Phase I (Dane County Regional Planning Commission, 2005)
- Dane County Water Quality Plan Summary Plan 2004 (Dane County Regional Planning Commission, 2004)
- East Washington Avenue Gateway Revitalization Plan (City of Madison, 2003)
- Madison Urban Area and Dane County Bicycle Transportation Plan (Madison Area Metropolitan Planning Organization, 2000)
- Dane County Water Quality Plan Appendix G—Groundwater Protection Plan (Dane County Regional Planning Commission, 1999)
- Dane County Water Quality: Conditions and Problems (Dane County Regional Planning Commission, 1999)
- Dane County Regional Hydrologic Study: Evaluation of Alternative Management Strategies (Dane County Regional Planning Commission, 1997)
- Vision 2020 Dane County Land Use and Transportation Plan (Dane County Regional Planning Commission, 1997)
- Environmental Corridors (Dane County Regional Planning Commission, 1996)

- Dane County Water Quality Plan Appendix B—Surface Water Quality Conditions (Dane County Regional Planning Commission, 1990)
- Yahara-Monona Priority Watershed Plan (Dane County Regional Planning Commission, 1992)
- Urban Wetlands in the Yahara–Monona Watershed: Functional Classification and Management Alternatives (Water Resource Management Program, 1990)
- Neighborhood Plans (http://www.ci.madison.wi.us/planning/ndp/index.html)

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B

APPENDIX B
Water-Quality Testing procedures

Semi-permeable membrane devices (SPMDs) were developed by the U.S. Geological Survey to act as a passive sampling water-quality indicator. They can be deployed in air, water, or soil. The SPMDs are flattened tubes of low-density polyethylene filled with a thin layer of the high molecular weight lipid triolein, a neutral lipid that is found in most aquatic organisms. Less expensive and easier to collect and analyze than biota, the SPMDs can be deployed for different lengths of time to determine possible bioconcentration rates. They are stationary, which allows contamination sources at different sections in the creek to be identified. The SPMD results are highly reproducible, can be standardized over different seasons and sites, and can be compared to results from other river and stream studies using SPMDs (Huckins and others, 2002). Using SPMDs does not require the removal of already scarce biota, such as fish, for tissue analysis. Because they act like biological tissue, the SPMDs can be used to determine which compounds fish would bioconcentrate in their tissues as they pass contaminated water through their gills.

The SPMDs accumulate nonionic organic compound with a K_{ow} value >1, meaning they absorb substances that prefer being in fat tissues rather than water. Such compounds include polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCBs), polychlorinated dioxins and furans, organochlorine pesticides, several "new generation" pesticides, pyrethroid insecticides, nonylphenols, some herbicides, several industrial chemicals, tributyltin, alkylated selenides, and others (Huckins and others, 2002). These contaminants are of concern due to their toxicity and carcinogenic tendencies. Some cause taste and odor problems in the water supply and others may cause health concerns, especially in humans.

We deployed the SPMDs in six sites throughout the Starkweather Creek watershed (table B-1; fig. B-1). The "above airport" (the Dane County Regional Airport) and the "above East Towne Mall" sites were chosen because they were far upstream on their respective branches. In theory, these would be the sites with the best water quality because they are upstream of the most likely sources of contamination. The "below airport" and "golf course ditch" (Bridges Golf Course) sites were chosen as places of specific interest. Airports are commonly sources of organic pollutants, and the golf course ditch drains an abandoned dump. The "Milwaukee Street" site was chosen because the U.S. Geological Survey has performed previous water-quality investigations there and because this site is downstream in the watershed and would offer a comparison to the SPMDs deployed upstream. The "below Lien Marsh" site was chosen as a comparison to the site above East Towne Mall to determine whether or not water quality improved or decreased as the creek passed through the wetlands associated with this reach.

We deployed two sets of six SPMDs in the study locations over the spring and summer

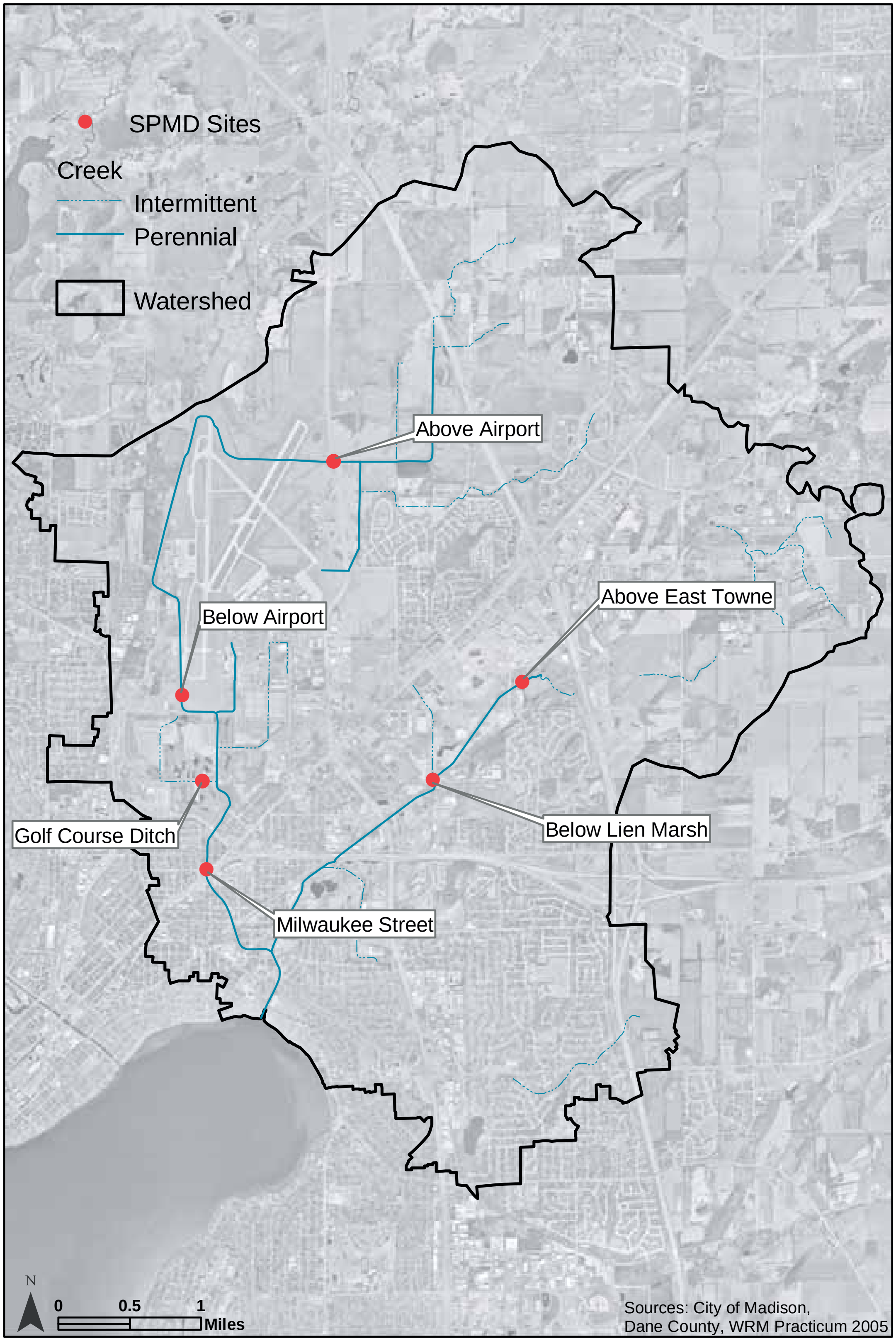

Figure B-1. *SPMD sampling sites.*

Table B-1. *Exact locations of SPMD deployment.*

Site Name	Location	Latitude	Longitude
Above airport	Upstream end of reach 7W	N 43° 08.792'	W 089° 19.387'
Below airport	Downstream end of reach 7W	N 43° 07.253'	W 089° 20.410'
Golf course ditch	Near upstream end of reach 6W	N 43° 06.810'	W 089° 20.421'
Milwaukee Street	Upstream end of reach 4W	N 43° 05.957'	W 089° 20.284'
Below Lien Marsh	Downstream end of reach 7E	N 43° 06.832'	W 089° 18.617'
Above East Towne Mall	Near downstream end of reach 8E	N 43° 07.479'	W 089° 17.717'

of 2005 to obtain an integrated sample of varying contaminant concentrations levels within the creek. The first set was deployed for 30 days beginning April 20, 2005. Over this period, the Starkweather Creek watershed received 3.85 inches of rain (National Climatic Data Center, 2006). We deployed the second set of six SPMDs on June 22, 2005, again for 30 days. During this time, 2.97 inches of rain fell on the watershed (National Climatic Data Center, 2006). On the first day of each deployment, a seventh SPMD was exposed to the atmosphere at each of the sites to account for airborne contaminants.

Upon removal from the creek, all the SPMDs were sent to EST, Inc., for dialysis to extract the lipid from the bag. Following dialysis, the liquid samples were concentrated down to approximately 0.5 mL using the Kuderna–Danish method. This volume was then filtered through a glass fiber filter paper, with hexane as a transfer solvent, and blown down again with UHP nitrogen gas.

Half of the sample from each site was preserved in DMSO, and the other half was ampulated in hexane. For the first half, 0.5 mL of DMSO was placed in an amber vial and the dialysates were transferred through a series of 3 hexane rinses. These vials were then placed under the nitrogen blown down unit again until all the hexane evaporated. At this point, an additional 0.5 mL of DMSO was added to the vial.

For the other samples, 0.5 mL of the dialystate was placed in an ampule using hexane as the transfer solvent. The ampules were then chilled in an IPA/dry ice solution and sealed with an oxygen/acetylene torch. The final sample volume was approximately 1 mL (Terry L. Spencer, verbal communications, July 29, 2005).

After the extraction process, the SPMD samples were sent to the Wisconsin State Laboratory of Hygiene for further testing.

The DMSO samples underwent a Microtox test, a process that determines a value of general toxicity. In this test a beaker is filled with a known value of luminescent bacteria that produce light as a function of their cellular respiration. The strain *Vibrio fisheri* NRRL B-11177 is typically used because it is highly sensitive to the toxicity of a wide range of chemicals. When exposed to toxins in water samples, some of these bacteria die, decreasing the total level of light emitted. As the toxicity of a water sample increases, more of these bioluminescent bacteria die, further decreasing the level of light emitted (Azur Environmental, no date). Relative values of toxicity are determined by comparing the level of light emitted by the bacteria before and after the addition of the SPMD extracts. In this case, bioluminescence was measured from the bacteria at the start of the test and given the value of 100 percent light remaining. The SPMD extract in the DMSO was then added to the beaker. After 15 minutes, the amount of light was measured again.

The results from this test for both sets of SPMDs are shown in figures B-2 and B-3. The relative toxicity between the sites can be determined by comparing the bioluminescence values. The trip blank or control sample, which was exposed only to the atmosphere over the course of SPMD deployment, displayed the least toxic rating. This rating served as the benchmark against which all other samples would be measured. The least toxic sample (highest relative amount of light remaining) and therefore the site with the best water quality within the creek was just upstream of the Dane County Regional Airport.

During the first sampling period, results from the site above the airport showed a toxicity that reduced the total light emitted over a 15-minute period to 67 percent. However, the SPMD collected from the site above the airport during the second sampling period had only 1 percent light remaining; the site below the airport was about 61 percent, very similar to the first reading above the airport. It is highly unlikely for the water quality to make such a drastic improvement over such a short distance downstream and without any active treatment. We hypothesized that at some point, the sample for the sites above and below the airport were switched with one another. After further specific contaminant analysis, we believe this to be the case, because chemical compounds found in the

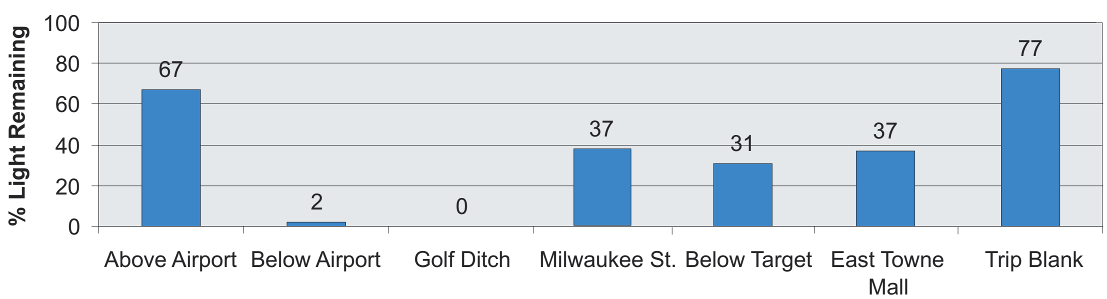

Figure B-2. *Results from the Microtox test showing relative toxicity between the sites, set 1*

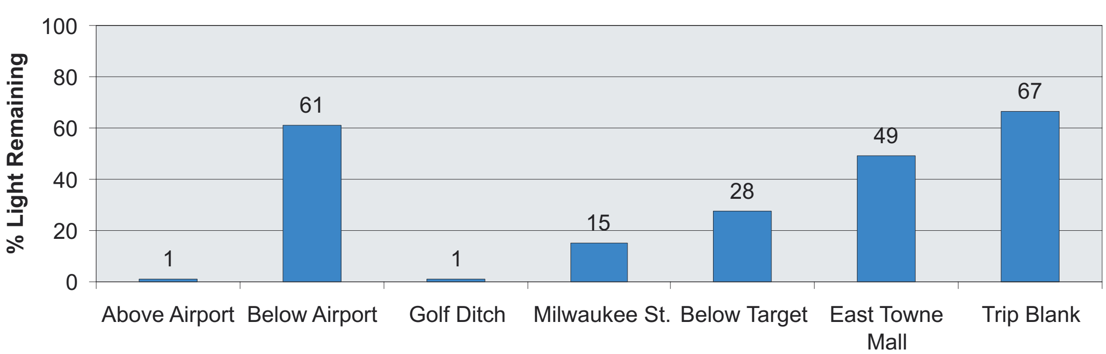

Figure B-3. *Results from the Microtox test showing relative toxicity between the sites, set 2.*

Table B-2. *Chemicals that were found in Starkweather Creek in higher concentrations relative to the concentrations found in the control sample.*

9-Methylanthracene	Methyl Fluorene +
Phenanthrene	Octylcyclohexane
Fluorene	Decylcyclohexane
Fluoranthene	cyclopenta(cd)pyrene
Pyrene	Dibenzo(ae)pyrene
Benz(a)anthracene	Dehydroabietic acid
chrysene/triphenylene	Benzo (a)pyrene
Benzo (b)fluoranthene	1-methylchrysene +
benzo(k)fluoranthene	benzo(GHI)fluoranthene
benzo(a)pyrene	retene
benzo(e)pyrene	9,10 Anthraquinone
Stigmasterol	Benz(a)anthracene-7,12-dione
Perylene	Phthalic acid(M)
indeno(cd)pyrene	Dodecanoic acid(M)
benzo(ghi)perylene	Tetradecanoic acid(M)
1-phenyl-naphthalene	

site below the airport from the first deployment and the site above the airport in the second deployment coincided. Consequently, we concluded that the site above the airport contained the best water quality of all the sampled points in the watershed.

The sites within the watershed that showed the worst water quality were the golf course ditch and the site immediately downstream of the airport. The samples from both sites killed nearly all the bacteria in the Microtox test after the 15-minute testing period.

The second SPMD at the Milwaukee Street site was the third most toxic location after the ditch and airport.

Gas chromatography mass spectrometer tests were performed on the SPMD extracts that were ampulated in hexane. The purpose of this analysis was to gain a general understanding of the types of organic compounds in the creek. Certain compounds had a much higher relative concentration in the Starkweather Creek samples than were found in the control sample. Consequently, these compounds are more likely to be in the creek at higher concentrations than the other compounds that were found. These compounds are listed in table B-2. A complete list of all the organic compounds that were found in the creek can be seen in table B-3 (next page).

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Table B-3. *Organic compounds found in Starkweather Creek*

Napthalene	22R, 17a(H),21b(H)-30-homohopane	Tritriacontane
1-methyl naphthalene	22s,17a(H),21b(H)-30-bishomohopan	Tetratriacontane
2-Methylnaphthalene	22r,17a(H),21b(H),30-bishomohopane	Pentatriacontane
2,6-Dimethylnaphthalene	22s,17a(H),21b(H)-30,31,32-trishomoh	Hexatriacontane
9-Methylanthracene	22r,17a(H),21b(H)-30,31,32-trishomoh	Cyclopenta(cd)pyrene
Phenanthrene	Methyl Fluorene	Dibenzo(ae)pyrene
Fluorene	Octylcyclohexane	22s,17a(H),21b(H)-30-homohopane
Fluoranthene	Decylcyclohexane	Benzo (a)pyrene
Pyrene	Undecane n-c11	1-methylchrysene
Benz(a)anthracene	Dodecane n-c12	Benzo(GHI)fluoranthene
Chrysene/triphenylene	Tridecane n-c13	Retene
Pristane	Tetradecane n-c14	9,10 Anthraquinone
Benzo (b)fluoranthene	Pentadecane n-c15	Benz(a)anthracene-7,12-dione
Benzo(k)fluoranthene	Hexadecane n-c16	Squalene
Benzo(a)pyrene	Heptadecane n-c17	1-octadecene
Benzo(e)pyrene	Octadecane n-c18	Phthalic acid(M)
Pyrene	Eicosane	Dodecanoic acid(M)
Perylene	Tetracosane	Tetradecanoic acid(M)
Indeno(cd)pyrene	Pentacosane	Palmitic acid(M)
Benzo(ghi)perylene	Hexacosane	Oleic acid (M)
Bis(2-ethylhexyl)phthalate	Heptacosane	Cholesterol
Butyl benzyl phthalate	Octacosane	Stigmasterol
Diethyl Phthalate	Nonacosane	Monopalmitin
Dibutyl Phthalate	Triacontane	1-phenyl-naphthalene
17b(H)-21a(h)-Norhopane	Hentriacontane	Dehydroabietic acid
17a(H)-21B(H)-hopane	Dotriacontane	Cholesta-3,5-diene

C APPENDIX C

Geographic Information System for Starkweather Creek

Starkweather Creek Watershed Geographic Information System

We used a geographic information system (GIS) in this project to enhance our ability to assess the current conditions of the Starkweather Creek watershed and provide a data resource for future analysis. In addition to gathering data to study the creek in relation to various aspects of this project, we also thought that a thorough and complete collection of data for the Starkweather Creek watershed would be of benefit for others interested in learning about or analyzing the watershed. The individual data layers as well as the Starkweather GIS are available on CD-ROM. The CD can be found on the back jacket of the hard copy of this report or is available for download from the Water Resources Management Practicum 2005 Web site, (www.nelson.wisc.edu/wrm/workshops/2005). Prior to using the data, a user license and disclaimers must be read and accepted.

The main intent of the GIS was to allow a simple way for those interested in the watershed, including novice GIS users, to view the data. Environmental Systems Research Institute, Inc. (ESRI) ArcReader technology was chosen as the desired map-viewing software application. ArcReader allows the user to view previously created ArcGIS maps using a few straightforward tools. Detailed instructions for using the software can be found by clicking the "Help" menu once the GIS application is installed and open. The ArcReader application is provided on the CD accompanying this report or can be downloaded free from the ESRI Web site (http://www.esri.com/software/arcgis/arcreader/download.html).

The CD also includes 1) a detailed list of all the included data layers, 2) a copy of the data disclaimer, 3) copies of each data layer and 4) PDF versions of each map generated for the report.

Data Acquisition and Organization

The first step in developing a GIS for any study area is to evaluate the data needs of the project. Because the goal of this Starkweather Creek watershed study was to assess and propose enhancement opportunities to improve watershed functions, we emphasized the collection of data relating to water resources. Data layers such as creek network, watershed boundary, wetland areas, springs, and floodplain delineation were determined to be the most critical. In addition, because the watershed is largely developed, land-use layers—such as parcels, land-use type, transportation network, park locations, and open-space areas—were also included.

We also obtained existing GIS data from a number of sources, such as the City of Madi-

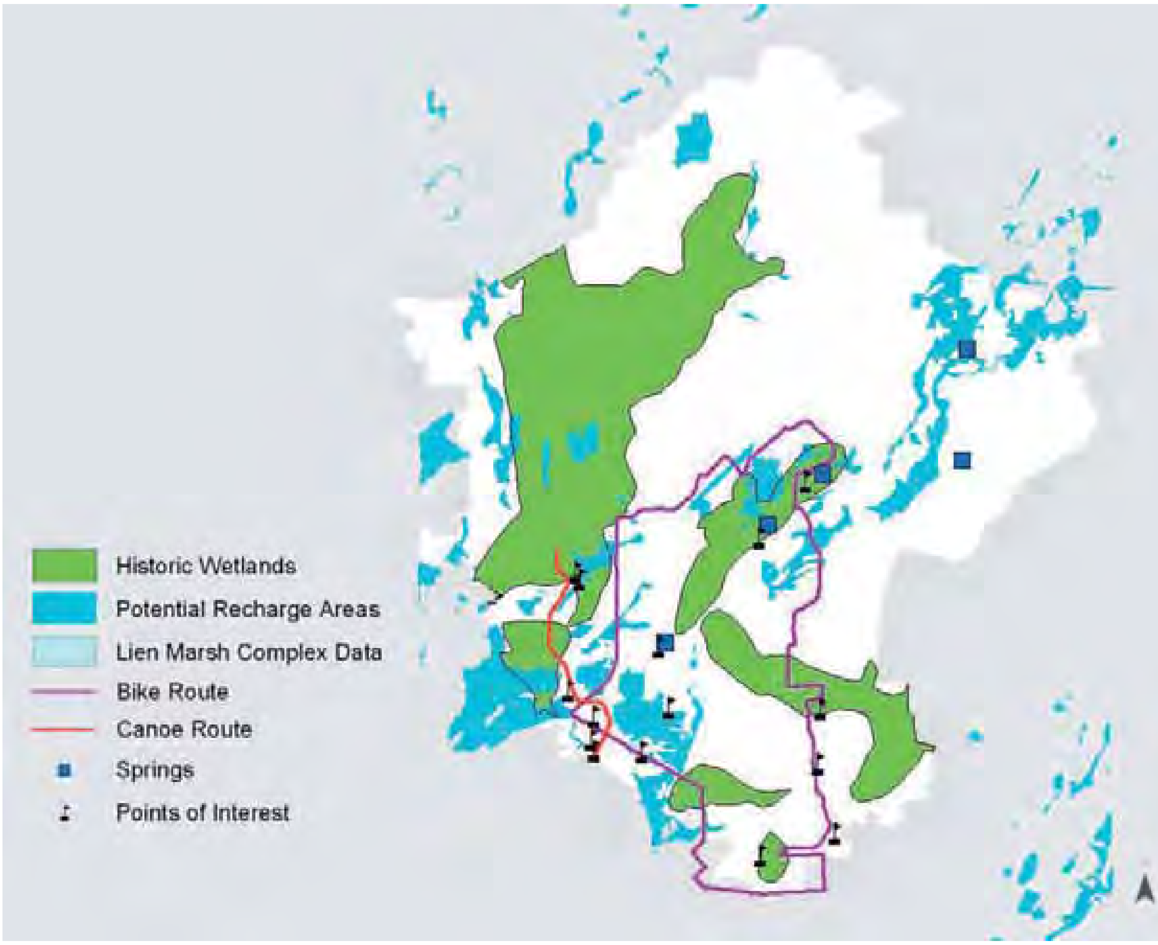

Figure C-1. *New layers generated as a result of this study.*

son, Dane County, the Wisconsin Geological and Natural History Survey, and the Wisconsin Department of Natural Resources. Appropriate permissions were granted from each agency to either use the data for analysis and maps and/or to provide the data for presentation in the Starkweather Creek GIS. Some of the data we were searching for could not be found. In these few cases, we were able to generate the necessary data. In addition, some of our analyses resulted in new GIS data layers; they are illustrated in figure C-1.

Upon receipt of each file, we performed a thorough quality assessment. We did not accept data for the GIS database unless its date, author, and projection were known and a metadata file was available. For each data file, we catalogued the following information: layer name, original location/name, owner/distributor, metadata file type, description of data, date, currency, permissions, and comments. Each accepted file was catalogued in a spreadsheet (table C-1) and organized into the Starkweather Creek GIS database. Most information collected in a GIS data layer is a static snapshot of what are actually dynamic data. Watershed attributes such as stream courses, parcel owners, and land-use types will change over time. For this reason, all GIS files received from local agencies were kept in their original format so that necessary future updates to the Starkweather

Table C-1. *Accepted files integrated into the Starkweather Creek geographic information system*

Layer Name	Original Name	Owner/Distributer	Description/Comments
Contours.shp	cntlbgd9, cntlbud9, cntlpwd9 (coverages)	Dane County Land Information Office	10ft elevation contours developed in 1995
Creek.shp	hydlarc.shp	WI Department of Natural Resources	1995 hydrology data (2000 is most recent)
dane_00.sid	dane__00.sid	Dane County Land Information Office	1 meter orthophotos from 2000
EnvCorr.shp	eeclsadx (coverage)	Dane County Regional Planning Commision	Environmental Corridors
Floodplain100yr.shp	flooddc.shp	Dane County Regional Planning Commision	100 year floodplain layer
Landuse.shp	lu2pbgd9, lu2pbud9, lu2pwpd9 (coverages)	Dane County Land Information Office	
Municipal_Bound.shp	mcdpdcd9 (coverage)	Dane County Land Information Office	City/Town boundaries 1999
roads	rdcldcd9 (coverages)	Dane County Land Information Office	2000 Roads layer (most current)
Sewershed.shp	Sewershed.shp	City of Madison Engineering	Sewershed of Starkweather Creek
Soils.shp	slspbgd9, slspbud9, slsppwd9 (coverages)	Dane County Land Information Office	Dane County soils layer developed by the NRCS
Springs.shp	springs.shp	WRM Practucum 2005	
Watershed.shp	watersheds.shp	Dane County Community Analysis and Planning Division	
WaterTableElev.shp	dn_wtel89_arclp.shp	Dane County Community Analysis and Planning Division	Watertable evelvation for Dane County. No metadata...
Wetlands_poly.shp	wetpw924 (coverage)	DNR Bureau of Fisheries Management and Habitat Protection	Wisconsin Wetlands Inventory. Polygons are wetlands 2 acres or greater
Wetlands_pt.shp	wetxw924 (coverage)	DNR Bureau of Fisheries Management and Habitat Protection	Wisconsin Wetlands Inventory. Points are wetlands smaller than 2 acres
water_bodies	hydpdcd9 (coverage)	Dane County Land Information Office	Lakesand ponds
wt_depth	wt_depth (grid)	WRM Practucum 2005	Depth to watertable raster file
Neighborhoods.shp	Neighborhoods.shp	WRM Practucum 2005	Adapted from City of Madison CAD data
Stormsewer.shp	stormsewer.shp	City of Madison Engineering	
Sanitarysewer.shp	sanitarysewer.shp	City of Madison Engineering	

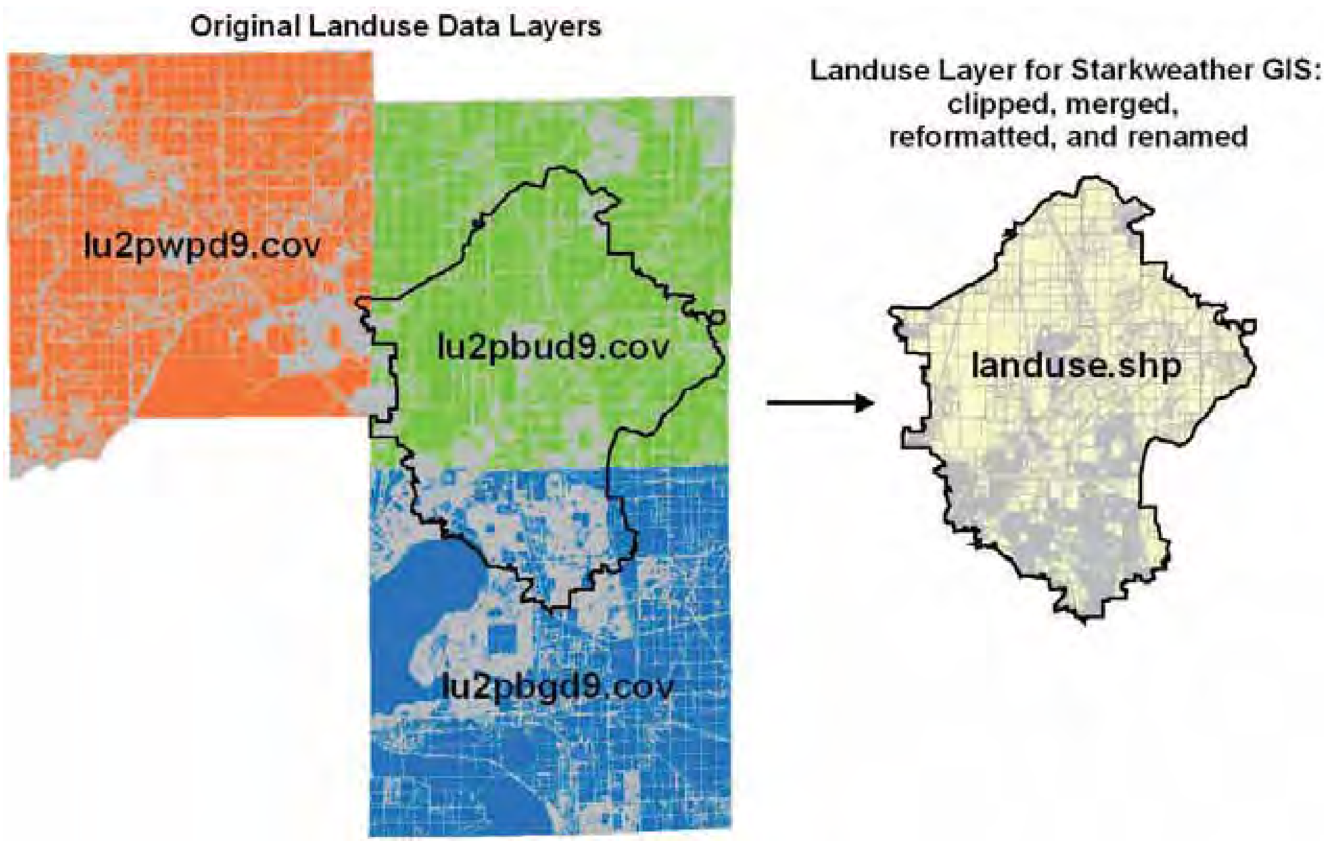

Figure C-2. *Modifications to land-use data.*

Creek GIS database could be as seamless as possible.

Most data were received in shapefile format; however, some coverage and raster data formats also exist in the GIS database. Only three minor changes were made to each layer. First, if a data type was received as a number of adjacent layers, the layers were merged to form one layer. Second, each layer was clipped so that only the features within the watershed remained in the layer. Finally, the names of the layers were changed, as necessary, so that they were more descriptive of the data they contained. Figure C-2 shows an example of the modifications that were made of land-use data that were received from Dane County. Other than the clipping and merging processes, we performed no other data manipulation.

GIS Analysis Conducted for the Recharge Areas Map

In addition to collecting data for the Starkweather Creek GIS, we also made use of some of the acquired data when conducting analysis for this report. The following is an illustration of the geoprocessing that was done to create the recharge areas depicted in figure 3-4 in chapter 3. The key factors that promote groundwater recharge are depth to bedrock, subsoil permeability and water-table depth (Dane County Regional Planning Commission, 1997). Table C-2 lists the GIS layers we collected that capture this spatial information; figures C-3 through C-6 show these layers.

Table C-2. *GIS layers used in recharge areas analysis.*

Necessary attributes	Data file	Source
Soil type, depth to bedrock	soils.shp	Natural Resource Conservation Service
Probable substratum permeability	subtab5.dbf	Natural Resource Conservation Service
Water-table elevation	dn_wtel89_arclp.shp	Bradbury and others (1995)
Ground-surface elevation	DEM (digital elevation model)	Dane County Land Information Office

For this analysis, we made significant efforts to acquire the highest quality data currently available at the time of our analysis. However, on the basis of the metadata and communications with a number of professors and GIS professionals working in Madison (Frederick W. Madison, Kenneth Potter, Mike Kakuska), we found that the soils layer was crudely derived on the basis of the historic soils mapping of the area. The polygons digitized for this layer should only be considered as suggestive boundaries between soil types rather than strictly identified boundaries.

To derive the recharge-area locations from these data layers, some preprocessing of the original data needed to be completed. First, the substratum permeability table was joined to the soils layer so that the permeability data could be viewed and analyzed spatially. The data field called "NEWNAME" in the substratum permeability defines permeability as shown in table C-3.

On the basis of the Dane County Regional Hydrologic Study and discussions with Kenneth Potter, professor of hydrology and civil engineering at UW–Madison, we determined three classes of permeability for soil types that have the potential to infiltrate at least 2 inches per hour: "very rapid," "rapid," and "moderately rapid" (table C-3).

The water-table layer used for this analysis was developed by the Dane County Regional Planning Commission in conjunction with the help of Roger Bannerman for the Dane County groundwater study. The layer depicts the water table as 10-foot contour lines. To compare this polyline layer with the soils polygon layer, the file was converted into a polygon coverage identifying approximate depth to the water table throughout the watershed. Using spatial analyst tools, our process to convert the contour lines into a surface layer was as follows (fig. C-7):

1. Convert dn_wtel89_arclp.shp polyline file to a TIN (Triangulated Irregular Network)
2. Convert TIN to a raster (ESRI GRID file format)
3. Use Map Algebra calculator to subtract water-table GRID from the DEM to get rasterized "depth to water table" over the surface of the watershed
4. Reclassify depth to water table into categories (table C-4)
5. Convert reclassed GRID to a polygon shapefile.

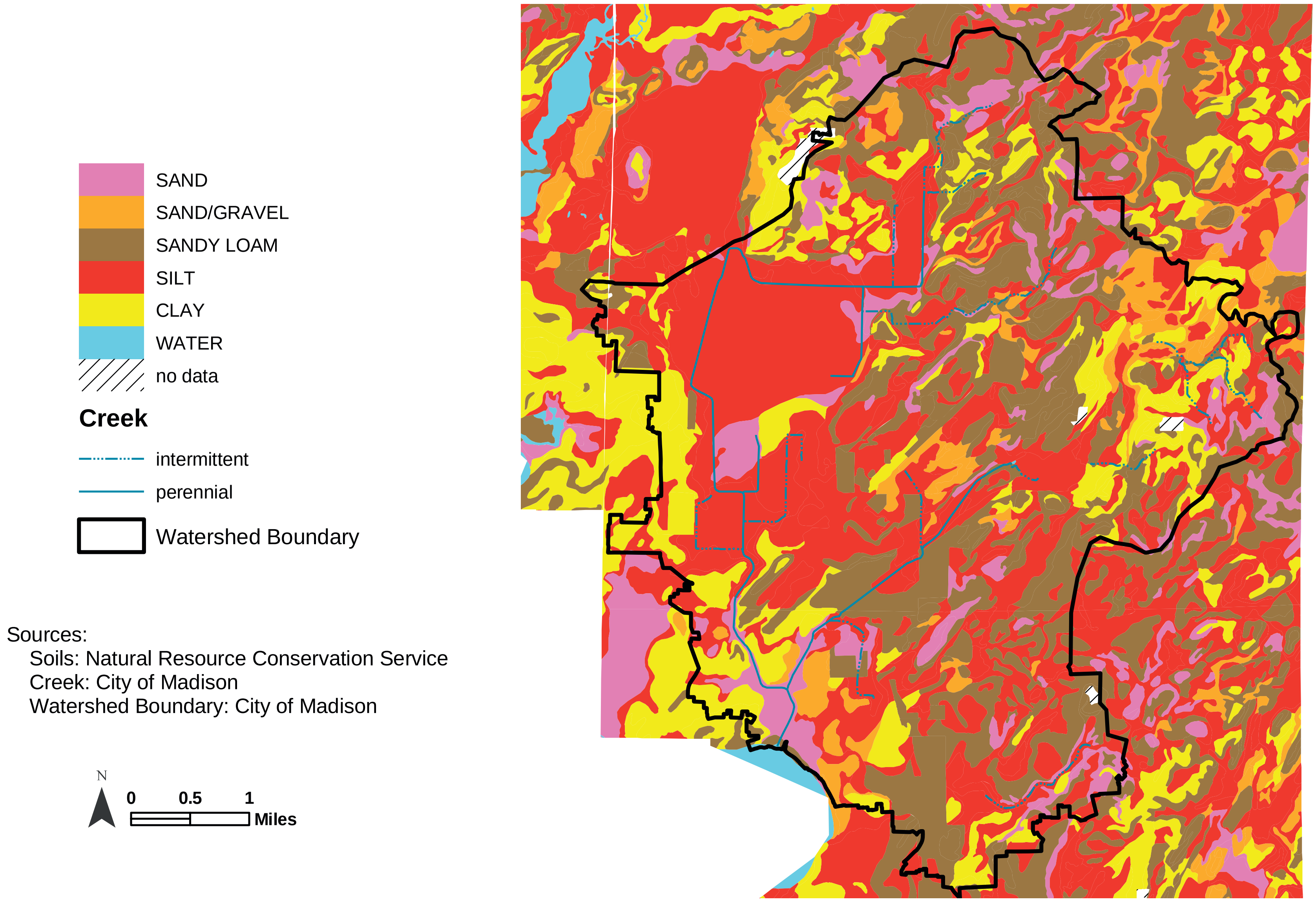

Figure C-3. *Subsoil texture.*

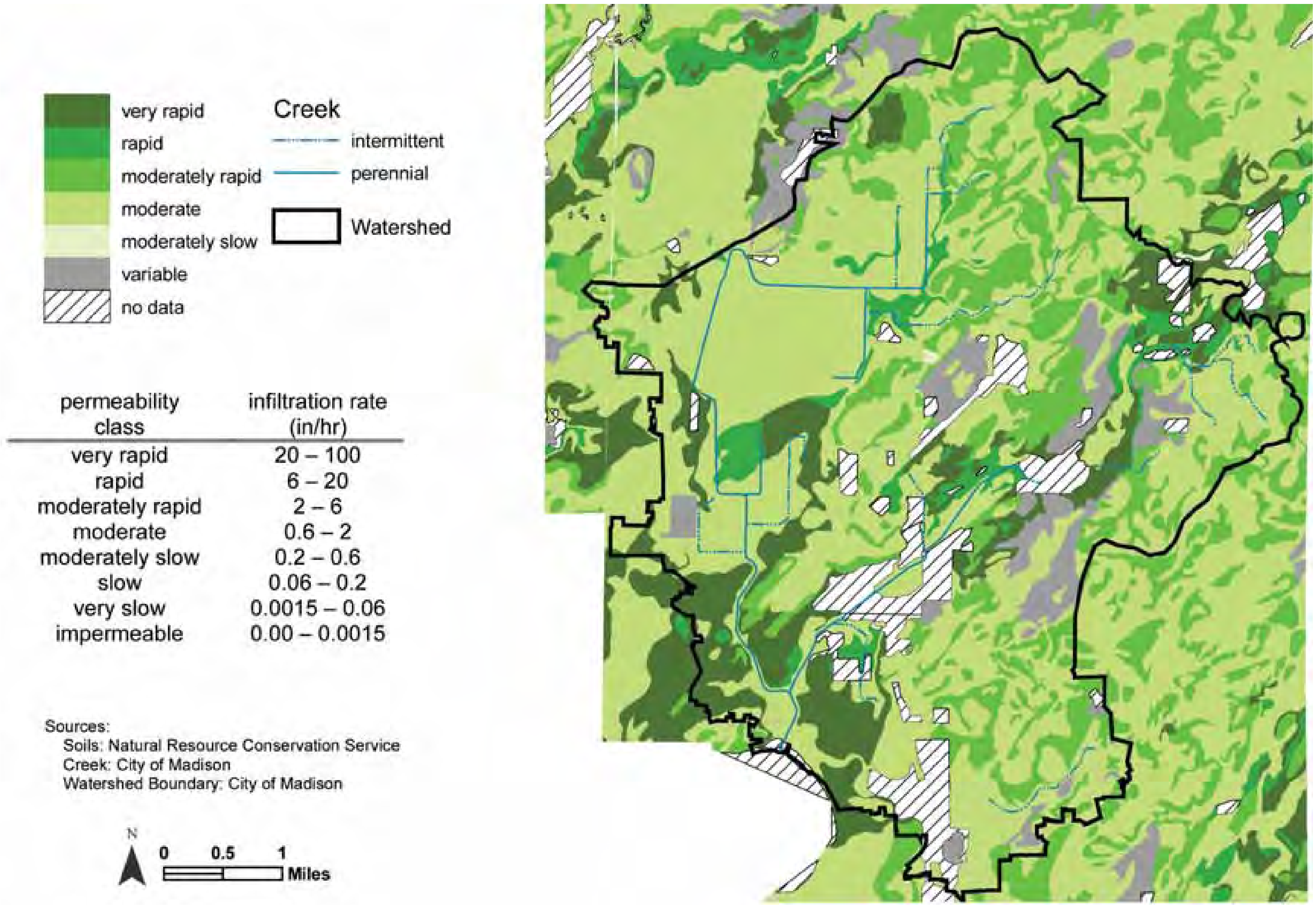

Figure C-4. *Substratum soil permeability.*

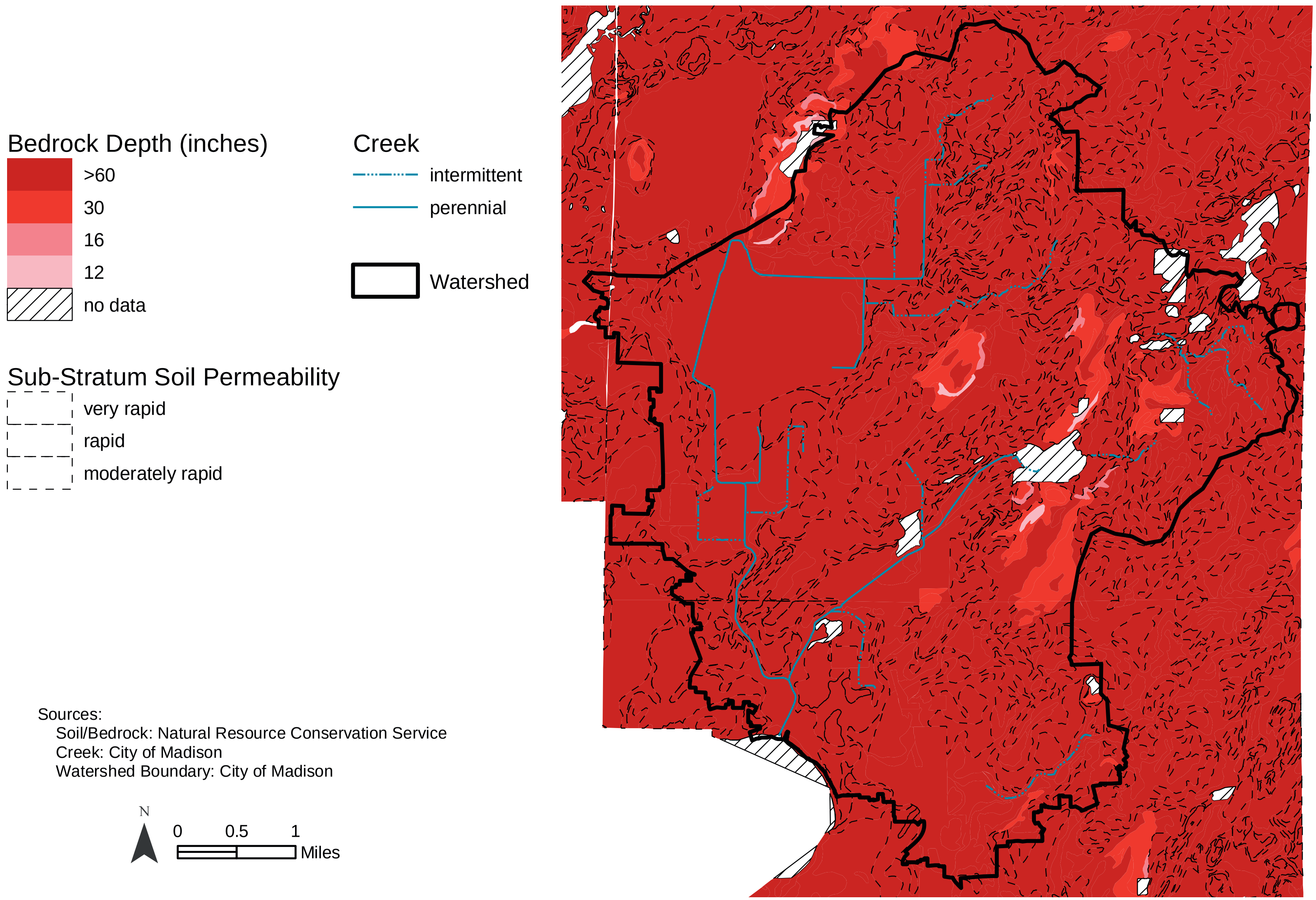

Figure C-5. *Bedrock depth and high permeability locations.*

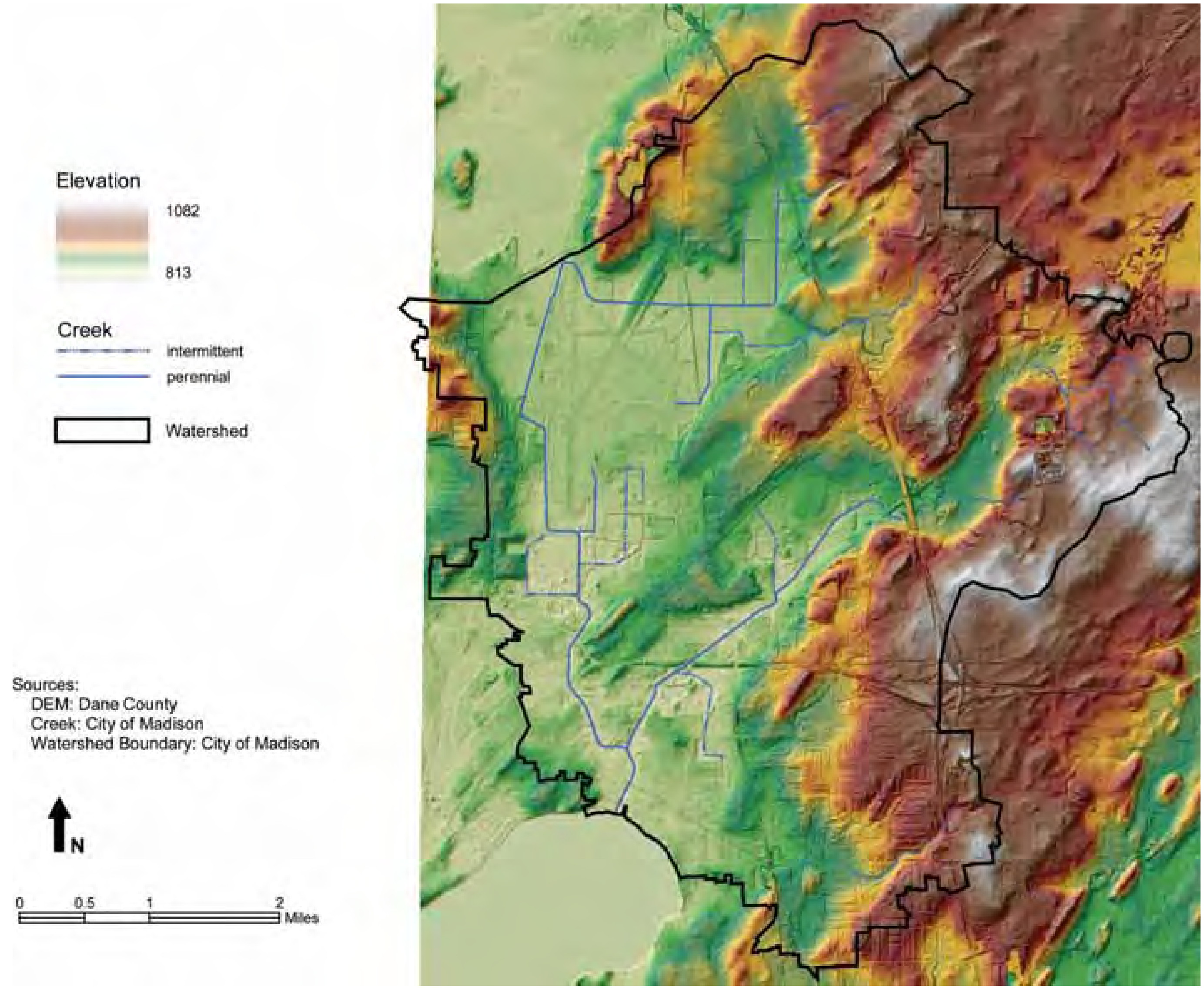

Figure C-6. *Digital elevation model. (Data for western edge of watershed were truncated.)*

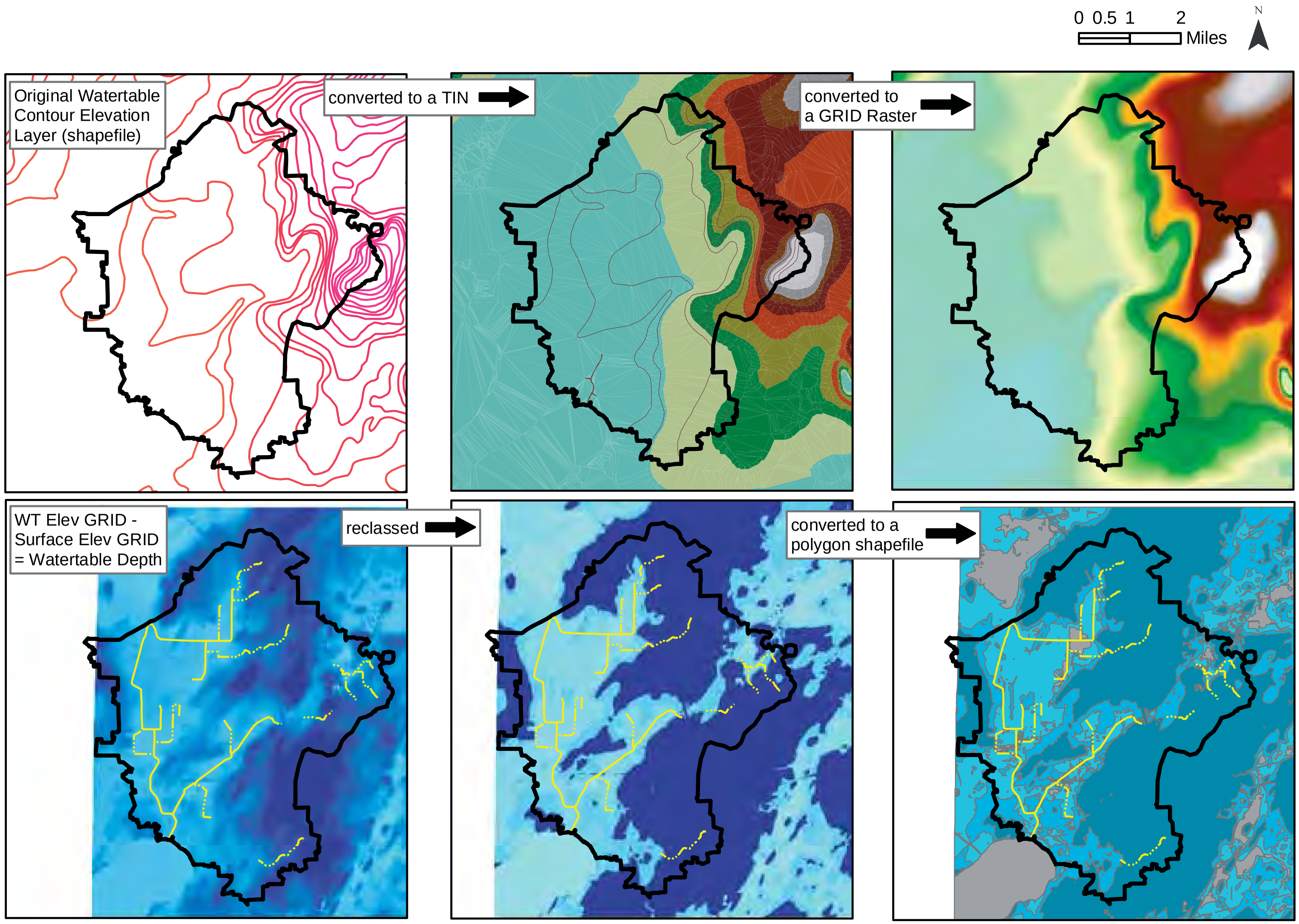

Figure C-7. *Generation of depth to water-table layer.*

Table C-3. *Permeability classes.*

Permeability class	Infiltration rate (in/hr)
very rapid	20 – 100
rapid	6 – 20
moderately rapid	2 – 6
moderate	0.6 – 2
moderately slow	0.2 – 0.6
slow	0.06 – 0.2
very slow	0.0015 – 0.06
impermeable	0.00 – 0.0015

Table C-4. *Categories for water-table depth.*

Depth	Infiltration effectiveness
less than 0 ft	Ponded water (poor infiltration)
0-10 ft	Shallow water table (poor infiltration)
10-25 ft	Suitable water-table depth
25 ft and greater	Ideal water-table depth

Once the data layers were transformed into the same format, the two polygon shapefiles, water table and permeable soils, were overlaid and clipped accordingly to derive the final layer identifying potential recharge areas. The categories of potential recharge were determined on the basis of these two layers (table C-5).

Table C-5. *Categories for recharge potential.*

Category	Infiltration	Water-table depth
A	Very rapid	25-193 ft
B	Very rapid	10-25 ft
C	Rapid	25-193 ft
D	Rapid	10-25 ft
E	Moderately rapid	25-193 ft
F	Moderately rapid	10-25 ft

Watershed analysis

To perform a detailed analysis of the Rolling Meadows subwatershed to determine the benefits that small-scale infiltration practices can have on runoff and infiltration volumes at a local level, we used the data in table C-6 (see next page). This analysis is described in chapter 3.

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Table C-6. *Input data for watershed analysis.*

Start at Test #																	
1	Check Input for Logical Errors	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
End at Test #	(See "Error Check" for Details)																
16	Test #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
(16 Tests)	Title of Run	Single_family	Multi_family	Nursing_Home	Transport	Vacant	Recreation	Churches	Schools	Commerical	Single_family_10	Multi_family_10	Nursing_Home_10	Transport_10	Churches_10	Schools_10	Commerical_10
Storm Information	Precipitation (in):	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
DO NOT CHANGE	Storm Distribution Type:	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Basic Area Information	Total Area (mi2)	0.1678	0.0209	0.0079	0.0683	0.0038	0.0064	0.0073	0.0228	0.0029	0.1678	0.0215	0.0079	0.0683	0.0073	0.0228	0.0073
	% Rooftop	23	24.9	14.6	0	0	0	5.6	5.5	8.6	23	24.9	14.6	0	5.6	5.5	8.6
	% Driveway	7	9	19.2	0	0	0	26.9	8.1	46.7	7	9	19.2	0	26.9	8.1	46.7
	% Street	0	0	0	80	0	0	0	0	0	0	0	0	80	0	0	0
	% Lawn	70	66.1	66.2	20	0	100	67.5	86.4	44.7	68.275	64.233	65.105	0	67.08	85.988	44.055
	% Enhanced	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
	% Raingarden	0	0	0	0	0	0	0	0	0	1.725	1.8675	1.095	20	0.42	0.4125	0.645
Flow Information	% Rooftop to Lawn	50	50	50	0	0	0	50	50	25	50	50	50	0	50	50	25
	% Rooftop to Enhanced	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Rooftop to Raingarden	0	0	0	0	0	0	0	0		50	50	50	0	50	50	50
	% Lawn Receiving Rooftop	25	25	25	0	0	0	25	25	10	25	25	25	0	25	25	10
	% Enhanced Receiving Rooftop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Driveway to Lawn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Driveway to Enhanced	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Driveway to Raingarden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Lawn Receiving Driveway	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Enhanced Receiving Driveway	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Street to Lawn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Street to Enhanced	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Street to Raingarden	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0
	% Lawn Receiving Street	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Enhanced Receiving Street	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Lawn to Enhanced	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Lawn to Raingarden	0	0	0	0	0	0	0	0	0	25	25	25	0	25	25	25
	% Enhanced Receiving Lawn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	% Enhanced to Raingarden	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raingarden Information	Depression Depth (in)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Soil Thickness (in)	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Soil Infiltration Capacity (in/hr)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
	Subsoil Infiltration Capacity (in/hr)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
	% Soil Porosity	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
	% Soil Field Capacity	33	20	20	33	20	20	20	20	20	20	20	20	33	20	20	20
Curve Number Information	Rooftop	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
	Driveway	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
	Street	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98	98
	Lawn	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69	69
	Enhanced	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61
	Raingarden	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

APPENDIX D
Lien Marsh Data and MG&E Marsh Plant List

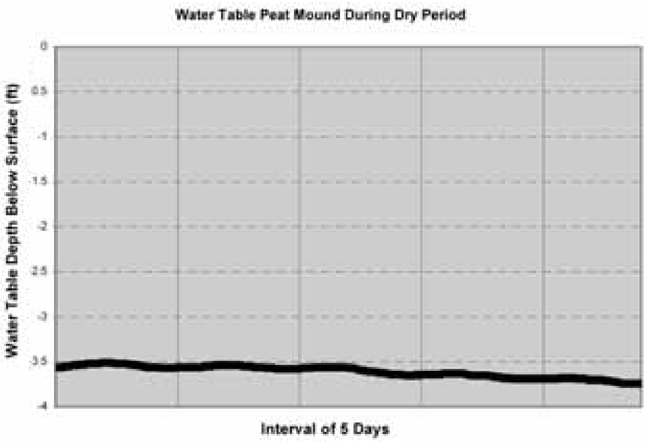


Figure D-1

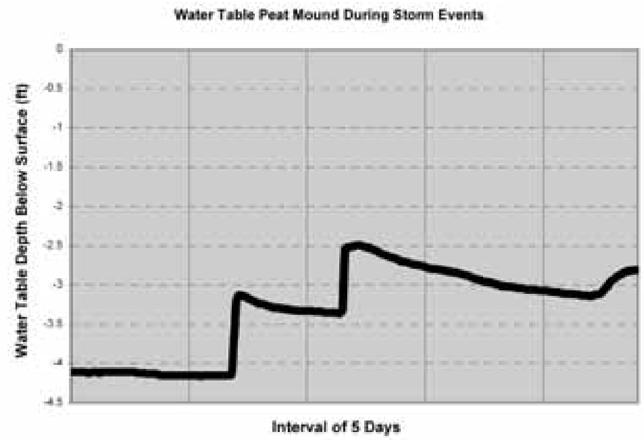


Figure D-2

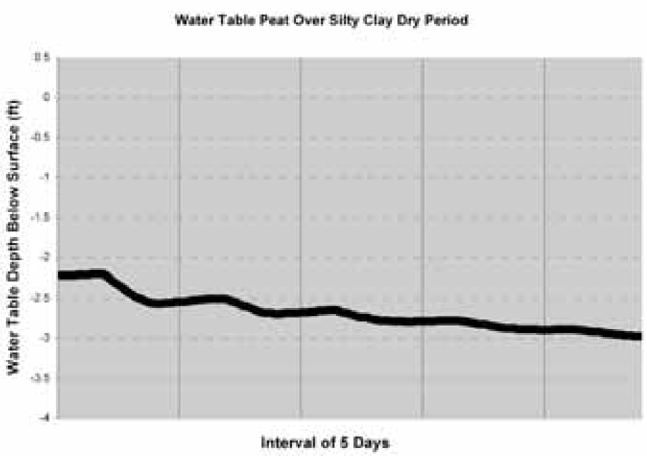


Figure D-3

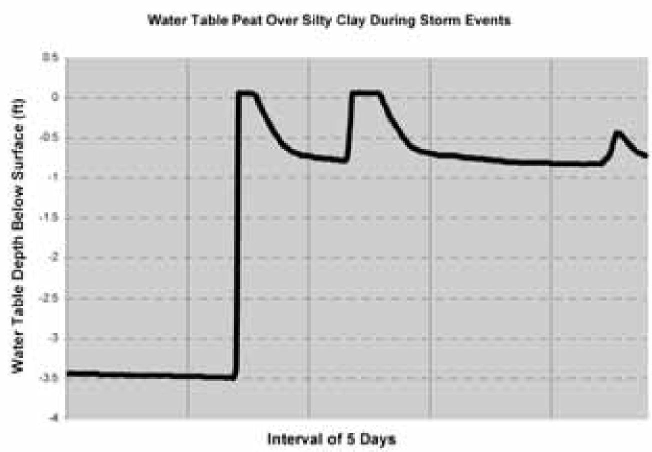


Figure D-4

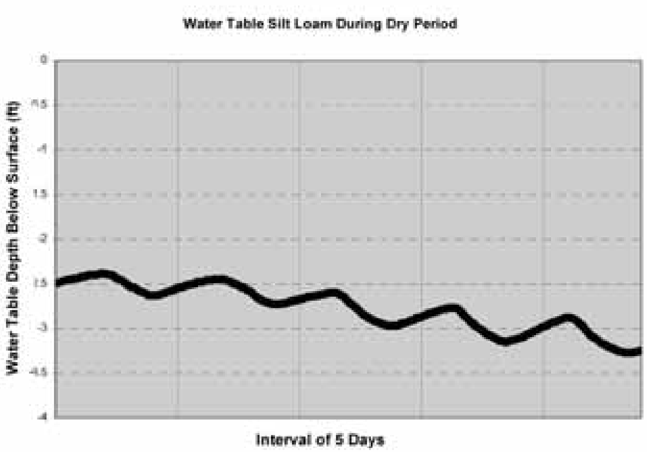


Figure D-5

Figure D-6

Figures D-1 to D-6. *Water-table data for Lien Marsh.*

Table D-1. *Plant species list for MG&E Marsh.*

Acer saccharinum	*Phalaris arundinacea*
Asclepias incarnate	*Polygonum amphibium*
Barbarea vulgaris?	*Polygonum pensylvanicum*
Bidens frondosa	*Rhamnus frangula*
Calamagrostis canadensis	*Rhus* sp.?
Campanula aparinoides	*Ribes glandulosum?*
Carex lacustris	*Rubus occidentalis*
Carex stricta	*Rumex orbiculatus*
Convulvulus sepium	*Sagittaria latifolia*
Cornus racemosa	*Salix bebbii*
Cuscuta gronovii	*Salix interior*
Dryopteris thelypteris	*Salix nigra?*
Eupatorium maculatum	*Sambucus Canadensis*
Eupatorium perfoliatum	*Scirpus acutus*
Geum canadensis	*Scirpus cyperinus*
Helianthus grosseserratus	*Solanum dulcamera*
Impatiens capensis	*Solidago gigantea*
Iris virginica shrevei	*Stachys palustris*
Lactuca seriola	*Typha angustifolia*
Lonicera sp.	*Typha latifolia*
Mentha arvensis	*Ulmus* sp.
Mimulus ringens	*Verbena hastata*
Oenothera biennis	*Viola pallens?*

Table D-2. *Physical and chemical parameters tested in Lien Marsh.*

	Temp (°C)	Cond. (μs/s)	Diss. O_2 (ppm)	Diss. P (ppm)	Diss. N (ppm)	Diss. Iron (ppm)	Alkalinity (mg_{CaCO3}/L)
Testing 04/02 (spring melt)							
Well #1 (shallow)	4.0	806					
Well #2 (screen 3.85'-4.85')	6.0	960	2.0		0.6-0.8		
Well #3 (screen 9.17'-10.17')	7.4	967					
Creek	13.7	1040	10.0	0.1	2.5		
Ditch	8.6	1766	6.0	0.2	0.3		
Fen pond	13.8	780	9.0	bdl	bdl		
Bulrush area outlet	5.5	2280	3.0	bdl	bdl		
Testing 05/25							
Well #1 (shallow)	12.6	840	2.0	bdl	bdl	1.0	200-250
Well #2 (screen 3.85'-4.85')	12.2	989	0.6	0.2	0.3	0.1	250-350
Well #3 (screen 9.17'-10.17')	12.2	984	—	bdl	3.0	bdl	
Vibracore 1 (screen 12.6'-13.0')	9.6	965	0.6	bdl	2.5	bdl	250
Testing 7/18 (drought)							
Detention pond			4.0	bdl	bdl		
Fen pond					bdl		100.0
Ditch			2.5	2.0	bdl		
Creek			9.0	bdl	4.5		
Vibracore 1 (screen 12.6'-13.0')			2.5				
Well #3 (screen 9.17'-10.17')			3.0				
Well #2 (screen 3.85'-4.85')			3.0				
Testing 7/23 (post rainstorm)							
Detention pond inlet			7.0	0.2	0.1-0.2		
Behind detention pond overflow			5.0	0.3	0.1		
Inside wetland near outlet			2.0	3.5	bdl		
Creek			5.0	0.4	1.5-2.0		
Ditch			2.0	0.4	bdl		
Fen Pond			6.0	0.1	0.1		
Testing 7/27 (dry)							
Detention Pond Inlet			8.0	0.1	bdl		
Behind detention pond overflow			5.0	0.2	bdl		
Inside wetland near outlet			1.5	4.5	bdl		
Testing 7/31 (dry)							
Creek upper part of wetland				0.1-0.2	>5.0		
Creek lower part of wetland				0.1-0.2	4.0-4.5		
Behind detention pond overflow				0.2	bdl		
Inside wetland near outlet				4.5	bdl		
Test Kit Detection Limits:			**0.1**	**0.1**	**0.1**	**0.1**	**~50**

(bdl=below detection limit)

E

APPENDIX E
Local Schools and Funding Opportunities

Table E-1. *Schools located within Starkweather Creek Watershed or who enroll students residing within the watershed. Principal information was current as of 9/1/05.*

	School	Address	Principal
Elementary School			
	Sandburg	4114 Donard Dr.	Michael Deignan
	Elvehjem	5106 Academy Dr.	lisa Knistad
	Kennedy	221 Meadowlark Dr.	Craig Campbell
	Shenk	230 Shenk St.	Sheila Briggs
	Lowell	401 Maple St.	Beverly Cann
	Hawthorne	3344 Concord Av.	Catherine McMillian
	Lake View	1802 Tennyson Ln.	Linda Sweeney
Middle School			
	Whitehorse	218 Shenk St.	Anne Nolan
	Sherman	1610 Ruskin St.	Ann Yehle
	O'Keefe	510 S. Thorton Av.	Patrick Delmore
	Sennett	502 Pflaum Rd.	Colleen Lodholz
High School			
	Shabazz	1601 N. Sherman	Sally Schultz
	LaFollette	702 Pflaum Rd.	Mike Meissen
	East	2222 E. Washington	Alan Harris

Table E-2. *State funding opportunities for infiltration campaigns.*

State Funds	Source	Purpose	Availability	Amount	More information
River Protection Management Grants	DNR	● Land purchase or conservation easements ● Development of local regulations and ordinances ● Control of nonpoint source pollution ● Restoration projects (instream and shoreland habitat and protection) ● DNR approved activities for implementation of planning recommendations ● Education, planning and design activities necessary for the implementation of a management project	Counties, cities, towns, villages, tribes and other local government units, "qualified river management organizations, and qualified nonprofit conservation organizations."	Reimbursment up to 75% of $50,000	http://dnr.wi.gov/org/caer/cfa/Grants/Forms/RiverGuidelines04.pdf
Aquatic Invasive Species Grant	DNR	● Information and education on the types of existing and potential aquatic invasive species in Wisconsin ● Information on the threats they pose for the state's aquatic resources ● Information on the techniques available for their control ● Planning and conducting projects that will prevent the introduction of aquatic invasive species into waters where they currently are not present ● Controlling and reducing the risk of spread from waters where they are present ● Restoring native aquatic communities	Public and private entities	Cost-share up to 50% of $75,000	http://www.uwsp.edu/cnr/uwexlakes/grants/AIS_long.pdf
Wetland and Shoreland Restoration Grant	DNR	● Restoration or enhancement of a wetland or lands draining to a wetland which will substantially contribute to the protection or improvement of a lake's water quality or its natural ecosystem	All lake management units. Non-profit organizations are not eligible.	● 100% state funded up to $10,000, if the project is identified in a comprehensive land use plan ● Wetland restoration projects are eligible to receive 75% of up to, but not exceeding $100,000 per grant	http://www.legis.state.wi.us/cr_final/02-122.pdf

Table E-3. *Federal funding opportunities for infiltration campaigns.*

Federal Funds	Source	Purpose	Availability	Amount	More information
Five Star Restoration Matching Grants Program	National Association of Counties, Wildlife Habitat Council, National Fish & Wildlife Foundation and EPA	• Community-based wetland, riparian, and coastal habitat restoration projects that build diverse partnerships and foster local natural resource stewardship through education, outreach and training activities. • Projects involving only research, monitoring, or planning are not eligible for funding.	The stars in "Five-Star" are the partners, funders, and/or participants necessary to complete the project including: • Schools or youth organizations (e.g., state or local youth conservation corps, county job training programs); • Local or tribal governments (e.g., boards of county commissioners, departments of planning, environment or parks and recreation); • Local businesses or corporations; • Conservation organizations or local citizens groups; • State and federal resource management agencies; and • Foundations or other funders.	Awards are between $5,000 and $20,000; the average grant is $10,000	http://www.nfwf.org/programs/5star-rfp.cfm
National Corporate Wetlands Restoration Partnership	"Public-private partnership between the federal government, state governments and private corporations"	To restore impaired, but ecologically important, wetlands and other aquatic habitats in the country's watersheds. • Assist Federal, state, and local agencies in meeting the national goal to restore 100,000 acres of wetlands annually by 2005 through approved Coastal America Partnership restoration projects. • Establish and support a network of wetland or other aquatic habitat restoration education and research sites. • Create a CWRP in each of the 50 states.	• Federal, state, and local agencies • Private companies and non-profit organizations	Industry contributions generally will be matched by federal/state funds on an average 4:1 ratio.	http://www.coastalamerica.gov/text/prospectus.pdf
North American Wetlands Conservation Act Grants Program (US Standard Grants & Small Grants)	US Fish & Wildlife Service	• 4-year plan of action supported by a NAWCA grant and partner funds to conserve wetlands and wetlands-dependent fish and wildlife through acquisition (including easements and land title donations), restoration and/or enhancement of wetlands. • Provides matching grants to organizations and individuals who have developed partnerships to carry out wetlands conservation projects in the United States, Canada, and Mexico.	Matching funds must be non-Federal	• Standard grants from $50,001 to $1,000,000 • Small grants up to $50,000	http://www.fws.gov/birdhabitat/nawca/grants.htm
Water Quality Cooperative Agreements US EPA Region 5 NPDES	Environmental Protection Agency	• Projects that will advance NPDES program strategies to implement watershed based efforts, • Reduce impacts of wet weather flows, • Improve monitoring and assessment for environmental results, • Address pollution from on-site and decentralized wastewater systems, • Build Tribal capacity to effectively manage on-site and decentralized wastewater treatment systems , • And demonstrate collaborative innovative approaches to control or reduce pollution to protect and restore water quality on a watershed basis.	• State water pollution control agencies, • Interstate agencies, • Tribes, • Colleges and universities, • Individuals, • And other public or nonprofit organizations	Typically range in size from $30,000 up to $400,000.	http://www.epa.gov/region5/water/stpb/pdf/r5_wqca_final_v062105.pdf

continued

Table E-3. *continued*

Grassland Reserve Program	Natural Resources Conservation Service	• Conserve, restore and protect two million acres of grassland, rangeland, shrubland and pastureland by purchasing easements, entering into long-term rental agreements, and providing technical and financial assistance to participants for restoring the functions and values of grasslands and shrublands. • Emphasizes support for working grazing operations; enhancement of plant and animal biodiversity; and protection of grassland and land containing shrubs and forbs under threat of conversion to cropping, urban development, and other activities that threaten grassland resources.	• Eligible producers must have 40 contiguous acres for consideration as a GRP • Both landowners and operators may participate on rental and restoration agreements. • Dairy and livestock farmers should seriously consider the Grassland Reserve as a way to support permanent pasture and hayland.	• Permanent Easements. USDA makes a payment based on the fair market value of the property less the grazing value. • 30-year easements. USDA pays 30 percent of the fair market value – less the grazing value. • Rental Agreements. 10, 15, 20 or 30-year duration. USDA pays 75 percent of the grazing value in annual payments for the length of the agreement. GRP Rental Rates are available for each Wisconsin county. • Restoration Agreements. USDA pays up to 90 percent of the restoration costs on grassland and shrubland that has never been cultivated and not more than 75 percent on restored grassland and shrubland (land that once was cultivated).	http://www.wi.nrcs.usda.gov/programs/grp.html
Wetlands Reserve Program	Natural Resources Conservation Service	A voluntary program to restore and protect wetlands on private property.Landowners can receive financial incentives to restore wetlands that have been drained for agriculture.	• Landowners with lands that have been previously drained for agricultural purposes, but only before December 23, 1985. • Landowners who choose to participate in WRP may sell a conservation easement or enter into a cost-share restoration agreement with USDA to restore and protect wetlands. • The landowner voluntarily limits future use of the land, yet retains private ownership. The landowner and NRCS develop a plan for the restoration and maintenance of the wetland.	The program offers landowners three options: permanent easements, 30-year easements, and restoration cost-share agreements of a minimum 10- year duration.	http://www.wi.nrcs.usda.gov/programs/wrp.html

Table E-4. *Local funding opportunities for infiltration campaigns.*

Local Funds	Source	Purpose	Availability	Amount	More information
Graham-Martin Prairie Foundation *(may not be a continuing grant program)*	Graham-Martin Prairie Foundation-Administered by Dane County, Administered by the City of Madison	● $200,000 gift to the County of native grasses and wildflowers, part of which the County is using to establish a grant program for homeowners, schools and nonprofit organizations to promote rain gardens and native landscapes. ● The City of Madison was also gifted $100,000 from the Graham-Martin Foundation to assist in the development of raingardens to reduce polluted runoff into local lakes and streams. ● Rain Gardens help water soak into the ground and prevent pollutants from running off into lakes and streams.	Dane County rain garden funds: Homeowners, municipalities, schools and nonprofit organizations were eligible to apply for a grant of plants or seeds to establish rain gardens or prairies in 2005. Businesses were not eligible.	Dane County: Provides up to $10,000 for municipalities, schools and nonprofit organizations and up to $200 per homeowner.	http://www.danewaters.com/business/PlantDane.aspx
1,000 Raingardens Project *(funding for this project is not solidified)*	EPA Administered by the City of Madison-Engineering Department	To promote infiltration in the City of Madison	Homeowners would be eligible for cost sharing any portion of the rain garden--technical assistance, plants, or construction. Businesses would also be eligible for cost sharing if they are not installing a rain garden to meet a permit requirement.	To be determined…	http://www.cityofmadison.com/engineering/stormwater/1000rg.htm

F

APPENDIX F

North Platte Site Conditions (URPL 601, 2004)

Deed Restrictions on Garver Property

Deed restrictions were placed on the Garver property by Olbrich Botanical Gardens to ensure that the property be used in a manner consistent with the goals and mission of Olbrich. The Wisconsin Department of Natural Resources (DNR) also placed a restriction in return for funding received by Olbrich Botanical Gardens for the cleanup of the site. The third restriction was placed on the property by the City of Madison Landmark Commission to guarantee that the property would not be altered by construction or demolition without consultation. These restrictions may act as an impediment to certain redevelopment activities and require that the City of Madison, the Wisconsin DNR and the City of Madison Landmark Commission review all activities on the site.

Warranty Deed

This property is conveyed subject to the restriction, enforceable by Grantor, that the property be used, in perpetuity, as parklands devoted primarily to botanical gardens, except that the buildings currently on the property may be used for storage, offices, and other municipal uses on an interim basis. Following are the details on these deed restrictions.

Wisconsin DNR Stewardship Grant and Management Contract

The Stewardship Property shall be used in perpetuity as parklands devoted primarily to botanical gardens except that the buildings currently on the property may be used for storage, offices, and other municipal uses on an interim basis.

City of Madison Landmarks Commission

Name of the building or site: Garver Feed and Supply Company

1. That all building permits for the altering or constructing all buildings on said site shall be submitted to the Landmarks Commission of the City of Madison, Wisconsin for approval.

2. That all permits for demolition of any buildings on said site shall be submitted to the Landmarks Commission of the City of Madison, Wisconsin, for approval.

Land Use

According the most recent Dane County Land Use data, produced in 1998, the Garver Property is listed as an industrial property. This will need to be amended, as the property is now city-owned. Existing land uses are shown in Figure 3.

Reprinted from Urban and Regional Planning, 2004, Course 601: Redevelopment of the Garver Feed Mill: Site analysis and conceptual plans, University of Wisconsin–Madison.

The parcel is part of a larger complex of parkland and open space, including the Olbrich Botanical Garden, Olbrich Park, and O.B. Sherry Park, as well as Starkweather Creek and nearby Lake Mendota. Adjacent land uses include commercial to the west and residential to the east.

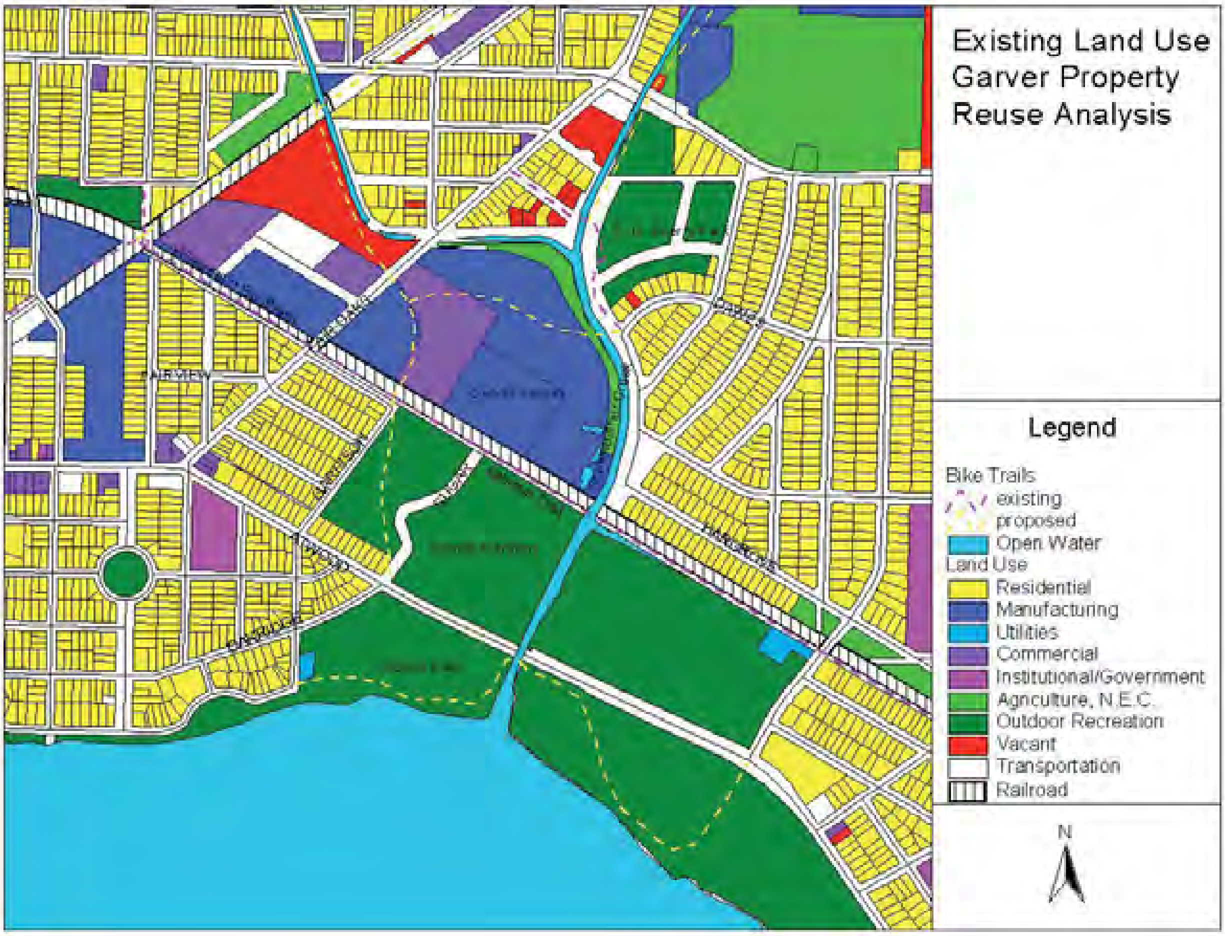


Figure 3. Existing land uses near Garver property.

City of Madison Zoning Regulations

Historically, the Garver property was part of a vital manufacturing corridor on the near east side of Madison. While manufacturing is no longer a staple of this community, the zoning regulations for the property still reflect its historical use. Redevelopment of the site may require zoning changes from a Limited Manufacturing District (M1) to something more applicable for the new use(s) of the building. Since the termination of manufacturing and warehousing uses in this area, the intent and purpose of this district are no longer applicable to the site. Rezoning this property would be dependent on the new use(s), but project managers should be aware of the need for possible rezoning.

Limited Manufacturing District (M1)

The Garver Building is currently zoned as a Limited Manufacturing District (M1) by the City of Madison. The purpose that the City of Madison sets forth in this district is to "accommodate existing non-nuisance type industrial uses presently located in relative proximity to residential areas" (Sec. 28.10(4)(a), City of Madison Zoning Code).

Additionally, "Development in the M1 limited manufacturing district is limited primarily to certain commercial uses and certain industrial uses, such as the fabrication of materials and specialized manufacturing and research institutions, all of a non-nuisance type" (Sec. 28.10(4)(a), City of Madison Zoning Code).

There are a variety of permitted uses under this zoning category, and some that may be relevant to the Garver redevelopment including amusement establishments; greenhouses; meeting, convention, or exhibition halls; offices; parks and playgrounds; restaurants (including catering services); restaurant/theatre; and farmers markets. Likewise, there is a large list of conditional uses for the M1 District. The one relevant conditional use is outdoor eating and recreation areas of restaurants and taverns.

The City of Madison also regulates the floor area ratio in this District. In the Limited Manufacturing District (M1), "the floor area ratio shall not exceed 2.0" (Sec. 28.10(4)(e), City of Madison Zoning Code).

There are also yard requirements for this District. The regulations are targeted towards the provision of a buffer between the Limited Manufacturing use and adjacent residential properties. Therefore, looking at the Garver property, the northern and the southwest third of the property line would be applicable to these regulations. Specifically, the southwestern part of the property (if this zoning district is maintained) would need to maintain a 25-foot yard. However, with the existence of the railroad right-of-way, this yard requirement may be trumped by the right-of-way distance. The northern, rear property line must have a yard of "10 feet in depth for buildings less than two stories in height, and 30 feet for buildings two stories or more in height" (Sec. 28.10(4)(f), City of Madison Zoning Code).

Conservancy District (C)

The current Olbrich Botanical Gardens (south of the Wisconsin and Southern railroad lines) is zoned Conservancy District (C). The purpose of the Conservancy Zoning District is to:

> Preserve and perpetuate in an open state certain areas such as lakes and waterways, wetlands and marshes, floodplains and stream beds, certain agricultural lands, slopes and other areas of aesthetic value which, because of their unique physical features, are deemed desirable and functional as natural drainage ways and water retention areas, natural habitat for plant and animal life, greenbelts and other multiple purpose uses beneficial to the community *(Sec. 28.07(2)(a), City of Madison Zoning Code).*

The permitted uses in this district include land and water preserves, such as arboretums, public parks and playgrounds, and educational, recreational, and office uses for governmental, educational, and nonprofit agencies.

A variety of conditional uses may be allowed in the Conservancy District. One such use is land and water preserves, (including restaurants or facilities “for outdoor recreation, including hotels, motels and other buildings containing dwelling units or lodging rooms for use by the transient public when accessory to such outdoor recreational use”) provided that the buildings and structures are not located less than 300 feet from any lot in a residence district. (Sec. 28.07(2)(c)11, City of Madison Zoning Code).

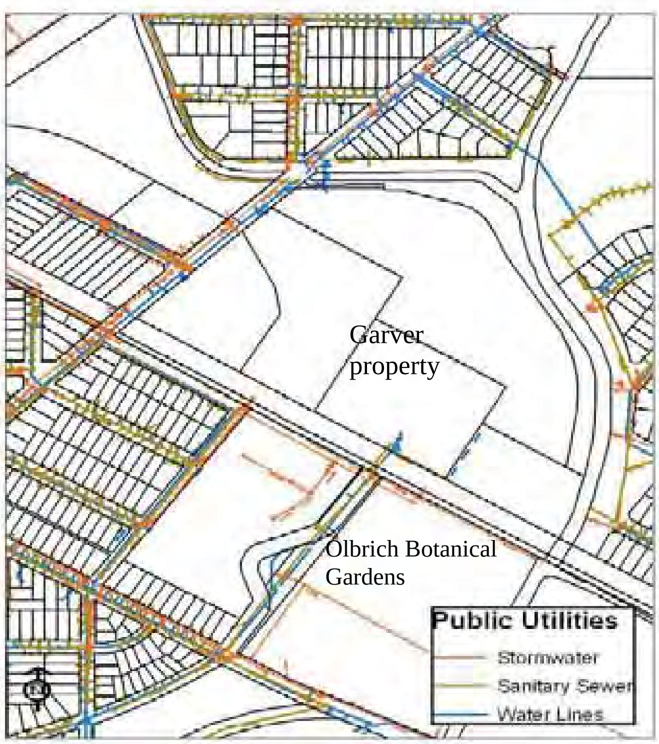
Another conditional use is accessory uses such as “dwelling units and lodging rooms in detached buildings for persons regularly employed on the premises and their immediate families” (Sec. 28.07(2)(c)16, City of Madison Zoning Code). Additionally, “municipally owned recreational buildings and community centers” may be allowed, however, these buildings must be located at least 50 feet from any lot in a residential district (Sec. 28.07(2)(c)19, City of Madison Zoning Code). Other municipal uses that are city owned and operated may also be allowed. According to the lot area and lot width requirements of this District, the lot area must not be less than 10 acres, while the lot width and street frontage must not be less than 500 feet.

The height regulations in the Conversancy District do not allow any buildings or structures, “other than a civic auditorium complex,” to exceed 2 stories or 35 feet in height.

Additionally, there are yard requirements for all buildings and structures (those other than a civic auditorium complex). The minimum yard requirement is at least 60 feet, the minimum side yard requirements are each 80 feet, and the rear yard is at least 100 feet.

Surrounding Districts

Surrounding the Garver property are General Residence Districts (R4) to the north and south, and to the east, a Single and Two-Family Residence District. On the west side of the property, the Limited Manufacturing District (M1) continues. In addition, there are two small areas, to the north of the property, that are zoned as wetlands.



Utilities

Utilities serving Olbrich, the Garver property, and the surrounding area are shown in Figure 4.

Stormwater

Because of the close proximity of Starkweather Creek and Lake Monona, stormwater runoff from the Garver property needs to be carefully considered in the redevelopment process. Stormwater runoff in and around Olbrich Botanical Gardens is primarily managed through conveyance. Conveyance is designed to move water using pipes and other impervious surfaces. As a management tool, it neither makes an allowance for infiltration nor does it prevent or mitigate stormwater pollution. The conveyance system on the northern section of the site allows for stormwater that has been collected in the surrounding neighborhoods to be drained into Starkweather Creek. The main stormwater pipe location around the northern section of the site uses pipes under the streets. Fair Oaks Avenue has a stormwater pipe that follows the road going north and south and drains into Starkweather Creek. The neighborhood north of Fair Oaks Avenue has several stormwater pipes leading either to Starkweather Creek or to the pipes under Fair Oaks Avenue.

Figure 4. Public utilities.

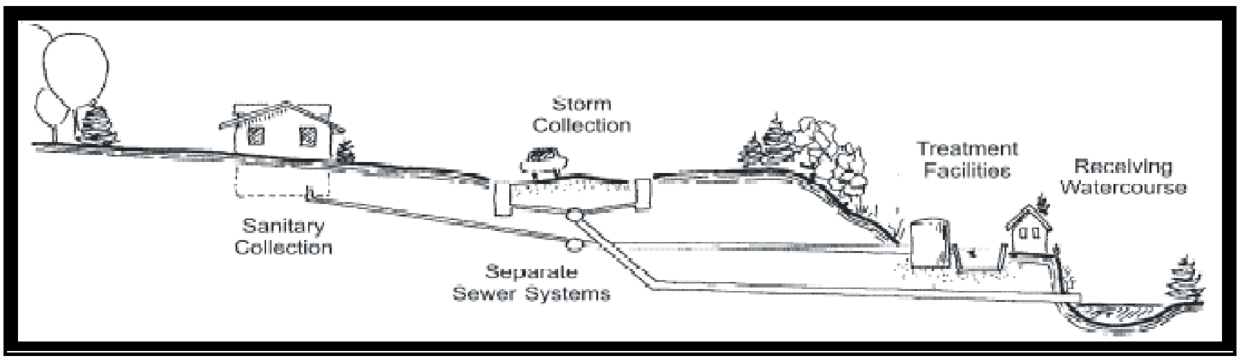


Figure 5. Separate Sanitary Sewer system and Stormwater drainage system. (Source: http://www.ene.gov.on.ca/envision/gp/4224e)

The stormwater pipes on the southern section of the site are designed in a similar fashion. However, the pipes from the southern neighborhoods are connected to underground pipes situated along the railroad tracks that stretch across the Olbrich property. The stormwater pipes follow the railroad east and drain into a lower section of Starkweather Creek.

Two separate stormwater pipes are located on the current Olbrich Botanical Gardens site. The first is shaped like an upside-down “T” with the top connecting to the conveyance section that stretches along the railroad tracks and the lower section parallel to the east and west section along the railroad tracks. This section is under the current maintenance facility of Olbrich Botanical Gardens. These pipes all connect to areas around Sugar Avenue and drain into Starkweather Creek.

Sanitary Sewer

The Olbrich site has one sanitary sewer line that connects the current buildings on the Olbrich site, including the Garver building (Figure 4). The sewer line runs along Sugar Avenue. There are several locations around the site where additional sanitary sewer could be connected:

- The intersection of Fair Oaks Avenue and Gateway Place
- The intersection of Bryan and Fair Oaks Avenue
- Along the East to West Section of Starkweather Creek connecting the dead end section of Ivy and Fair Oaks Avenue
- Along the North and South Section of Starkweather Creek Drive
- Along Emmet Street connecting with Fair Oaks Avenue
- Along Garlson Street connecting with Emmet
- Along Sugar Avenue connecting the Olbrich Botanical Gardens and stretching to the Garver building
- Along Atwood Avenue
- Along Lakeland Avenue

Water Lines

Olbrich has one water line that connects the current buildings and the Garver building (Figure 4). The water line runs along Sugar Avenue. There are several locations around the site where water lines could be connected:

- Along Fair Oaks Avenue and Gateway Place
- Along Ivy Street going through O.B. Sherry Park and following Starkweather Creek Drive
- Along Emmet Street
- Along Garlson Street
- Along Sugar Avenue
- Along Atwood Avenue

Other Water System Facilities

- Municipal well #8 is located across from Olbrich Botanical Gardens on the south side of Atwood Avenue
- A municipal reservoir is located at the end of Starkweather Creek near Atwood Avenue
- A municipal booster pump station is located near the entrance of Olbrich Botanical Gardens

Transportation

Roads

The two primary roads providing access to the site are Atwood Avenue and Fair Oaks Avenue. The only road providing direct access to the site is Sugar Avenue, which is routed through the existing Olbrich Botanical Gardens' parking lot.

There are a high number of daily vehicular trips generated near and around the Garver property. Table 1 indicates the traffic volumes reported at key locations on Atwood

Avenue as reported in the Wisconsin Highway Traffic Volume Data Book (Wisconsin Department of Transportation 2002).

Location	Number of Trips (2002)
Atwood/Fair Oaks	10,800
Atwood/Garrison	18,600
Atwood/Sugar (Oak Ridge)	17,200
Atwood/Starkweather Creek (east)	17,200

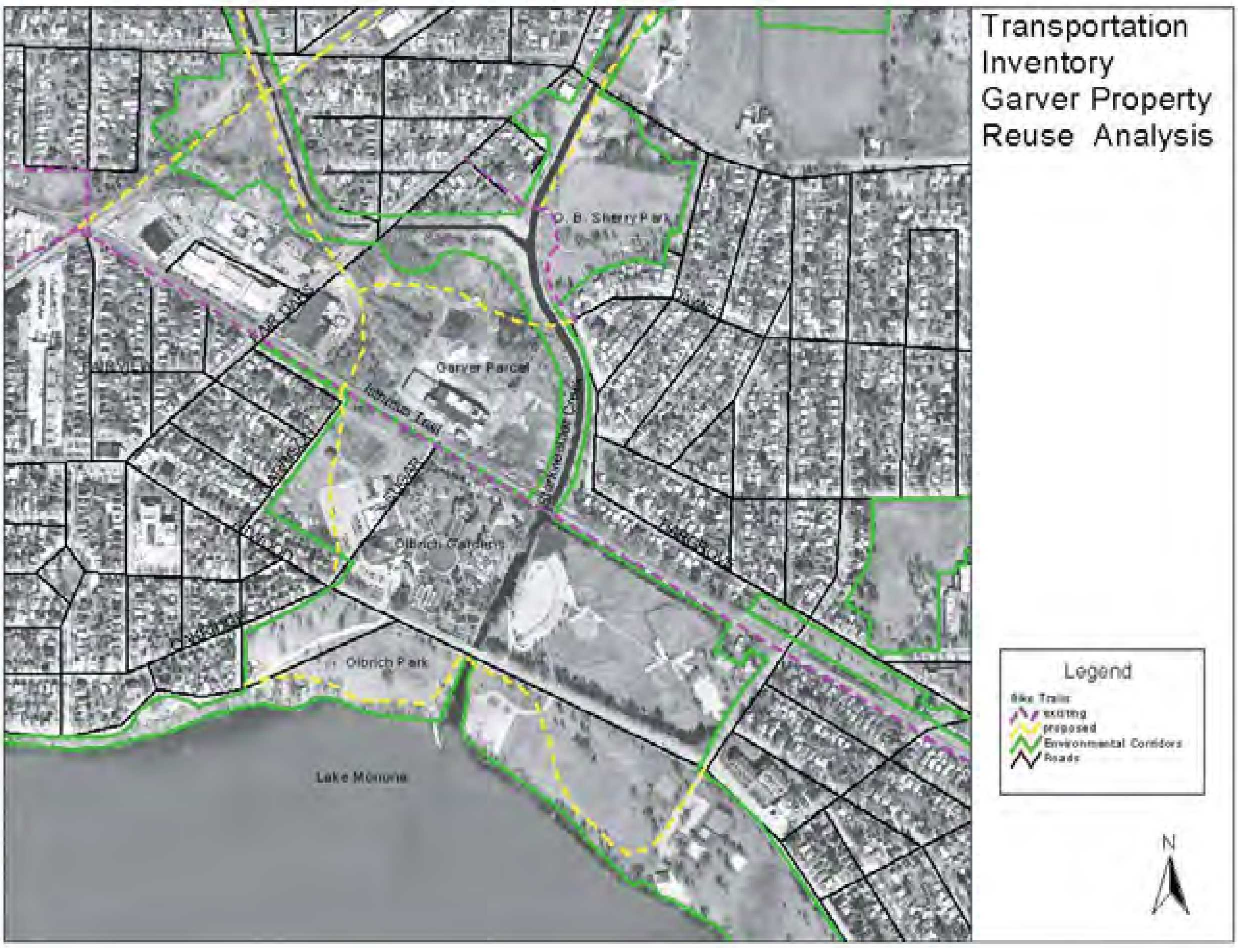


Figure 6. Recreation trails.

Recreation Trails

The Isthmus Bicycle Trail forms the southern boundary of the Garver parcel (Figure 6). This trail is part of the larger Capital City Trail network that ultimately connects in to the regional Ice Age Trail. Bicyclists and pedestrians use this trail for recreation and daily commutes. The City has proposed an additional recreation trail that would traverse the northern third of the parcel, linking it to the existing neighborhood recreational trails.

Rail

The Wisconsin Southern Railroad corridor is located to the south of the Garver parcel. This rail line is still active and several trains run along the tracks each week.

Environment

Environmental Corridors

The Dane County Regional Plan Commission has developed official environmental corridors for Dane County. These corridors delineate natural features, parks, and open space. On the Garver parcel, environmental corridors are located parallel to main and western branch of Starkweather Creek. If used as open space in the future, the Garver parcel will be included within the environmental corridor.

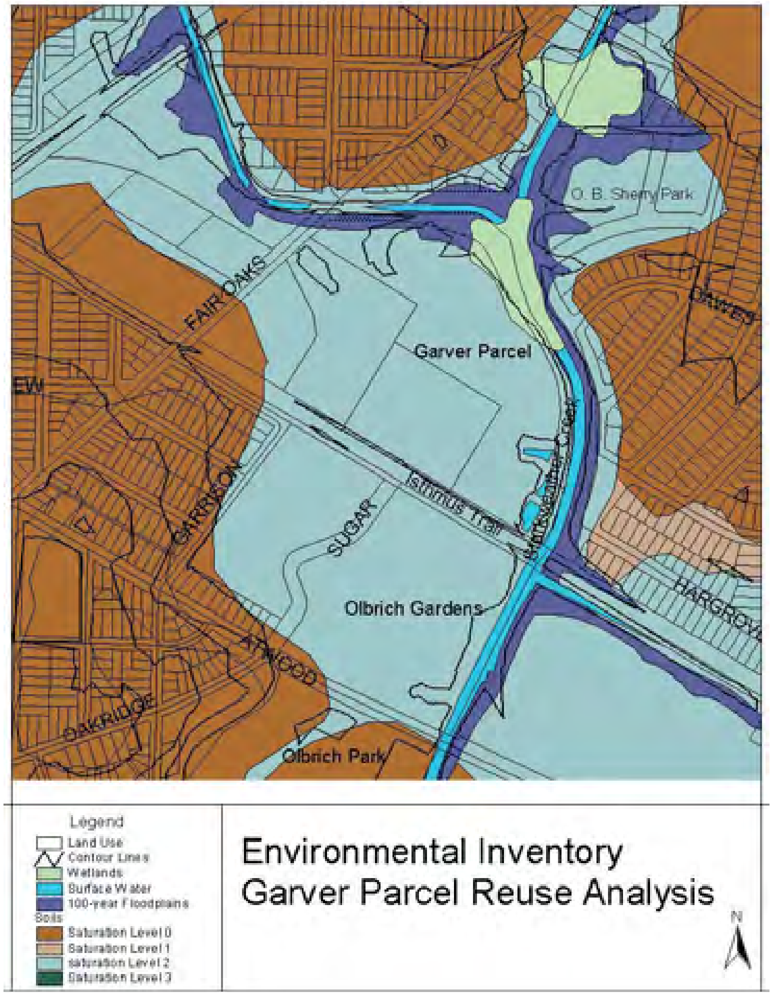


Figure 7. Environmental Inventory.

Open Space

The Garver parcel is part of a large city green space and open space complex. This includes Olbrich Botanical Gardens, Olbrich Park, O.B. Sherry Park, the Isthmus Trail, Starkweather Creek, and Lake Monona (Figure 2).

Water Resources

Starkweather Creek forms the eastern boundary of the project site. This creek has been channelized and drains into the Lake Monona basin.

Soils

According to the Dane County Soil Survey, the soil type within the project area is Colwood silt loam. The Colwood series consists of deep, poorly drained, nearly level soils on low benches in old lake basins. This site was once part of a wetland complex and was drained to provide buildable land.

Starkweather Creek Watershed

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