Dane County Water Quality Plan

Appendix B Update

Surface Water Quality Conditions

Prepared by the Staff of the Capital Area Regional Planning Commission March, 2014

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October 9, 2014

DNR File No. DC-0159

Mr. Kamran Mesbah, Deputy Director
Capital Area Regional Planning Commission
City County Building, Room 362
210 Martin Luther King Jr. Blvd.
Madison, WI 53703

Subject: Amendment to the *Dane County Water Quality Plan*, Updating Appendix B "Surface Water Quality Conditions"

Dear Mr. Mesbah:

We have completed our review of the subject amendment request that was submitted to the Department on April 15, 2014 by the Capital Area Regional Planning Commission (CARPC). The Department hereby approves this amendment to the *Dane County Water Quality Management Plan*, entitled "Appendix B "Surface Water Quality Conditions".

The amendment updates the previously published report on surface water conditions prepared by the Dane County Regional Planning Commission in 1992 and, as such, provides supplementary information to the Wisconsin Department of Natural Resources' ongoing statewide Areawide Water Quality Management Planning Program. This update provides an overview of water quality conditions in the county including the importance and relationship of land use in the watershed and its effect on aquatic health, Dane County's interpretation of statewide water quality standards and monitoring protocols, and surface water condition descriptions for individual waters in the county. This report also proposes expanding monitoring programs for Dane County to fill data gaps and direct future efforts.

Assistance for this update was provided by staff from the Wisconsin Department of Natural Resources, the Madison Metropolitan Sewerage District, the Dane County Land and Water Resources Department and Agrecol Environmental Consulting. In October 2012 the report was sent to all municipalities in the region for their review and comment. Subsequently, a public hearing was held on February 14, 2013 and the Capital Area Regional Planning Commission adopted the amendment per Resolution 2013-1.

While the Department is approving this amendment, please be aware that data, condition assessments, assessment protocols, and recommendations in this report are to be used as informational in nature. It should not be interpreted as superseding or replacing WDNR decision making authority for future site specific decisions and project proposals based on water quality conditions, standards and protection measures. While this report represents a snapshot in time, site specific water quality conditions and standards decisions are subject to change based on science, updated protocols, data and statewide policy and guidance changes.

This amendment becomes a part of the *Dane County Water Quality Management Plan* and will be forwarded to the US Environmental Protection Agency to meet the requirements of the Clean Water Act of 1987 (Public Law 92-500 as amended by Public Law 95-217), and outlined in the federal regulations 40 CFR, Part 35.

This review is an equivalent analysis action under s. NR 150.20 (2) (a) 3, Wis. Adm. Code. By means of this review, the Department has complied with ch. NR 150, Wis. Adm. Code, and with s. 1.11, Stats.

The approval of this amendment does not constitute approval of any other local, state, or federal permit that may be required for sewer construction or associated land development activities.

If you believe that you have a right to challenge this decision, you should know that the Wisconsin statutes and administrative rules establish time periods within which requests to review Department decisions must be filed. For judicial review of a decision pursuant to sections 227.52 and 227.53, Wis. Stats., you have 30 days after the decision is mailed, or otherwise served by the Department, to file your petition with the appropriate circuit court and serve the petition on the Department. Such a petition for judicial review must name the Department of Natural Resources as the respondent.

To request a contested case hearing pursuant to section 227.42, Wis. Stats., you have 30 days after the decision is mailed, or otherwise served by the Department, to serve a petition for hearing on the Secretary of the Department of Natural Resources. All requests for contested case hearings must be made in accordance with section NR 2.05(5), Wis. Adm. Code, and served on the Secretary in accordance with section NR 2.03, Wis. Adm. Code. The filing of a request for a contested case hearing does not extend the 30 day period for filing a petition for judicial review.

Sincerely,

Thomas J. Mugan

Thomas J. Mugan, P.E., Chief
Wastewater Section
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I. Executive Summary

The quality of the region's surface waters is probably as good as can be expected given more than a century of intensive urban development and agricultural production in the region. The condition of streams and lakes in the region span the range of excellent to officially "impaired," depending on the intensity of land use they have been subjected to and the natural resilience of these systems to outside disturbances (**see Maps 1, 2, 4, and Attachment A**). The good news perhaps is it is not too late to reduce the impacts to our surface waters as well as reverse some of the damage that has already been done. We are beginning to see some improvements. Our knowledge and experience-base associated with these complex aquatic ecosystems is also growing and improving.

What has clearly emerged from the literature is that the health of a water body is very much a reflection of the type and character of the land use and practices in the watershed. If land use in a watershed is properly managed, its associated waterbody will be healthier and more resilient and can more easily recover from episodic events, such as spills or climatic extremes. Whereas previous pollution control efforts were directed at controlling pollutants at the source, researchers have found that the health of a waterbody has much to do with maintaining natural hydrologic conditions or regime. In fact, by the time water quality problems become evident, the resource has in many cases already been degraded by water *quantity* impacts (i.e., greater frequencies and durations of higher stormflows resulting in channel incision, streambank erosion, sediment and nutrient loading, and associated habitat destruction).

The significance of hydrologic changes and pollutant loading is clear: strategies that reduce runoff volumes, thereby mimicking more natural flow conditions, will reduce the frequencies of larger/more erosive flows as well as increase baseflows during biologically critical dry-weather periods. Also, since pollutant loading is a function of flow (i.e., pollutant concentration times volume), reducing the volume of runoff will result in reduced pollutant loads as well. This is in addition to conventional practices that capture and treat the "first flush" of pollutants during runoff events or practices that minimize pollutants at the source.

The concept of runoff reduction marks an important philosophical milestone.[1] The promise of runoff reduction is that the benefits go well beyond water quality improvements. If site and stormwater designs can successfully implement runoff reduction strategies, they will do a better job at replicating more natural hydrologic conditions. This goes beyond conventional peak rate controls to also address additional concerns associated with runoff volume, duration, and frequency of flow, groundwater recharge, and protection of stream channels and biological habitat. Many of these practices can also perform double-duty. Implemented in upland areas of the watershed, they can also provide enhanced wildlife habitat and other natural resource amenities such as outdoor recreation, open space, and scenic beauty. These elements need to be emphasized and promoted very deliberately as integral components of our urban and agricultural landscape – or risk being plowed and paved over. On the resource side of this equation, a more systematic and tiered water resources monitoring program is needed to better gauge how well we are doing in this regard, as well as directing our efforts to where they are needed most. Water resource monitoring conducted over the last three decades illustrates a few important stream, lake, and groundwater quality findings as the basis for future actions and work in the region:

- Despite the significant growth and development that has occurred over the last three decades, in general, surface water quality in streams is not declining and is actually improving for various parameters and in many locations due to wastewater treatment plant upgrades and other point source pollution controls. More recent improvements in some areas have also resulted from improved land management and conservation practices. While much has been accomplished in this regard, more work is needed.
- Over-fertilization and sedimentation of our lakes and streams from rural and urban nonpoint source stormwater runoff continues to be a problem. These impacts are more difficult to measure and remedy since they cannot usually be traced to a single point or origin. Priority Watershed Projects, local stormwater management ordinances and plans, and agricultural conservation practices

1 Center for Watershed Protection, 2008.

are being pursued which implement strategies for reducing runoff and pollution from these varied sources. The Rock River TMDL[2] and associated nutrient trading opportunities are good examples of the innovative and cost-effective measures being developed for addressing this problem. This collaborative approach should be considered as a model in other parts of the region as well – to help prevent waters from becoming impaired as well as *improve* conditions where opportunities permit through prescriptive watershed plans.

- Groundwater indicates worsening trends, especially increasing nitrates from overuse of fertilizers and increasing salt concentrations evident in stream baseflow and municipal wells. More attention needs to be directed at reducing the amount of these materials being applied to the land surface. The effect of municipal well water withdrawals on water table levels and stream baseflows is also a growing concern. More efforts are needed to minimize water use along with innovative measures to direct more precipitation into the ground to help make up for these withdrawals – such as enhanced infiltration through engineered soils, rain gardens, and bioretention facilities; along with water supply planning to evaluate and avoid/minimize wells withdrawals in sensitive areas.

- The current monitoring program should be continued and also expanded. While certain water resource information problems and improvements have been revealed through monitoring activities, much is still unknown due to limited resource information. A more systematic and tiered approach is needed to assess water resource conditions throughout the region following the WDNR's Wisconsin Consolidated Assessment Listing Methodology. Continued identification of problems, trends, and success stories through monitoring activities will help provide the necessary information and impetus for directing more efficient and cost-effective resource management plans, projects, and strategies to where they are needed most.

These topics are detailed more fully in subsequent sections of this report.

2 Total Maximum Daily Load (see Chapter III).

II. Introduction

Water is a significant resource in the Capital Region, contributing tremendously to the region's environmental and economic well-being, as well as the quality of our everyday lives. The quality of our ground and surface waters has much to do with the reason people live, visit, and move here. Dane County is the second-largest metropolitan area and one of the fastest-growing counties in Wisconsin. This is amid the backdrop of over a century of intensive agricultural production. The quality of our lakes, streams, and groundwater supplies and the ecological and economic systems they support will deteriorate unless measures are taken to address the impacts of our activities. The purpose of this report is to characterize the condition of the water resources in the region and to provide general guidance and insight for protecting and restoring these vital treasures.

The stated goal of the Clean Water Act is to maintain and restore the physical, chemical, and biological integrity of the waters of the United States (33U.S.C§1251(a)). The *Dane County Water Quality Plan* is the official areawide water quality management plan for Dane County, Wisconsin, described and guided by state Administrative Rule NR 121. The purpose of the plan is to provide a policy framework and guidance for federal, state, and local water quality protection programs in Dane County. The plan includes 11 technical appendices containing detailed data and supporting information on a variety of subject areas. The plan and its technical appendices have been continually revised, updated, and expanded since completion and certification of the initial *Water Quality* Plan in 1979. This report updates Technical Appendix B *Surface Water Quality* Conditions with new information collected and developed since the last update in 1992. The report provides an overview of water quality conditions in the county including: the importance and relationship of land use in the watershed and its effect on aquatic health; established water quality standards and monitoring protocols; more detailed surface water condition descriptions for individual water bodies in the county; a proposed expanded monitoring program to fill data gaps and direct future efforts; and finally, future horizons in terms of more cost effective pollution control strategies and policy guidance.

One of the difficult aspects of water resource management is that often only the water quality component is considered. Water quality criteria are the main regulatory tools used in managing receiving waters. These are typically concentrations of specific pollutants set so as to protect human health and beneficial uses of receiving waters from adverse impacts. However, relying primarily on these water quality criteria to manage nonpoint source pollution is often not an effective approach because biological and ecological impacts can be related to water *quantity* changes that often occur well below these pollutant criteria.

Many of the effects of our activities on the land are, for the most part, relatively small. When considered on a watershed basis, however, their cumulative effect can be substantial – so-called "death by a thousand cuts." In order to manage these effects, we need to understand them on a watershed basis, where the effects are discernible, but prevent them on an individual site basis, where the physical changes to the environment are being made and mitigation measures are easier to implement.

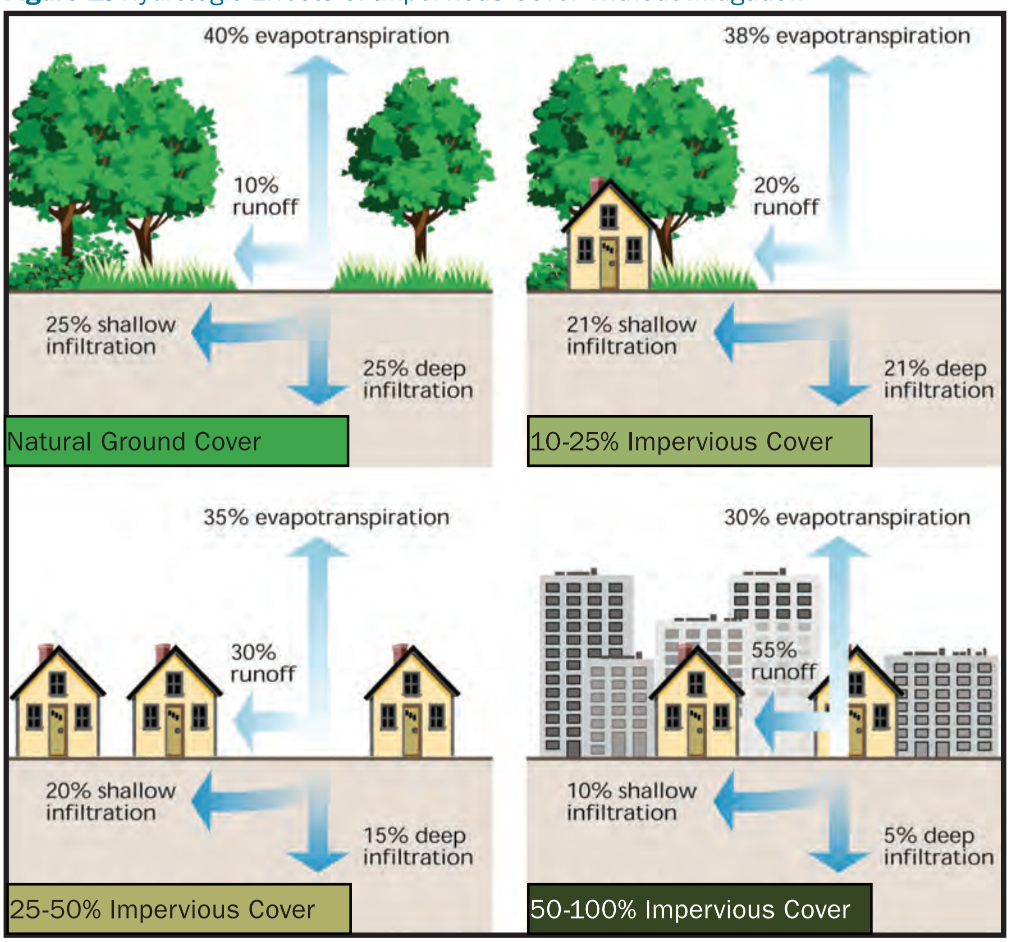
What has emerged from the scientific literature and research around the nation is that the health of a water body is very much a reflection of the type and character of the land use in the watershed. Also, if land use in a watershed is properly managed, its associated waterbody will be more resilient and can more easily recover from an episodic event (such as a spill). As more acres of agricultural land become urbanized in the region, additional emphasis will be needed to address the changing landscape – in addition to repairing previous change to the land cover. While much effort and progress has been made with regard to point and nonpoint source pollution control, more work is needed to understand and assess the susceptibility of natural resources to changes in hydrologic regime.

A. Ecohydrology and Biodiversity

Ecohydrology is an emerging scientific sub-discipline shared by the ecological and hydrological sciences. It is defined as the overlap between these two fields realized by the impact of hydrology on biologic ecosystems. There has been a shifting program emphasis over the last 20 years. What has clearly emerged from the literature is that the relationship of land use to aquatic ecosystem function is driven by factors beyond pollutant levels alone. The focus is being directed more towards the increasing *volumes* of stormwater runoff resulting from our activities on the land. For example, below 40 percent connected impervious area in the watershed,[3] biological decline has been found to be more strongly associated with hydrologic changes than with chemical water quality declines.[4] By the time water quality impacts become evident, the stream ecosystem has in many cases already been degraded by water *quantity* changes.[5] These impacts include changes in landforms and the modification of natural hydrologic patterns or regime, degradation of physical habitat, disruption of ecological structure, functions and processes, and the associated biological changes tending towards more tolerant species composition.

One of the most obvious manifestations of development in a watershed has historically been the increase in connected impervious surfaces in the urban landscape. Urbanization reduces natural vegetation, replacing it with streets, rooftops, driveways, and parking lots. **Figure 1** shows the progression of connected impervious surface area and the changes in the hydrologic regime as the result of development where stormwater management or mitigation is absent. Compared to more urbanized areas in the state and the U.S., connected watershed impervious cover ranges between 0 to 40 percent in Dane County.[6] Because of compaction during the development process, turf and landscape areas can also increase the total runoff even from vegetated areas. This is also true of agricultural production activities (e.g., row cropping, barnyards, feedlots) where the natural vegetation has been altered.

Figure 1. Hydrologic Effects of Impervious Cover Without Mitigation



Source: Schuler 1994

3 Connected Impervious Area generally includes paved surfaces such as streets, driveways, parking lots, or short (<20 feet) lawn areas which discharge directly to a storm sewer or water body rather than a specially designed stormwater treatment facility or practice.

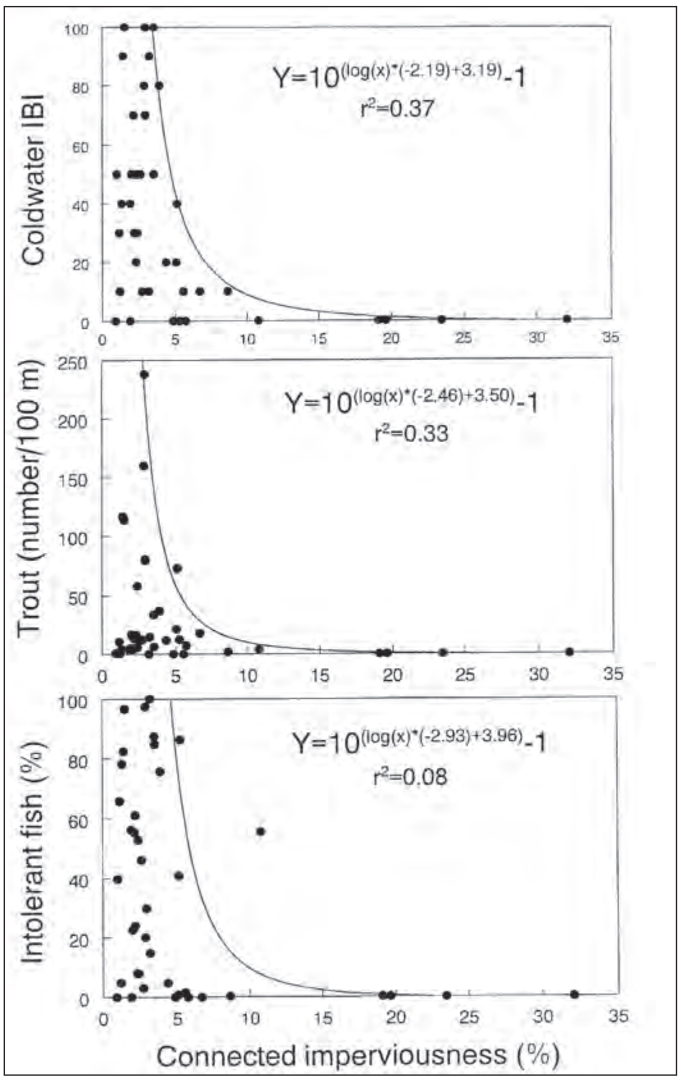
4 Horner, 2001.

5 Shaver, 2007 and Lyons 2004.

6 DCRPC, 2005.

Studies in Wisconsin clearly illustrate the strong effects of upstream land uses on stream ecosystems. Wang found the amount of connected impervious surface area in the watershed was negatively correlated with coldwater IBI,[7] catches of coldwater and coolwater fishes, and the percentage of intolerant (sensitive) fish (**Figure 2**).[8] It was positively correlated with the percentage of tolerant fish. Watershed urbanization has major effects on fish communities in warmwater streams as well.[9] As can be seen from the graphs, relatively low levels of urbanization in these watershed (8-12 percent connected imperviousness) has led to rather precipitous declines in ecological function and diversity.

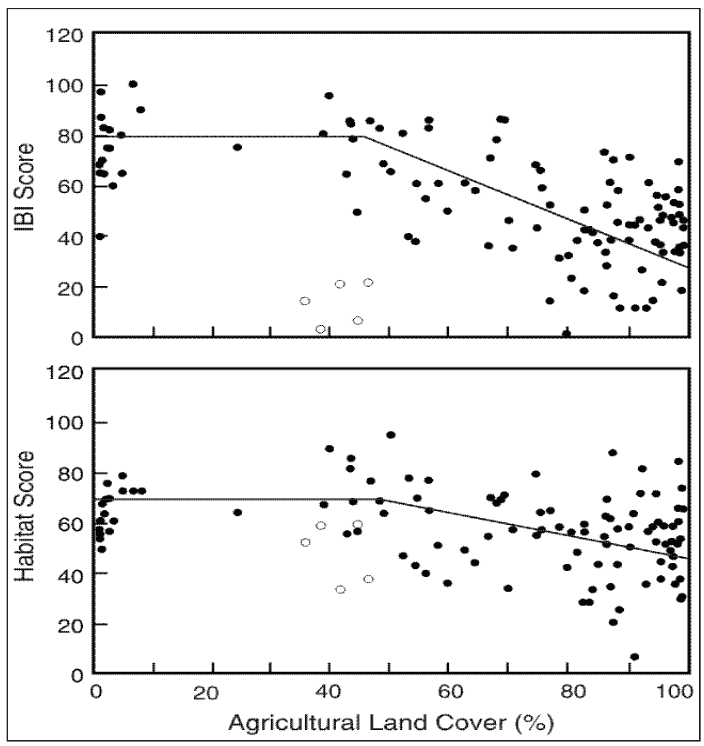
Figure 2. Relationships Between Percent Watershed Connected Imperviousness and the Coldwater Index of Biotic Integrity (IBI), Trout Abundance, and Percent Intolerant Fish in Minnesota and Wisconsin Trout Streams



Source: Wang et. al., 1997.

The amount of agricultural land use also tends to be negatively correlated with stream habitat quality and biotic integrity, although the relationship is nonlinear, **Figure 3.** When upstream land use is less than about 50 percent agriculture, no significant relationship existed between land use and biotic integrity or habitat. However, when agriculture exceeds 50 percent, biotic integrity and habitat scores decrease. This decreasing trend is stronger for biotic integrity than for habitat. This suggests there may be a threshold level at which agricultural impacts begin to become apparent or overwhelm the assimilative capacity of the stream.

Figure 3. Relationships Between Watershed Agricultural Land Use and Habitat Scores and Index of Biotic Integrity (IBI) scores. Open circles are considered outliers



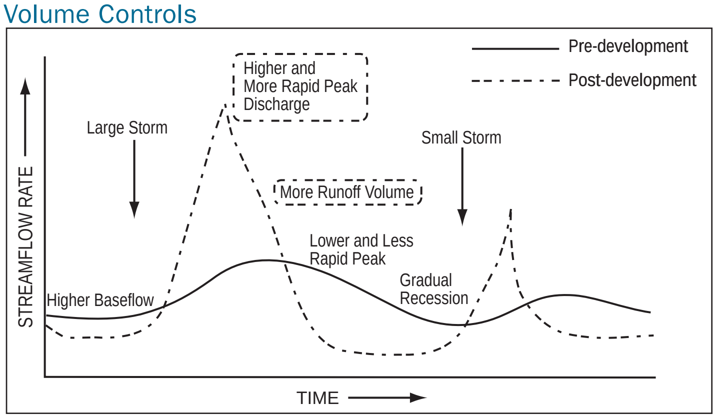
Source: Wang et. al., 1997

7 Index of Biotic Integrity; Lyons, 1996.
8 Wang, 2003.
9 Wang 1997, 2000, 2001.

The findings demonstrate that the response to changes in watershed land use is complex but predictable. The fish assemblage changes dramatically, moving from low to high connected imperviousness in the watershed as a consequence of both species loss and replacement. Water temperature and baseflow were identified as important habitat factors explaining stream fishassemblage.[10] These parameters are particularly critical during summer dry-weather periods. Other periods of the year are more critical for high flow events, such as spring thaw runoff.

Figure 4 shows typical pre-development and post-development stream flow hydrographs for a watershed that is being developed for urban land uses without any mitigation practices. As development progresses the stream hydrology changes from a more gradual and subdued groundwater-dominated system (solid line) to one dominated more and more by flashier surface water impacts (dashed line). The area below the hydrographs represents the volume of runoff. The increased peak flow and runoff volume resulting from development is significant because of the increased pollutant load it can carry, the elevated potential for flooding, and the higher likelihood of channel and stream bank erosion downstream.

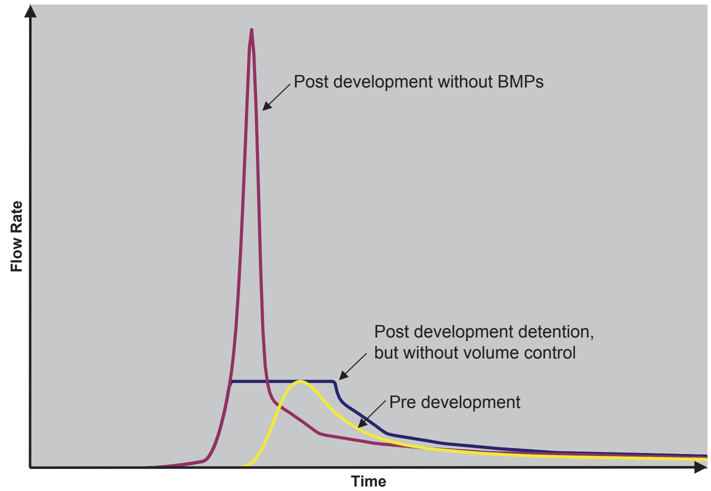
Figure 4. Stream Hydrographs Showing Pre-Development and Post-Development Flowrates Without Runoff and Volume Controls



Source: Shaver et. al., 2007

Conventional post-development stormwater detention practices (without volume control) can reduce peak flows (**Figure 5**), but results in longer durations of higher flows through the storm hydrograph (i.e., except for the peak, each point on the blue line is higher than its corresponding point on the yellow line).

Figure 5. Effect of Development on Runoff Flow Rates and Volumes



Source: Capital Area RPC generated with HydroCAD

The potential hydrologic impacts of land use changes within a watershed are well established:

- More bankfull or higher stream volumes
- More frequent and higher floods
- Higher peaks and flashier stormflow for a given size storm
- Longer duration of high streamflows
- Less groundwater recharge, resulting in lower dry-weather baseflow levels
- Greater water table and wetland water level fluctuation

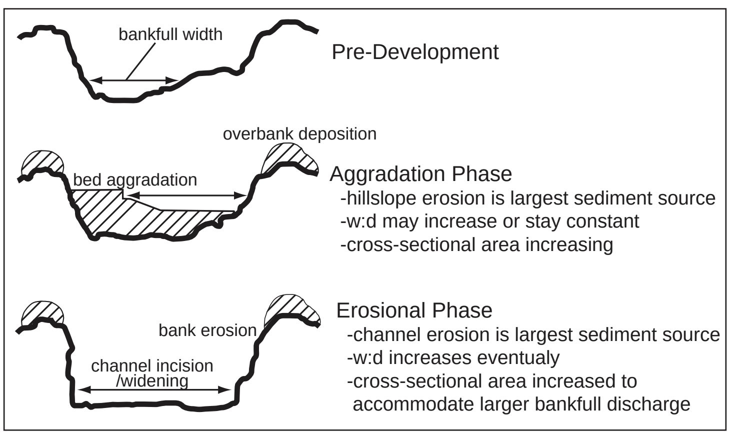
While this holds true for agriculture as well, the effects may be more subdued depending on the type/extent of ground cover and agricultural practices. This is because the large amounts of open space typically associated with agricultural production generally has a positive or mitigating effect compared to developed land – to a degree.

In either case (ag or urban), as the infiltration capacity of the land in the watershed decreases, stormwater runoff volumes and rates increase, causing the frequency and magnitude of stormflows to rise and baseflows to fall. Increased peak flows and runoff volumes increase the erosive force of the channel flows and can significantly reduce the streambed and bank stability and the sediment load equilibrium that has established itself over

10 Wang, 1997.

time. Increased volumes and rates of runoff can overload natural drainage systems that have adapted themselves to historical conditions. As the frequency of bankfull events increases, the stream attempts to enlarge its cross section to reach a new equilibrium associated with the increased flows. Greater frequencies and durations of higher stormflows can result in channel incision, streambank undercutting, increased streambank erosion, sediment loading and transport along the streambed (**Figure 6**). The results are wider, straighter, sediment-choked streams, greater water temperature fluctuations, as well as loss of riparian cover, shoreland, and aquatic habitat. The streambed is covered by sand and silt, and pollutant loading of other constituents (e.g., toxic materials, metals, and organics) is also increased. Often by the time the water quality impacts become evident, the stream ecosystem has already largely been damaged by the water *quantity* impacts.[11]

Figure 6. Changes in Stream Channel Geomorphology without runoff controls



Source: Shaver et. al., 2007

The major factors that determine runoff rates and volumes are hydrologic soil group (i.e., soil texture/infiltration capacity), land use/cover type (i.e., commercial, residential, pasture, meadow, open space), land treatment/management practices (i.e., Best Management Practices or BMPs[12]), hydrologic condition (i.e., runoff potential affected, for example, by plant density or residue), and antecedent soil moisture condition. Another important factor is whether an area is connected directly to the drainage system ("connected") or whether the flow is directed to a control facility or spread over pervious areas before entering the drainage system ("disconnected"). Runoff reduction strategies are typically focused on managing these variables, which often requires balancing the many options under one's control, the resource objective(s), as well as economic and financial considerations.

The significance of hydrologic changes and pollutant loading is clear: strategies that reduce runoff volumes, thereby mimicking more natural flow conditions, will reduce the frequencies of larger/more erosive flows. Also, since pollutant loading is a function of flow (i.e., pollutant concentration times volume), reducing the volume of runoff will result in reduced pollutant loads as well. This is in addition to conventional practices that capture and treat the "first flush" of pollutants during runoff events or practices that minimize pollutants at the source. The health of tributary and feeder streams is also crucial to protecting fish communities. Temperature, pollution, and anoxia events can be avoided by fish by moving into tributary channels where conditions are still favorable. Thus, efforts must be made to ensure high quality feeder streams as well as the stream's mainstem.

Overall, it is much easier to incorporate hydrologic protection measures early in the design *before* an area becomes developed or at the source than to try and restore the situation after the fact. State and local stormwater management rules to reduce runoff volumes from new development have been in effect for nearly a decade. Much of the current impacts on our water resources are due to development that occurred before these regulations were put into effect. Please refer to Technical Appendix D: Urban Nonpoint Source Analysis[13] to the *Dane County Water Quality Plan* for a more complete discussion and analysis of urban stormwater management standards and practices that communities have enacted. From an agricultural perspective, the *Dane County Land and Water Resource Management Plan*[14] is a 10-year action and implementation plan that focuses on soil and water quality concerns through various local, state and federal programs.

The conclusion of the research is that without adequate mitigation practices even low levels of unmitigated urban development and higher levels of agriculture production

11 Personal communication with John Lyons, DNR Research Watershed Ecologist. August 2004. Madison, WI.
12 See List of Environmental Indicators and Terms Used in This Report.

13 http://danedocs.countyofdane.com/webdocs/PDF/capd/2011_postings/WQP/Appendix_D_Draft.pdf
14 http://www.countyofdane.com/lwrd/landconservation/papers/lwrm08/LWRM_Plan_2008_with_Maps.pdf

can damage stream systems. Conservation strategies that protect the riparian area, minimize the effects of imperviousness, and mitigate its impacts can reduce this damage. This is amid the backdrop of over a century of intensive agricultural production throughout the county and the relatively recent efforts towards promoting conservation practices. Despite the progress that has been made in these areas, more work is needed.

The concept of runoff reduction marks an important philosophical milestone. The promise of runoff reduction is that the benefits go beyond water quality improvements. If site and stormwater designs can successfully implement runoff reduction strategies, they will do a better job at replicating more natural hydrologic conditions. This goes beyond conventional peak rate control to also address additional concerns associated with runoff volumes, duration and frequency of flow, groundwater recharge, as well as protection of stream channels and biological habitat.

B. Water Quality Considerations

Whereas federal and state legislation has successfully reduced point source pollution over the past 30 years, nonpoint source pollution continues to degrade water quality in the United States.[15] The primary culprits in the region are phosphorus and sediment. Virtually every water body in the region has been impacted by phosphorus or sediment to some degree as a result of our activities on the land, and some of our waters have become excessively impaired. Although phosphorus is an essential nutrient for plant growth, excess phosphorus is a concern for most aquatic ecosystems. Where human activities do not dominate the landscape, phosphorus is generally in short supply. The absence of phosphorus limits the growth of algae and aquatic plants. When a large amount of phosphorus enters a water body, it essentially fertilizes the aquatic system, allowing more plants and algae to grow, leading to excessive aquatic plant growth. This condition of nutrient enrichment and high plant productivity is referred to as eutrophication. Eutrophication is detrimental to aquatic life, it reduces recreational opportunities, and affects the economic well-being of surrounding communities.

15 Wang, 2002.

More specifically, excessive growth of algae in a water body or "algae bloom" can block sunlight from penetrating the water, choking out beneficial submerged aquatic vegetation. An algae bloom may also include toxic blue-green algae or cyanobacteria, which are harmful to fish and pose health risks to humans. Algal blooms, particularly those that form surface scums, are particularly unsightly and can have unpleasant odors. This makes recreational use of the water body unpleasant, and can affect the everyday quality of life of people who live close by. In addition, large areas of excessive vegetation growth, such as the invasive exotic Eurasian Water Milifoil, can form large mats and inhibit or prevent access to a waterway, which restricts use of the water for fishing, boating, and swimming. When the large masses of aquatic plants die, the decomposition of the organic matter depletes the supply of dissolved oxygen in the water, suffocating fish and other aquatic life. Depending on the severity of the low dissolved oxygen event, large fish kills can occur.

Many water bodies in the region are also impaired by excess sediment loading. Sediment that is suspended in the water scatters and absorbs sunlight, reducing the amount of light that reaches submerged aquatic vegetation, which reduces its photosynthetic rate and growth. Bottom-rooted aquatic plants (called macrophytes) produce oxygen, provide food and habitat for fish and other aquatic life, stabilize bottom sediments, protect shorelines from erosion, and take up nutrients that would otherwise contribute to nuisance algae growth. As photosynthetic rates decrease, less oxygen is released into the water by the plants. If light is completely blocked from bottom dwelling plants, photosynthesis ceases, oxygen production stops, and the plant will die. As the plants are decomposed, bacteria will use up even more oxygen from the water.

Reduced water clarity can have other direct impacts on biologic diversity and ecologic food webs, including insects, frogs, fish, other reptiles, waterfowl, and mammals – upon which they feed and they themselves serve as food. Suspended sediments interfere with the ability of fish and waterfowl to see and catch food and can clog the gills of fish and invertebrates, making it difficult for them to breathe. When sediments settle to the bottom of a river, they can smother the eggs of fish and aquatic insects, as well as suffocate newly hatched insect larvae.

Settling sediments can also fill in spaces between rocks, which provide shelter for aquatic organisms. Excess sediments can also cause an increase in surface water temperature, because the sediment particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall (warmer waters hold less dissolved oxygen), and harm aquatic life even further. In addition to its direct effects, sediment may also carry nutrients, heavy metals and other pollutants into water bodies. In fact, a large proportion of the phosphorus that moves from land to water is attached to sediment particles. This means that managing sediment sources can help manage phosphorus. Therefore, efforts aimed at improving water quality are often focused on addressing phosphorus and sediment together because their sources, transport, and management options are closely linked. Controlling phosphorus and sediment also serves as a surrogate or proxy for addressing a host of related water quality constituents and concerns described in the following sections.

While considerable progress has been made in many areas of the county since the adoption of the Clean Water Act in 1972, more work is needed. The following sections provide more detailed descriptions of the water quality metrics and conditions in individual rivers, lakes, and streams in the region. The introduction provided here is intended to help the reader understand, organize, and assimilate the more detailed information contained in subsequent sections of this report. It is hoped that the water resources management framework outlined here will provide the necessary insight, guidance, and approach to help leverage and focus our limited resources on the most beneficial management strategies and practices in what seems to be an ever-challenging and difficult financial and political climate.

III. Water Quality Standards

Water quality standards are the foundation of Wisconsin's water quality management program. They serve to define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. The WDNR is authorized to establish water quality standards that are consistent with the Federal Clean Water Act (Public Law 92-500) through Chapter 281 of the Wisconsin Statutes. These water quality standards are explained in detail in Chapters NR 102, NR 103, NR 104, NR 105, and NR 207 of the Wisconsin Administrative Code. These water quality standards rely on three elements to collectively meet the goal of protecting and enhancing the state's surface waters. They include:

- ***Designated Uses***, which define the goals for a waterbody,
- ***Water Quality Criteria***, which are set to protect the water body's designated uses, and
- ***Anti-Degradation Provisions,*** to protect water quality from declining.

A. Designated Uses

Designated uses are goals or intended uses for surface waterbodies in Wisconsin which are classified into the following categories, described in Chapter NR102:

Recreational Use – All surface waters are considered appropriate for recreational use unless a sanitary survey has been completed to show that humans are unlikely to participate in activities requiring full body immersion.

Public Health and Welfare – All surface waters are considered appropriate to protect for incidental contact and ingestion by humans.

Wildlife – All surface waters are considered appropriate for the protection of wildlife that relies directly on the water to exist or rely on it to provide food for existence.

Fish and Aquatic Life – All surface waters are considered appropriate for the protection of fish and other aquatic life. Surface waters vary naturally with respect to factors like temperature, flow, habitat, and water chemistry. This variation allows different types of fish and aquatic life communities to be supported. Wisconsin currently recognizes the following Fish and Aquatic Life subcategories based on the waterbody's capacity to support a diverse and healthy fish community (Table 1).

Table 1. Fish and Aquatic Life Use Subcategories

COLD	**Coldwater Community:** Surface waters capable of supporting a coldwater sport fishery, or serving as a spawning area for salmonids and other coldwater fish species. Representative aquatic life communities associated with these waters generally require cold temperatures and concentrations of dissolved oxygen that remain above 6 mg/L. Since these waters are capable of supporting natural reproduction, a minimum dissolved oxygen concentration of 7 mg/L is required during times of active spawning and support of early life stages of newly-hatched fish.
WWSF	***Warmwater Sport Fish Community:*** Surface waters capable of supporting a warmwater-dependent sport fishery. Representative aquatic life communities associated with these waters generally require cool or warm temperatures and concentrations of dissolved oxygen that do not drop below 5 mg/L.
WWFF	***Warmwater Forage Fish Community:*** Surface waters capable of supporting a warmwater-dependent forage fishery. Representative aquatic life communities associated with these waters generally require cool or warm temperatures and concentrations of dissolved oxygen that do not drop below 5 mg/L.
LFF	***Limited Forage Fish Community:*** Surface waters capable of supporting small populations of forage fish or tolerant macro invertebrates (aquatic insects) that are tolerant of organic pollution. Typically limited due to naturally poor water quality or habitat deficiencies. Representative aquatic life communities associated with these waters generally require warm temperatures and concentrations of dissolved oxygen that remain above 3 mg/L.
LAL	***Limited Aquatic Life Community:*** Surface waters capable of supporting macro invertebrates or occasionally fish that are tolerant of organic pollution – typically small streams with very low flow and very limited habitat, certain marshy ditches, concrete-lined drainage channels, and other intermittent streams. Representative aquatic life communities associated with these waters are tolerant of many extreme conditions, but typically require concentrations of dissolved oxygen that remain about 1 mg/L.
FAL	***Fish and Aquatic Life Community:*** Waters that do not have a specific use designation subcategory assigned but which are considered fishable, swimmable waters.

Source: Wisconsin 2010 Consolidated Assessment and Listing Methodology

It is important to point out that a waterbody's Fish and Aquatic Life Use Designation is legally recognized in Wisconsin Administrative Code. This designation is used to determine water quality criteria and effluent limits. A stream can obtain a codified designated use by applying formal stream classification procedures.

Classifications for waterbodies are derived from:

1. Streams classified and listed in NR 102 and NR 104 (*Note: all waters not officially codified in NR 102 or NR 104 are codified as Warmwater Sport Fish Community, which is the default classification and listed as "DEF").*
2. Streams formally classified during the Wisconsin Pollutant Discharge Elimination System (WPDES) permitting process. These streams are surveyed and classified to provide the basis for the permit's effluent discharge limitations.
3. Trout streams identified by reference in WDNR's publication *Wisconsin Trout Streams*.
4. ORW and ERW streams officially approved as such by the WDNR board and listed in NR 102.10 and NR 102.11. Officially, ORW/ERW waterbodies are not fish and aquatic life use designations but are a separate category for the WDNR anti-degradation program (**see pg 13**). These waterbodies receive a fish and aquatic life use classification for the purpose of determining water quality criteria and/or effluent discharge limitations.

Assignment of designated uses for the protection of fish and aquatic life has been an iterative process dating back to the late 1960s. While the WDNR strives to maintain a contemporary list of designated uses, it cannot visit each stream, river, or lake very often. In fact, many of the designated uses that are included in the Wisconsin Administrative Code date back to the 1980s. The current designated use for individual streams are listed in **Attachment A**. Updates to the list may be found by visiting WDNR's Water Basin website and accessing the desired watershed and water body details.[16]

16 http://dnr.wi.gov/water/basin/

Current and Attainable Uses

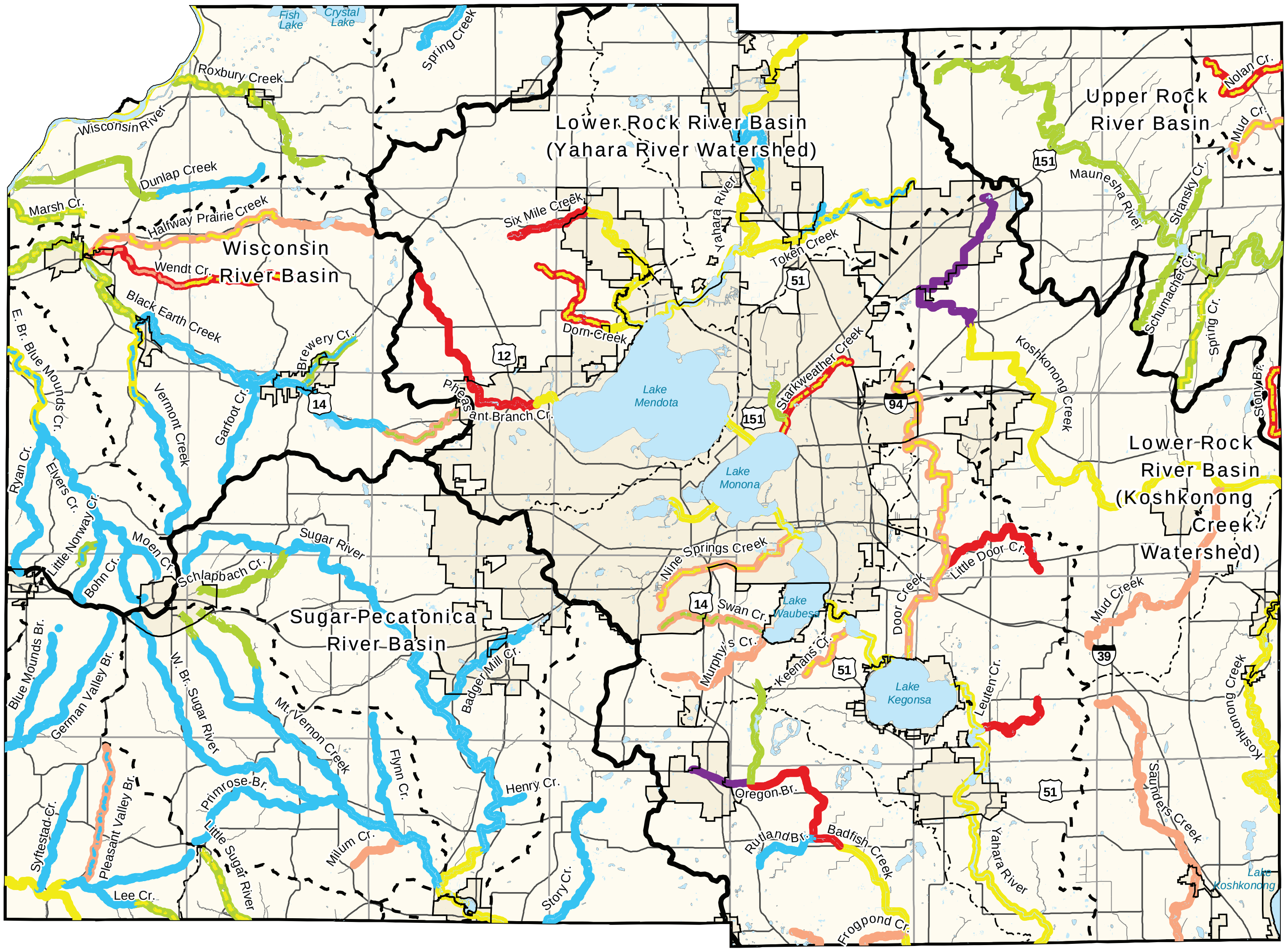
Determining the Fish and Aquatic Life subcategory for each waterbody is one of the first steps in managing water quality. In order to facilitate the determination of a designated use to reflect the most current understanding of stream/river ecology, the WDNR published updated guidance in 2004.[17] The informal guidance is used by biologists who monitor Wisconsin's stream and river communities. It provides a framework for the collection and assessment of field data to recommend which Fish and Aquatic Life subcategory a particular water or segment best fits.

Using this methodology, the "Current Use" is the fish and aquatic life community the WDNR biologist believes the water currently supports. **This is not a formal designation; it is based on the current condition of the water**. Current Fish and Aquatic Life determinations for streams in the region are shown on **Map 1**. The "Attainable Use" is the use the WDNR biologist believes the water could be attained by managing "controllable" sources of impairment. These actions include effluent requirements for point sources, and cost-effective and reasonable Best Management Practices for nonpoint source pollution control. Beaver dams, low gradient streams, naturally occurring low flows, and land cover/use are generally considered "uncontrollable" natural or cultural factors. The Attainable Use may be the same as the Current Use or it may be higher.

Current and Attainable Uses are not formal designations. They are based on the current condition of the water or the condition that could be achieved through management plans or activities. **They are not designed for, nor should they be used for regulatory purposes**.[18] Note that the Current and Attainable Use determinations may actually be different than the codified Fish and Aquatic Life Use designations for some streams. This is because the Current/Attainable Use determinations are used for more informal fisheries management purposes, activities, and guidance; whereas the Codified Use designations are used for more formal or regulatory pollution control and permitting activities, where there may be more significant legal and financial considerations.

17 WDNR, 2004.
18 WDNR, 2004.

Map 1



Fish and Aquatic Life in Streams

Dane County, Wisconsin

Source: WDNR Surface Water Data Viewer and Basin Plan stream tables

Current	Attainable	Subcategory
blue solid	blue dashed	Cold Water Fishery (COLD)
yellow solid	yellow dashed	Warm Water Sport Fishery (WWSF)
orange solid		Warm Water Forage Fishery (WWFF)
red solid		Limited Forage Fishery (LFF)
purple solid		Limited Aquatic Life (LAL)
green solid	green dashed	Fish and Aquatic Life (FAL)

Major Basin Boundaries
Watershed Boundaries
Sub-Watershed Boundaries

September, 2012

Projection:
Lambert Conformal Conic
Dane County Coordinates - NAD 83(91)

Prepared by: The Capital Area Regional Planning Commission

N

0 1.25 2.5 5 Miles

B. Water Quality Criteria

Water quality criteria are specified numeric or narrative requirements relating to each of the use designations recognized by Wisconsin. Each designated use has its own set of requirements that must be met to protect the intended use. Some of these requirements relate to the amount of the physical (e.g., temperature) or chemical (e.g., dissolved oxygen) conditions that must be met to avoid causing harm. Other requirements relate to allowable maximum concentrations of chemical compounds or levels of bacteria. Wisconsin's water quality criteria may be either numeric (quantitative) or narrative (qualitative) and are authorized by state statutes and enumerated in the Wisconsin Administrative Code, Chapters NR 102, NR 104, and NR 105.

Numeric criteria

Numeric criteria are expressed as a particular concentration of a substance or an acceptable range. For example, the pH value shall be from 6-9 standard units. Numeric surface water quality criteria have been established for conventional parameters (e.g., dissolved oxygen, pH, temperature), toxics (e.g., metals, organics, ammonia), and pathogens (e.g., *E. coli*, fecal coliform), **Table 2**. These numeric criteria are established for each designated use.

Narrative criteria

All waterbodies must meet a set of narrative criteria which qualitatively describe the conditions that should be achieved. A narrative water quality criterion is a statement that prohibits unacceptable conditions in or upon the water such as floating solids, scum, or nuisance algae blooms that interfere with public rights. These standards protect surface waters and aquatic biota from eutrophication, algae blooms, and turbidity, among other things. The association between a narrative criterion and a waterbody's designated use is less well defined than it is for numeric criteria; however, most narrative standards protect aesthetic or aquatic life designated uses. Wisconsin's narrative criteria are found in Ch. NR 102.04(1).

C. Anti-Degradation

Wisconsin's anti-degradation policy is intended to maintain and protect existing uses and high quality waters. This part of a waterbody quality standard is intended to prevent water quality from slipping backwards and becoming poorer without cause, especially when reasonable control measures are available. Anti-degradation is an important aspect of pollution control because preventing deterioration of surface waters is less costly to society than attempting to restore waters once they have become degraded. The anti-degradation policy in Wisconsin is stated in NR 102.05(1) of the Wisconsin Administrative Code and is associated primarily with wastewater effluent permitting.

One aspect of Wisconsin's anti-degradation policy is the designation of Outstanding Resource Waters and Exceptional Resource Waters. These are surface waters which provide outstanding recreational opportunities, support valuable fisheries and wildlife habitat, have good water quality, and are not significantly impacted by human activities (**Map 2**). More specifically:

Outstanding Resource Waters (ORWs) – have excellent water quality and high-quality fisheries. They do not receive wastewater discharges. These point source discharges will not be allowed in the future unless the quality of such discharges meets or exceeds the quality of the receiving water. This classification includes national and state wild and scenic rivers and the highest quality Class I trout streams.

Exceptional Resource Waters (ERWs) – have excellent water quality and valued fisheries but may already receive wastewater discharges or may receive future discharges necessary to correct environmental or public health problems.

Table 2. Standards for Fish and Aquatic Life (Chapter NR 102)

Parameter	Standard
Dissolved Oxygen	Except as provided in NR 104.02(3), variance stream subcategories, the dissolved oxygen content in surface waters may not be lowered to less than 5 mg/L at any time.
	Dissolved oxygen in classified trout streams shall not be artificially lowered to less than 6 mg/L at any time, nor shall the dissolved oxygen be lowered to less than 7 mg/L during the spawntng season.
Temperature	There shall be no temperature changes that may adversely affect aquatic life. Natural daily and seasonal temperature fluctuations shall be maintained.
	The maximum temperature rise at the edge of the mixing zone above the existing natural temperature shall not exceed 5°F for streams and 3°F for lakes. The temperature shall not exceed 89°F for warm water fish.
	There shall be no significant artificial increases in temperature where natural trout reproduction is to be protected.
pH	The pH shall be within the range of 6.0 to 9.0, with no change greater than 0.5 units outside the estimated natural seasonal maximum and minimum.
Phosphorus	A total phosphorus criterion of >0.100 mg/L is established for rivers listed in NR 102.06(3) and >0.075 mg/L for other rivers or streams.
	For reservoirs and lakes, total phosphorus criteria are established at between 15 and 40 ug/L (based on type).
Other Substances	Unauthorized concentrations of substances are not permitted that alone or in combination with other materials present are toxic to fish or other aquatic life. Surface waters shall meet the acute and chronic criteria as set forth in or developed pursuant to NR 105.05 and 105.06. Surface waters shall meet the criteria which correspond to the appropriate fish and aquatic life subcategory for the surface water, except as provided in NR 104.02(3).
Standards for Recreational Use	
Bacteria	The membrane filter fecal coliform count may not exceed 200 per 100 ml as a geometric mean based on not less than 5 samples per month, nor exceed 400 per 100 ml in more than 10 percent of all samples during any month.
Standards for Public Health and Welfare	
–	All surface waters shall meet the human threshold and human cancer criteria specified in or developed pursuant to NR 105.08 and 105.09, respectively. The applicable criteria vary depending on whether the surface water is used for public drinking water supplies and vary with the type of fish and other aquatic life subcategory.
Standards for Wild and Domestic Animals	
–	All surface waters shall be classified for wild and domestic animal uses and meet the wild and domestic animal criteria specified in or developed pursuant to NR 105.07.

D. 303(d) Impaired Waters and TMDLs

Waters not meeting one or more of the water quality elements above are included on Wisconsin's 303(d) Impaired Waters list established under Section 303(d) of the Clean Water Act.[19] In addition, Federal law requires that Total Maximum Daily Loads (TMDLs) be established for water bodies listed on the WDNR's Impaired Waters List.[20] A TMDL is an analysis that determines how much of a pollutant a water body can assimilate before it exceeds water quality standards. A TMDL is the sum of waste loads from point sources, nonpoint sources (including natural background levels of the pollutant), including a margin of safety. **Map 2** shows the 303(d) Impaired water bodies in Dane County.

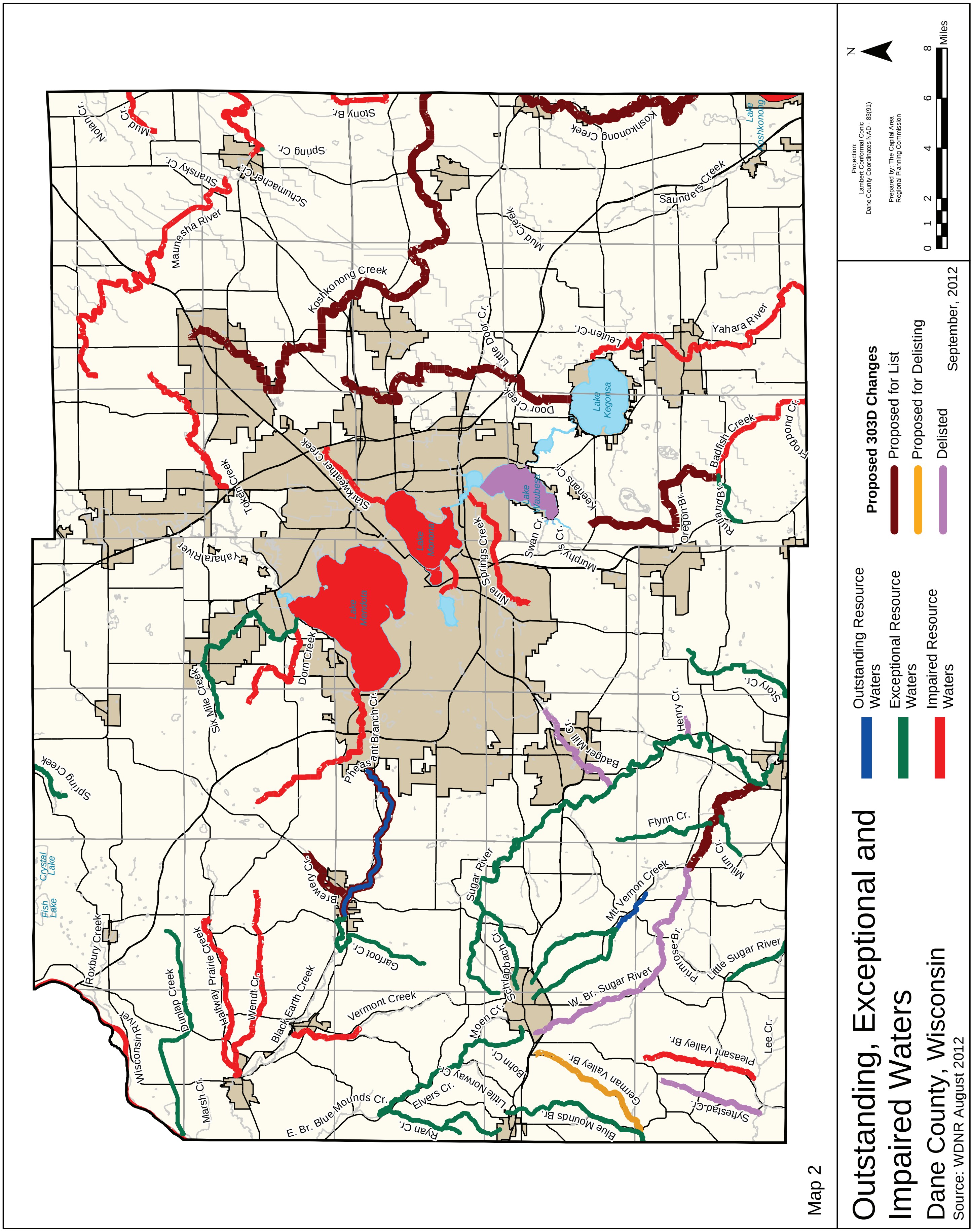
The WDNR 2010 Impaired Waters List includes twenty-seven waters in our region. Four of these waters (Badfish Creek, Lake Mendota, Lake Monona, and the Wisconsin River) are impaired due to PCBs. This is historical contamination and not the result of current practices. Seven of the listed water bodies are urban beaches (Bernies, Brittingham, Esther Park, James Madison, Olbrich Park, Olin Park, and Vilas Park) impaired by E. Coliform bacteria. Urban stormwater runoff is a likely contributor to this impairment. Sediment and total suspended solids impaired fifteen resources on the list. In about half of these cases phosphorus, E. Coliform, metals, or biological oxygen demand was also identified as the pollutant. Of the fifteen water bodies impaired due to sediment and total suspended solids, the Dane County Waterbody Classification Project[21] classified nine as rural waters (Dorn Creek, German Valley Branch, Halfway Prairie Creek, Maunesha River, Mud Creek, Pleasant Valley Branch, Stony Brook, Vermont Creek, and Wendt Creek). Agricultural runoff is the most likely source of impairment in these cases. Two are classified as urban waters (Nine Springs Creek and Starkweather Creek). Urban runoff is the most likely source of impairment in these cases. Four were classified as developing waters (Lake Koshkonong, Pheasant Branch, Token Creek, and the Lower Yahara River). Both agricultural and urban runoff are likely sources of the impairment in these cases. Wingra Creek is impaired by chronic aquatic toxicity from an unknown pollutant. Urban runoff is the most likely source of impairment.

19 http://dnr.wi.gov/topic/impairedwaters/
20 http://dnr.wi.gov/topic/tmdls/
21 DCRPC, 2005

Seven water bodies (or portions thereof) are proposed to be added during the 2012 update cycle (Black Earth Creek, Brewery Creek, Door Creek, Koshkonong Creek, and West Branch Sugar River) due to phosphorus criteria exceedance and PCBs (Oregon Branch and Lake Wingra). One stream (German Valley Branch) is proposed to be de-listed. Four streams (Badger Mill Creek, Henry Creek, Syftestad Creek, and upper portions of the West Branch Sugar River) have been de-listed previously.

In September 2011 the U.S. EPA approved the Rock River Basin TMDL, which includes the entire Yahara River Valley along with other associated waters in eastern Dane County. The TMDL identifies phosphorus and sediment reduction targets to meet water quality goals[22] (see **Section VIII Future Horizons**). The other 303(d) Impaired Waters in the region are in varying stages of development/implementation. For more information visit the WDNR's Impaired Waters website.

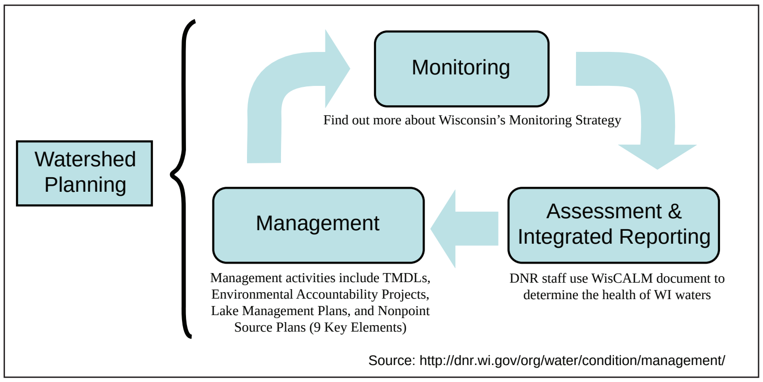
22 Cadmus, 2010.


Map 2
Outstanding, Exceptional and Impaired Waters
Dane County, Wisconsin
Source: WDNR August 2012
Outstanding Resource Waters
Exceptional Resource Waters
Impaired Resource Waters
Proposed 303D Changes
Proposed for List
Proposed for Delisting
Delisted
September, 2012
Projection: Lambert Conformal Conic Dane County Coordinates NAD - 83(91)
Prepared by: The Capital Area Regional Planning Commission
N
0 1 2 4 6 8 Miles
Lake Mendota
Lake Monona
Lake Waubesa
Lake Kegonsa
Lake Koshkonong
Crystal Lake
Fish Lake
Wisconsin River
Yahara River
Sugar River
W. Br. Sugar River
Little Sugar River
Maunesha River
Koshkonong Creek
Starkweather Creek
Nine Springs Creek
Badfish Creek
Saunders Creek
Door Creek
Little Door Cr.
Mud Creek
Six Mile Creek
Token Creek
Dorn Creek
Pheasant Branch Cr.
Black Earth Creek
Vermont Creek
Garfoot Cr.
Halfway Prairie Creek
Wendt Cr.
Dunlap Creek
Roxbury Creek
Spring Creek
Marsh Cr.
E. Br. Blue Mounds Cr.
Blue Mounds Br.
Ryan Cr.
Elvers Cr.
Little Norway Cr.
Moen Cr.
Bohn Cr.
Schlappbach Cr.
German Valley Br.
Pleasant Valley Br.
Syftestad Cr.
Lee Cr.
Primrose Br.
Mt. Vernon Creek
Flynn Cr.
Milum Cr.
Badger Mill Cr.
Henry Cr.
Story Cr.
Oregon Br.
Rutland Br.
Frogpond Cr.
Keenans Cr.
Swan Cr.
Murphys Cr.
Leuten Cr.
Brewery Cr.
Stony Br.
Spring Cr.
Schumacher Cr.
Stransky Cr.
Mud Cr.
Nolan Cr.

IV. Surface Water Monitoring

Watershed planning in Wisconsin employs a strategy of Adaptive Resource Management, defined as a structured, iterative process of optimal decision-making in the face of uncertainty, with the aim of reducing uncertainty over time via system monitoring (**Figure 7**). Adaptive management is a tool which should be used not only to change a system, but to learn about it as well.

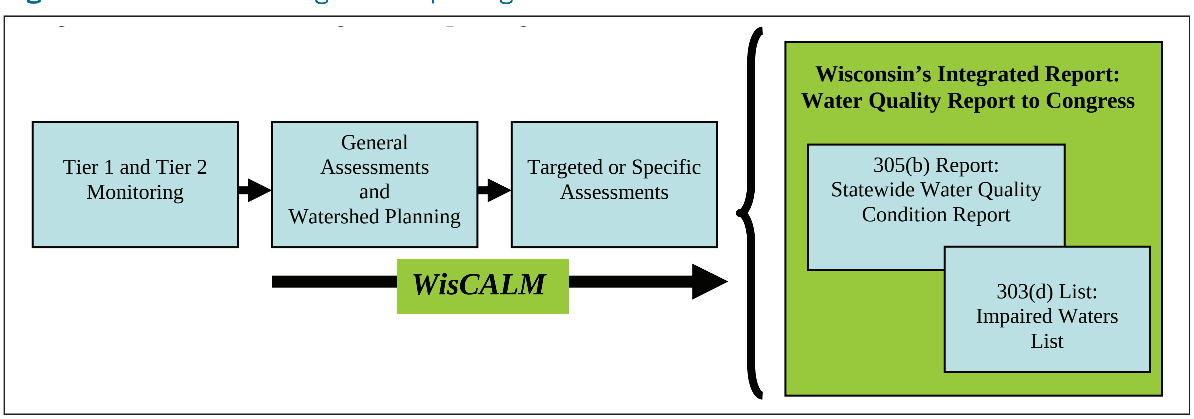
Figure 7. Watershed Planning in Wisconsin



Wisconsin's water quality management program begins with monitoring studies where waters are sampled to collect data or results at particular sites. Monitored waters are then assessed by comparing monitoring data to guidelines designed to evaluate water condition against water quality standards. A two-step process may be used to assess the water.[23] First, a *general condition assessment* is conducted to identify the current status of the water (i.e., the federal Clean Water Act Section "305(b) assessment"). The general assessment may place waters in four different categories: excellent, good, fair, or poor. Waters placed in each category are reviewed by WDNR biologists and *specific condition assessments* are conducted to determine whether or not a waterbody is impaired or not meeting water quality standards. Based on the results of the condition assessments, water quality biologists and managers determine which actions may be needed to ensure that water quality standards are met. This includes anti-degradation of existing water quality conditions (particularly for high quality or "excellent condition" waters), as well as restoration of water condition for those considered "impaired." The process through which a waterbody is identified as fully supporting its designated use versus being impaired is summarized in **Figure 8**.

Both the monitoring results and the assessment data are stored in state and federal databases and the majority of data are available online to agencies and the public. Waters that do not meet water quality standards are placed on Wisconsin's 303(d) Impaired Waters list. Subsequently, a TMDL is required by the federal government (U.S. EPA) for all identified impaired waters. A TMDL includes an analysis of sources that cause or contribute to the impairment, and an allocation of allowable loads among those sources so that the receiving water can meet the applicable water quality standard(s). Every two years, states are required to submit list updates to the U.S. EPA for approval. The WDNR submitted impaired waters lists in 1996 and updates in 1998, 2002, 2004, 2006, and 2010. WDNR did not submit, and U.S.EPA did not require, a list in 2000. The 2012 update is currently pending.

Figure 8. Wisconsin's Integrated Reporting Process



Source: WDNR 2012

23 Wisconsin 2012 Consolidated Assessment and Listing Methodology (WisCALM). WDNR, 2012. http://dnr.wi.gov/topic/surfacewater/documents/final_2012_wiscalm_04-02-12.pdf

A. Types of Monitoring.

The WDNR's *Water Division Monitoring Strategy*[24] directs monitoring efforts in a manner that efficiently addresses the wide variety of management information needs while providing adequate depth of knowledge to support management decisions. The *Strategy* employs a three-tiered approach to information gathering. This careful investment in monitoring effort ensures that the status of Wisconsin's water resources can be determined in a comprehensive and efficient manner without depleting the capacity to conduct in-depth analysis and problem solving where needed. Three tiers of monitoring are identified:

Tier 1 – Statewide Baseline Monitoring

Under Tier 1 WDNR staff and partners collect baseline condition information at a broad spatial scale. This level of monitoring helps determine water quality status and trends for specific water types, accounting for inherent variation in ecological landscapes. This analysis is critical for identifying potential problem areas. Results from Tier 1 (baseline) monitoring can be used to provide statistically valid assessments of broad categories of waters statewide. This procedure is helpful when water resources are too numerous to evaluate individually. Wisconsin's over 84,000 stream miles, for example, call for this dispersed sampling effort which provides, through inference, a technically rigorous and credible 'snapshot' of statewide water conditions.

Figure 9. General Water Condition Continuum

Excellent	Fully Supporting Designated Use
Good	Supporting Designated Use
Fair	Supporting Designated Use
Poor	Not Supporting Designated Use*

Source: WDNR 2012

More specifically, data collected under WDNR's tiered monitoring system are used to identify where a specific river or stream falls on a continuum of water condition, which is the core assessment to determine if a waterbody is attaining its applicable designated uses. WDNR uses four levels of water condition to represent a water's placement on the overall water quality continuum (**Figure 9**). Waters described as *excellent* and *good* clearly attain each assessed designated use. Waters described as *fair* are also meeting their designated uses, but may be in a state that warrants additional monitoring to assure water conditions are not declining. Waters that are described as *poor* may be considered impaired, and may warrant placement on Wisconsin's 303(d) Impaired Waters list.

The power of the Tier 1 dataset lies in its cumulative picture of resource condition with respect to land type variability and inherent aquatic potential of representative stream types. Tier 1 data is collected on random, stratified sample locations and by itself may be used to trigger more detailed analysis. But on its own, a Tier 1 site does not provide the minimum number of samples needed to understand aquatic ecosystem health. Tier 1 monitoring or other credible sources of information may be used to identify problem areas that will be prioritized for further study under Tier 2.

Tier 2 – Targeted Evaluation Monitoring

Waterbodies identified under Tier 1 as not meeting minimum levels for core indicators (fair or poor) are prioritized and monitored more intensively under Tier 2. Under this tier, confirmation of the problem is made along with documentation of the cause(s). Thus, it is a more comprehensive evaluation of individual waterbodies, often requiring cross-program collaboration among WDNR staff. Tier 2 monitoring is often used to verify whether waterbodies should be placed on the 303(d) Impaired Waters list and to develop comprehensive water quality management plans, such as TMDLs. It may also provide the pre-data for determining how well a waterbody responds to management, as evaluated under Tier 3. Monitoring in response to episodic events such as fish kills, where the cause and extent of the problem must be determined, also falls under Tier 2, as do short-term, one-time research projects.

24 WDNR, 2008a.

Tier 3 – Management Effectiveness and Compliance Monitoring

Tier 3 monitoring provides follow-up analysis of management plans that have been implemented for problem waterbodies, and evaluates permit compliance and the effectiveness of permit conditions. Monitoring under this tier evaluates how well core indicators have responded to management actions. Effectiveness of water-specific management actions is determined using core indicators from the more intensive sampling designs under Tier 2 that are specific to the problem being addressed. The chosen indicators are compared before and after management actions are implemented.

Regulatory monitoring of permitted entities is also included in Tier 3. Effluent monitoring helps WDNR determine whether permitted entities are meeting their permit conditions and state regulations, and to assess the health of waters receiving effluent. Monitoring of public drinking water wells is also carried out under Tier 3 to ensure that surface and groundwater meet federal public health standards for contaminants in drinking water.

Use of Data from Other Sources

In addition to Department-generated data, the WDNR biennially seeks information from partners and the public to use in its assessment of waterbodies. Partners include federal agencies such at the U.S. Geological Survey, the U.S. EPA and the U.S. Fish and Wildlife Service, other state agencies and Universities, regional planning commissions, and major municipal sewerage districts. The Department will review information provided by any individual or group at any time; however, the data used for listing purposes must have been obtained using documented quality assurance procedures. Agencies and individuals submitting data for water quality assessment purposes must show that a minimum number of samples were collected at appropriate sites and at critical periods, and that certified laboratories were used for sample analysis. If these data indicate a potential water quality problem at a specific site, additional data are collected by WDNR staff to verify the extent of the problem and determine if a waterbody should be placed on the impaired waters list.

B. Key Indicators

General Condition Assessments

The choice of indicators to assess a waterbody's condition is based on the WDNR's *Water Division Monitoring Strategy.*[25] As stated, the program relies on a tiered approach to monitoring to maximize sampling effort while doing so as efficiently as reasonably possible. Examples of General Assessment data include fish and macroinvertebrate indices of biotic integrity (IBIs) at a minimum of one per stream segment. Using this information, waterbodies are grouped based on their general condition (excellent, good, fair, or poor). Fish surveys are most valuable when conducted in summer, and macroinvertebrate sampling is best in fall. For lakes, Trophic State Index (TSI) Values (based on Secchi disk or chlorophyll-a data) are determined by satellite-inferred or in-lake data during the summer index period (July 15 – September 15). At least three samples per season per parameter are needed in a 5-year period for in-lake data. If satellite-inferred, then 1 value from each of 3 different years. Other parameters may also be used in general assessments such as *E. coli* to assess recreational uses, and fish tissue sampling to provide specific fish consumption advice.

Specific Condition Assessments

More detailed assessments are tailored to the specific concerns for a waterbody. During Specific Assessments, more detailed information is collected to determine relationships between pollutants, impairments, and stressors and may include a watershed inventory to identify possible sources of pollutants. Indicators are sub-divided into the following categories (**Tables 5 and 8**):

- Biological indicators
- Lake eutrophication indicators
- Conventional physical-chemical indicators
- Toxicity-based indicators

25 WDNR, 2008a

C. Assessment Thresholds

When it is determined that a waterbody should be placed within a particular condition group (excellent, good, fair, or poor), the assessment threshold is applied when placing waters on the Impaired Waters List. These thresholds are based on numeric water quality criteria included in Chapters NR 102-105 (Wis. Adm. Code), WDNR technical documents, and federal guidance. In some cases, qualitative thresholds based upon narrative standards may be used to make assessment decisions. In those cases, a thoroughly documented analysis of the contextual information should be used in conjunction with professional judgment to collectively support a decision.

The numbers of times a water quality standard may be exceeded over a period of time and still provide the desired level of protection is referred to as the *exceedance frequency.* A complete and representative data set for each parameter is required to make an assessment decision. When those data are evaluated, the exceedance frequency should be used to make a final assessment decision. The exceedance frequency varies for each indicator and under ideal circumstances would be representative of the relationship between the number of exceedances and the time it takes for a lake, river, or stream community to recover from an exceedance event. The exceedance frequencies for each parameter in Wisconsin are defined in **Tables 5 and 8** for Fish and Aquatic Life Use. Very few models can accurately predict the recovery rate of any particular aquatic community. Best professional judgment is encouraged in making an assessment decision. The purpose of minimum data requirements is to provide consistent decisions across the state based on similar levels of information.

Dissolved oxygen provides a good example of describing how the factors of frequency, duration and magnitude of threshold exceedances may result in a decision about whether or not to include a waterbody on the impaired waters list. In waters where measured dissolved oxygen is very low (magnitude) and data are available to indicate this occurs often (frequency), the WDNR would be inclined to recommend a waterbody as "impaired." In some cases, the time during which the dissolved oxygen actually falls below the criterion may be measured in minutes (duration) while in others, it could occur for hours at a time. This is not uncommon for those streams that exhibit what is known as a diurnal (day and night) fluctuation. This occurs in streams where higher densities of plants and algae create very high concentrations of dissolved oxygen during the day when photosynthesis is active, but the concentrations drop to very low levels at night into dawn when respiration is consuming oxygen instead of producing it. Diurnal fluctuations may occur regularly during a summer – especially in waters where there may be excessive nutrients. Such diurnal fluctuations coupled with exceedances of high magnitude may cause stress on the aquatic community and result in the WDNR recommending the water as "impaired." In contrast, the WDNR may not recommend a waterbody for listing when data indicate dissolved oxygen concentrations below the criterion occur very infrequently and only last for a short period of time. This is not uncommon when a stream receives stormwater runoff during a rainfall or snowmelt event. In these cases, the stress to aquatic life may be minimal.[26]

In all cases, WDNR staff looks for corroborating information, such as the various biological indices that can be used to measure stress within an aquatic community. Data indicating the type and number of species of fish, macro invertebrates (such as insects or snails), plants, or algae are evaluated. The state draws upon a number of datasets it has including fish, habitat, and macroinvertebrate assessment data to make these decisions. These datasets provide a quantitative approach to be used when determining whether a waterbody should be listed. In addition, researchers have access to water chemistry data that include dissolved oxygen, phosphorus, pH, temperature, toxic substances, and others. If the suite of available data does not suggest an evident impairment, then the water will not be listed, but will be recommended for additional monitoring through Tier 2, as resources allow. The WDNR will provide a rationale for those cases where data are available that show that a water quality criterion has been exceeded, but the water has not been recommended for the impaired waters list. In most cases, the indicator has not reached the magnitude, duration or frequency to warrant placing a waterbody on the list.

A rigorous assessment and 303(d) listing process is necessary as there are implications associated with a

26 WDNR, 2009c.

waterbody being listed as impaired. Federal law requires that all waters on the 303(d) Impaired Waters list must undergo a TMDL analysis or other equivalent water quality management plan. Waters that are listed may also require potential restrictions through Wisconsin Pollutant Discharge Elimination System (WPDES) and other State permits. Large amounts of data are typically needed to develop a TMDL. Corrective measures are implemented through the state's point and nonpoint source pollution control programs, potentially using new and innovative approaches such as pollutant trading, adaptive management, or other cost-effective strategies.

Waters that are not considered impaired may still be in need of management actions (**Table 3a**). For example, waters identified as "excellent" during the general assessment process may be considered for further evaluation for Outstanding Resource Water (ORW) or Exceptional Resource Water (ERW) listing. Management goals for waters considered "good" include maintaining existing condition (anti-degradation). Those considered "fair" will be placed on a list of waters for further monitoring and evaluation and may receive higher priority for grant funding through programs that offer cost-share incentives for restoration projects.

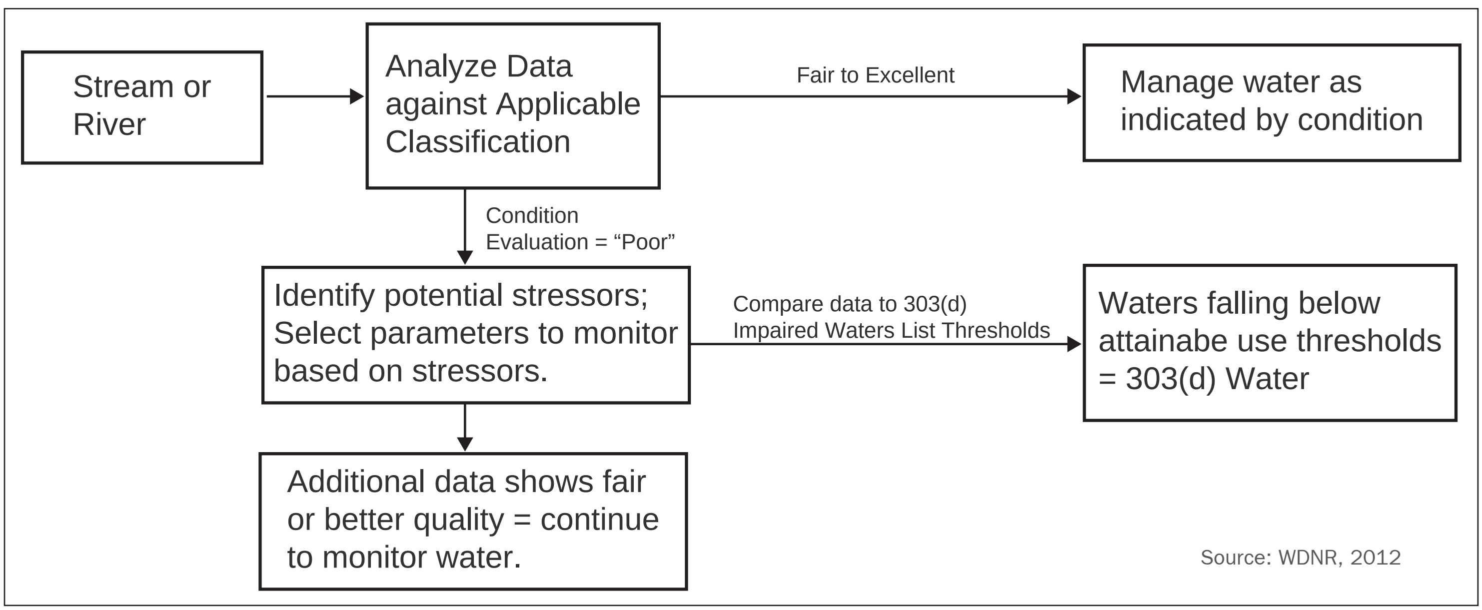
D. Assessment Methods

1. Fish and Aquatic Life

a. Rivers and Streams

WDNR has classified or grouped similar rivers and streams based on their water temperature and capacity to support a diverse and healthy fish community (**Table 1**). Like many other states, WDNR relies on biological indicators to assess the fish and aquatic life condition characteristics of streams and rivers in Wisconsin using a number of fish indices of biological integrity (F-IBIs) and a macroinvertebrate index of biological integrity (M-IBI). The development and verification procedures for all of the IBIs have been published in peer reviewed journals. The process through which a waterbody is identified as fully supporting versus impaired is summarized in **Figure 10**.

Figure 10. Overview of Assessment Process for Streams, Rivers – General and Specific Assessments



General Condition Assessments and Thresholds

Fish IBI

There are currently three different F-IBIs used to assess wadeable stream conditions and one IBI used to assess nonwadeable river condition. These include a coldwater F-IBI,[27] a warmwater F-IBI,[28] a small stream F-IBI,[29] and a large river F-IBI.[30] The indices were developed using a large statewide database of standardized fish assemblage samples from numerous reaches with different levels of human impact. An objective procedure was used to select and score the metrics that compose the IBI, choosing metrics that represent a variety of the structural, compositional, and functional attributes of a particular river/stream fish community.

In general, as the level of environmental degradation increases within a stream there is a corresponding decrease in the number of environmentally sensitive fish species, and an increase in environmentally tolerant species. The condition gradient (excellent, good, fair, poor) and the corresponding F-IBI score is shown in **Table 3a**.

Macroinvertebrate IBI

Data derived from aquatic macroinvertebrate samples also provide valuable information on the physical, chemical, and biological condition of streams; which along with stream habitat and fish community data permits a comprehensive assessment of stream health. Most aquatic macroinvertebrates such as immature insects live for one or more years in streams, integrating the combined effects of various environmental stressors over time. Since the majority of aquatic invertebrates have limited mobility (relative to fish), they can be good indicators of localized conditions, upstream land impacts, and water quality degradation. Various metrics and indices are used to interpret macroinvertebrate sample data. Historically, the WDNR used Hilsenhoff Biotic Index (HBI)[31] extensively as an indicator of low dissolved oxygen concentrations resulting from organic pollution (**Table 3b**). More recently, WDNR switched to primarily using a Macroinvertebrate IBI.[32] The M-IBI metric responds to the watershed scale impacts of agricultural and urban land uses, riparian habitat degradation, sedimentation problems, and scouring. The condition gradient (excellent, good, fair, poor) and the corresponding M-IBI score is also shown in **Table 3a**.

It is important to note that the M-IBI was developed and validated for wadeable cold and warmwater streams and cannot be used as an assessment tool for non-wadeable rivers or small streams without perennial flow.

27 Lyons, 1996.
28 Lyons, 1992.
29 Lyons, 2006.
30 Lyons, 2001.
31 Hilsenhoff, 1987.
32 Weigel, 2003.

Table 3a. Fish and Aquatic Life: Stream and River General Assessment Thresholds

Designated Use	Condition Category	Management Recommendation	Fish IBI	Macroinvertebrate IBI
Cold Stream: Stream supports coldwater fish and macroinvertebrate species	Excellent	Consider O/ERW Listing	Cold IBI 90-100	7.5-10
	Good	Maintain Condition	Cold IBI 60-80	5.0-7.4
	Fair	Restoration	Cold IBI 30-50	2.6-4.9
	Poor	Consider 303(d) Listing	Cold IBI 0-20	0-2.5
Small Cold Stream: Trout absent, but other coldwater fishes/inverts self-sustaining	Excellent	Consider O/ERW Listing	Cold IBI 50-60	7.5-10
	Good	Maintain Condition	Cold IBI 30-40	5.0-7.4
	Fair	Restoration	Cold IBI 10-20	2.6-4.9
	Poor	Consider 303(d) Listing	Cold IBI 0-10	0-2.5
Warm Water Sport Fish (WWSF): River	Excellent	Consider O/ERW Listing	Large River IBI 80-100	-
	Good	Maintain Condition	Large River IBI 60-79	-
	Fair	Restoration	Large River IBI 40-59	-
	Poor	Consider 303(d) Listing	Large River IBI 0-39	-
Warm Water Sport Fish (WWSF): Wadeable Stream	Excellent	Consider O/ERW Listing	Warm IBI 65-100	7.5-10
	Good	Maintain Condition	Warm IBI 50-64	5.0-7.4
	Fair	Restoration	Warm IBI 30-49	2.6-4.9
	Poor	Consider 303(d) Listing	Warm IBI 0-29	0-2.5
Warm Water Forage Fish (WWFF): Stream	Excellent	Consider O/ERW Listing	Small Stream IBI 100	7.5-10
	Good	Maintain Condition	Small Stream IBI 70-90	5.0-7.4
	Fair	Restoration	Small Stream IBI 40-60	2.6-4.9
	Poor	Consider 303(d) Listing	Small Stream IBI 0-30	0-2.5
Limited Forage Fish (LFF): Stream	Attaining	Maintain Condition	Small Stream IBI 40-100	2.6-10
	Non-Attaining	Consider 303(d) Listing	Small Stream IBI 0-30	0-2.5
Limited Aquatic Life (LAL); Stream	Attaining	Maintain Condition	-	2.6-10
	Non-Attaining	Consider 303(d) Listing	-	0-2.5

Source: WDNR

Table 3b. Hilsenhoff Biotic Index (HBI) Water Quality Scale

Hilsenhoff Biotic Index	Water Quality Scale	Degree of Organic Pollution
0.00-3.50	Excellent	Organic Pollution Unlikely
3.51-4.50	Very Good	Possible Slight Organic Pollution
4.51- 5.50	Good	Some Organic Pollution Probable
5 .51-6.50	Fair	Fairly Substantial Pollution Likely
6.51- 7.50	Fairly Poor	Substantial Pollution Likely
7.51- 8.50	Poor	Very Substantial Pollution Likely
8.51- 10.00	Very Poor	Severe Organic Pollution Likely

Source: Hilsenhoff, 1987

Specific Condition Assessments

If a general assessment results in a poor F-IBI and/or M-IBI values for a particular stream or river, additional assessment work is required prior to submitting the waterway as a potential 303(d) Impaired Water. If additional monitoring is required, the selection of indicators should be based on the nature of the stream or river issues known to the biologist. The available metrics may be expanded as resources allow. In addition to the collection of supplemental F-IBI and M-IBI data, studies may be designed to collect data over a larger river or stream reach and/or evaluate other factors influencing water condition. Some of the additional indictors that can be evaluated are listed in **Table 4**.

To date, many of the parameters listed here do not have established threshold criteria and WDNR staff must use targeted monitoring information from reference sites and/or apply professional judgment. As condition gradients are developed for those indicators, additional assessment tools will be available to decision makers. Until that time, water quality attainment decisions should made based on an exceedance of specified thresholds for indicators listed in **Table 5**. WDNR Biologists have extensive knowledge of the factors that influence community response in rivers and streams. Those insights should be considered when selecting what indicators to collect or when scheduling supplemental monitoring and proposing assessment decisions. When supplemental monitoring work is proposed, choosing indicators related to specific stressors is critical. Below are guidelines that may be useful in evaluating three categories of stressors that are often observed in Wisconsin river and stream communities:

1. *Habitat impairment due to excessive sedimentation*

   Monitoring should be considered for the following parameters: Habitat, Total Suspended Solids, Transparency, Flow, and Temperature.

2. *Dissolved oxygen depletion due to excessive nutrients*

   Monitoring should be considered for the following parameters: Phosphorus or Nitrogen Series (Ammonia, Kjeldahl, N02 + N03), Dissolved oxygen, pH, and Temperature.

3. *Aquatic toxicity due to presence of elevated toxic substances*

   Monitoring should be considered for the following parameters: Ambient Toxicity Tests (acute and chronic), pH, Ammonia, and Temperature, Toxic Metals, Pesticides, and/or Sediment Toxicity Tests.

Table 4. Potential Indicators for More Specific River and Stream Condition Assessments

Indicator	Indicator
Alkalinity	Nitrogen – (Nitrate & Nitrite)
Ammonia*	Organic Compounds*
Biochemical Oxygen Demand	Periphyton
Chlorides*	pH*
Dissolved Oxygen*	Phosphorus – Ortho
Exotic Species – Abundance	Phosphorus – Total*
Exotic Species – Presence/Absence	Sediment Chemistry
Flow	Solids – Total Suspended
Habitat – Qualitative	Solids – Settleable
Habitat – Quantitative	Specific Conductivity
Hardness	Temperature%
Heavy Metals*	Toxicity – Ambient*
Land Use	Toxicity – Sediment
Nitrogen – Total Kjeldahl	Transparency

* = Numeric Water Quality Criteria are available in chs. NR 102 or 105, Wis. Adm. Code

% Numeric Water Quality Criteria under development.

b. Lakes

WDNR has classified or grouped similar lake types based on similar physical data. More specifically, lake size, stratification (depth), hydrology, and watershed size are identified as the primary influences and, to a large degree, determine the natural communities each lake type supports (**Table 6**). Small Lake natural communities (less than 10 acres) are uniquely different from communities in larger lakes, but there is limited monitoring data available in Wisconsin in this regard. Currently there are no quality thresholds set for water quality, fisheries, or aquatic plants for lakes less than 10 acres. Therefore the 10-acre threshold reflects the limited availability of monitoring data with which to set thresholds for assessment. To address these small lakes in the future, Wisconsin may look to emerging wetland assessment tools for guidance.

General Condition Assessment and Thresholds

The WDNR focuses on in-lake water quality metrics to assess a specific lake's fish and aquatic life designated use. These in-lake parameters are well established and correlate strongly with fish and other associated aquatic life communities within in a lake (macroinvertebrates, aquatic plants, etc.). The most commonly used index of lake productivity is Carlson's Trophic State Index (TSI),[33] which provides separate, but relatively equivalent, TSI calculations based on either chlorophyll-*a* concentration or Secchi depth (including satellite clarity, which Wisconsin uses as a surrogate). Carlson also provides an equation to convert total phosphorus concentration to TSI, but the WDNR is not using that equation for General Condition assessments. Total phosphorus concentrations are used to determine whether a waterbody exceeds the thresholds for 303(d) listing as a pollutant.

Table 5. Impairment Thresholds for Rivers and Streams

Note: Data are evaluated from within the most recent 10 year period for all parameters.						
Parameters	**Minimum Data Requirement**	**Exceedance Frequency**	**Cold Waters**	**Warm Waters**	**Limited Forage Fish**	**Limited Aquatic Life**
Conventional physical and chemical indicators						
Temperature[A]	20 discrete daily values (May through October) * Samples should be collected at a frequency of no less than 1 sample per hour with a continuous recording thermograph or thermistor.	10% of Mean Daily Temperature values exceeds specified maximum for applicable use designation (Mean Daily Temperature is the arithmetic mean of all equally spaced samples collected within a 24- hour period)	>73˚F	>86˚F	>86˚F	>86˚F
			Mississippi R., Rock R., Wisconsin R: >86oF Lower Fox River: >87˚F Inland Lakes North of State Hwy 10: >86˚F Inland Lakes South of State Hwy 10: >87˚F Green Bay – South: >83˚F Green Bay – North: >78˚F Lake Michigan – South: >76oF Lake Michigan – North: >73oF Lake Superior: >73oF Chequamegon Bay: >76oF			
pH	10 discrete * values	10% or more of all values within a continuous sampling period or for instantaneous w/in season	Outside the range of 6-0 to 9.0 or if a change is > 0.5 units outside natural seasonal maximum (mean) and minimum (mean)			
DO	3 days of continuous measurements (no less than 1 sample per hour) in July or August; minimum of 3 years of data	10% or more of all values	<6.0 mg/L and <7.0 mg/L during spawning season	<5.0 mg/L	<3.0 mg/L	<1.0 mg/L
TP[B]	6 monthly samples (May - October)	Lower 95% confidence interval of the sample population median exceeds threshold	≥0.100 mg/l for rivers; ≥0.075 mg/l for streams			
Biological indicators						
Fish IBI	2 Fish IBI Values	Either 1 value per 2 consecutive field seasons or 2 or more values within one field season with corroborating data.	See associated Natural Community/ Designated Use - Fish IBI Chart Table 3a			
Macroinvertebrate IBI	3 Macroinvertebrate IBI Values	Either 1 value per 2 consecutive field seasons or 2 or more values within one field season with corroborating data.	See associated Natural Community/ Designated Use – Macroinvertebrate IBI Chart Table 3a			

Source: WDNR 2012

[A] Temperature values represent maximum temperaturs in NR 102

[B] One 'poor' F-IBI or one 'poor' M-IBI is also requied to corroborate the impairment of the FAL use.

33 Carlson, 1977.

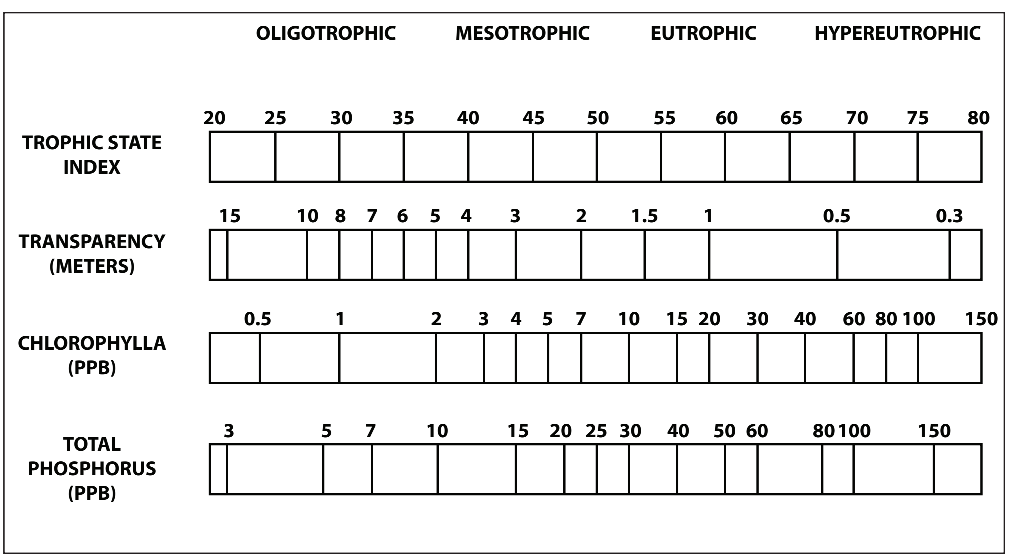
Because TSI is a prediction of algal biomass, typically the chlorophyll-*a* value is a better predictor than Secchi or satellite data. Water clarity as measured by Secchi depth or satellite is sometimes a more practical measure of algal production and water color. Algal production is known to be highly correlated with nutrient levels (especially phosphorus). High levels of nutrients can lead to eutrophication and blue-green algae blooms. This in turn limits the amount of available light to macrophytes (rooted aquatic plants) and adversely affects other aquatic organisms. Information from each of these parameters is valuable because the interrelationships between them can be used to identify other environmental factors that may influence algal biomass.

Table 6. Lake and Reservoir Natural Communities

Natural Community	Stratification Status	Hydrology
Lakes/Reservoirs<10 acres - Small	Variable	Any
Lakes/Reservoirs>10 acres		
• Shallow Seepage	Mixed	Seepage
• Shallow Headwater	Mixed	Headwater Drainage
• Shallow Lowland	Mixed	Lowland Drainage
• Deep Seepage	Stratified	Seepage
• Deep Headwater	Stratified	Headwater Drainage
• Deep Lowland	Stratified	Lowland Drainage
Other Classification (any size)		
• Spring Ponds	Variable	Spring Hydrology
• Two-Story Lakes	Stratified	any
• Impounded Flowing Waters	Variable	Headwater or Lowland Drainage

Source: WDNR 2012

Figure 11. Continuum of Lake Trphpic States in relation to Carlson Trophic Status Index



Source: WDNR 2012

Table 7. Trophic Status Index (TSI) Thresholds – General Assessment of Lake Natural Communities

Condition Level	Shallow			Deep			
	Headwater	Lowland	Seepage	Headwater	Lowland	Seepage	Two-Story
Excellent	<53	<53	<45	<48	<47	<43	<43
Good	53-61	53-61	45-57	48-55	47-54	43-52	43-47
Fair	62-70	62-70	58-70	56-62	55-62	53-62	48-52
Poor	≥71	≥71	≥71	≥63	≥63	≥63	>53

Source: WDNR 2012

TSI values range from low (<30), representing very clear, nutrient-poor lakes, to high (>70) for extremely productive, nutrient-rich lakes (**Figure 11**). The condition gradient (excellent, good, fair, poor) and the corresponding TSI score is shown in **Table 7**.

Note that the transition between a fair and poor condition for shallow lakes is set at a TSI of 71 (corresponding to total phosphorus of 100 µg/L) because this approximates total phosphorus concentrations that lead to a switch from aquatic plant dominated to algal dominated ecosystems in shallow lakes.[34] This represents a major ecosystem change and, once it occurs, it is very difficult to restore to the aquatic plant dominated state. The fair to poor transition threshold for deep lakes was set using a TSI value known to cause increased frequency of algal blooms, high amounts of blue-green algae and/or hypolimnetic oxygen depletion. A TSI of 63 (corresponding to total phosphorus of 60 µg/L) was chosen because it represents the threshold between eutrophic and hypereutrophic lakes.[35]

Overall, a General Condition Assessment status of "Poor" or "Fair" based on TSI score serves as a flag that TSI values and other parameters such as total phosphorus, temperature, dissolved oxygen, and pH should be evaluated against the additional impairment thresholds outlined in **Table 8**.

Specific Condition Assessments

Because chlorophyll-*a* is the most direct measure of trophic status, TSI-chlorophyll values may be used directly for listing as impaired. In other words, the TSI-chlorophyll threshold for generating a "Poor" TSI-chlorophyll status will automatically be recommended for 303(d) listing, unless otherwise justified. However, if the TSI value indicating poor condition was generated using satellite-based data or Secchi depth in lieu of having chlorophyll-*a* data, that data is not sufficient for 303(d) listing. Further monitoring may need to be conducted to collect enough in-situ chlorophyll-*a* data to recalculate the TSI and reassess the waterbody. Lakes may be listed for parameters other than TSI, such as total phosphorus, low dissolved oxygen, high temperatures, or pH. General assessment results of "Fair" based on TSI-chlorophyll, or "Poor" or "Fair" based on Secchi or satellite data serve as a flag indicating that biologists should further evaluate these other parameters.

34 Jeppesen, 1990.
35 Carlson, 1977

Table 8: Fish and Aquatic Life Impairment Thresholds for Lake Natural Communities

Note: Data are evaluated from within the most recent 10 year period for all parameters.
For TP and chl a, data from within the most recent 5 year period are used for impairment assessments.

Indicators	Min. Data Requirement (see text for details)	Exceedance Frequency (see text for details)	Impairment Threshold - LAKES - Fish & Aquatic Life Use						
			Shallow			Deep			
			Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Two-story fishery lake
Biological indicators									
chl a	6 values (3 values/2 yrs, or 2 values/3 yrs) from July 15 - Sept. 15	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥60 ug/L (≥71 TSI)	≥60 ug/L (≥71 TSI)	≥60 ug/L (≥71 TSI)	≥27 ug/L (≥63 TSI)	≥27 ug/L (≥63 TSI)	≥27 ug/L (≥63 TSI)	≥10 ug/L (≥53 TSI)
Maximum Rooting Depth	*Baseline aquatic plant survey*	*NA (1 survey)*	*(reserved until sufficient guidance available)*						
Floating Leaf Plant Community	*Baseline aquatic plant survey*	*NA (1 survey)*	*(reserved until sufficient guidance available)*						
Conventional physico-chemical indicators									
TP	3 monthly values for 2 years (June 1- Sept. 15)	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥100 ug/L	≥100 ug/L	≥100 ug/L	≥60 ug/L	≥60 ug/L	≥60 ug/L	≥15 ug/L
DO	10 discrete(1) epilimnetic values (ice free period, epilimnetic samples)	10% or more of all values	< 5 mg/L						
Temperature	20 discrete(1) values	Vary (see thresholds)	Daily (mean) and seasonal T° fluctuations (min. & max. daily mean) (2) not maintained; and Maximum T° increase exceeding 3°F above natural temperature(2)						
pH	10 discrete(1) values	Vary (see thresholds)	- Outside the range of 6.0-9.0 - Change >0.5 units outside natural seasonal maximum (mean) & minimum (mean) (2)						
Turbidity	10 discrete(1) values	*(to be determined)*	*(reserved until sufficient data available)*						
TSS	10 discrete(1) values	*(to be determined)*	*(reserved until sufficient data available)*						
Aquatic Toxicity-based indicators									
Acute aquatic toxicity	2 values within a 3-year period	Maximum daily concentration not exceeded more than once every 3 years	≥ values provided in Tables A & B below						
Chronic aquatic toxicity		Maximum 4-day concentration not exceeded more than once every 3 years	≥ values provided in Tables A & B below						

(1) Discrete values refer to samples collected on separate calendar days. DO, temperature and pH criteria are taken from s. NR 102.04, Wis. Adm. Code, Water Quality Standards for Wisconsin Surface Waters.
(2) Based on historical data or reference site.

2. Recreational Use

a. Lakes -- Blue-green Algal Blooms

Blue-green algae are natural occurring organisms found throughout the state and are an important part of Wisconsin's freshwater ecosystem. However, excessive nutrient loading (particularly phosphorus) can cause blue-green algae populations to grow rapidly under certain environmental conditions and form "blooms" that can impact water quality and pose health risks to people, pets, and livestock. Most species of blue-green algae are buoyant and when populations reach bloom densities, they float to the surface where they form scum layers or floating mats. In Wisconsin, blue-green algae blooms generally occur between mid-June and late September, although in rare instances blooms have been observed in winter, even under the ice. Blue-green algae blooms can cause many water quality problems including: a) reduced light penetration affecting the ability of macrophytes (rooted aquatic plants) to thrive; b) discoloration of water; c) taste and odor concerns, and d) reduction of dissolved oxygen concentrations due to massive decomposition of the cells when they die-off. **Table 9** shows the recreational impairment thresholds for lakes.

Another important consequence of blue-green algae is their ability to produce naturally-occurring toxins. Algal toxins can be harmful to humans and animals alike through skin contact, inhalation, or ingestion. Some of the species commonly found in Wisconsin that produce algal toxins include, *Anabaena* sp., *Aphanizomenon* sp., *Microcystis* sp., and *Planktothrix* sp. Where monitoring of blue-green algae occurs, notices are provided to local public health agencies when concentrations are presumed to exceed 100,000 cells/mL. That value represents the threshold for high risk to humans as established by the World Health Organization (WHO). Illnesses related to blue-green algae can occur in both humans and pets. People may be exposed to these toxins through contact with the skin (e.g., when swimming), through inhalation (e.g., when motor boating or water skiing), or by swallowing contaminated water. In 2009, the Wisconsin Department of Health Services documented over 41 cases statewide of human health exposure related to blue-green algae blooms including respiratory ailments (coughing), watery eyes and rashes. Animals can be even more susceptible to risks by drinking water directly from water bodies with dense algal blooms or by licking their fur after swimming.

When a waterbody is proposed to be included on the Impaired Waters List due to frequent and elevated algal cell counts, and data are available suggesting high total phosphorus concentrations, the pollutant is listed as total phosphorus and the impairment is identified as "Recreational Restrictions – Blue-green Algae." In the absence of meeting minimum data requirements for total phosphorus, the professional judgment of the regional biologist should be used to consider listing any waterbody that experiences frequent and severe blue-green algal blooms where there is strong reason to believe that nutrient levels may be contributing to such blooms.

b. Beaches – Bacteria

E. coli is a species of bacteria that serves as an indicator of the presence of fecal matter in the water. Although *E. coli* may not result in illness to humans, its presence suggests that there may be other harmful bacteria, viruses, or protozoans present. It is the presence of these other pathogens that elevate the risk of water borne illnesses in humans. Many, but not all, beaches are evaluated for Recreational Uses in Wisconsin.

U.S. EPA has established two different water quality criteria for *E. coli* – a single sample maximum of 235 cfu[36]/100 mL, and a long-term geometric mean maximum of 126 cfu/100 mL. Beach closure decisions are routinely made considering the single sample value. However, when evaluating *E. coli* data to determine if a beach should be included on the Impaired Waters List, the WDNR relies on data collected throughout the entire beach season because of the variability of E. coli populations in a beach environment on a day-to-day or even

Table 9. Recreational Impairment Thresholds for Lake Natural Communities

Note: Date are evaluated from within the most recent 10 year period for all parameters.
For TP and chl a, data from within the most recent 5 year period are used for impairment assessments.

Indicators	Min. Data Requirement (see text for details)	Exceedance Frequency (see text for details)	Impairment Threshold - LAKES - Recreational Use						
			Shallow			Deep			
			Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Headwater Drainage Lake	Lowland Drainage Lake	Seepage Lake	Two-story fishery lake
Conventional physico-chemical indicators									
TP	3 values from each of 2 years from June 1 - Sept. 15	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥40 ug/l	≥40 ug/l	≥40 ug/L	≥30 ug/L	≥30 ug/L	≥20 ug/L	≥15 ug/L
***Biological** indicators (to be used as supporting data only; these thresholds are rough guidance)*									
chl *a**	3 values from each of 2 yrs (or 2values/3yrs) from July 15 - Sept. 15	Annual Average exceeds for at least 2 years (or majority of yrs of data)	≥25 ug/L	≥25 ug/L	≥17 ug/L	≥14 ug/L	≥12 ug/L	≥10 ug/L	≥6 ug/L
AMCI plant metrics* (Abundance of low light tolerant spp.)	Baseline aquatic plant survey within last 5 yrs	NA (one survey)	*(reserved until sufficient data available)*						

* NOTE: While the TP impairment thresholds for Recreational Uses are based on codified criteria and are based on clear breakpoints in water quality corresponding to Recreational Uses, the chl *a* threshold for impairment is not based on a clear scientific breakpoint in water quality and is meant to be used only as loose guidance to provide supporting information in listing decisions. WDNR does not recommend listing for Recreational Use Impairment based solely on the chl *a* thresholds; rather, other corroborating evidence for listing would be needed. Similarly, biologists may consult research staff in Science Services to assess macrophyte data in the AMCI, but this should be used as supporting data rather than as a sole source for impairment listing.

Source: WDNR 2012

36 CFU = colony forming unit. This is the standard unit of measurement of bacteria in a laboratory test.

hour-to-hour basis. Accordingly, the WDNR requires a minimum of 15 samples collected during a beach season to calculate a long-term geometric mean. Datasets with fewer than 15 samples are considered insufficient. This threshold was selected to represent the number of weekly samples typically collected during a Wisconsin "beach season." In Wisconsin, the typical swimming season lasts about 15 weeks – Memorial Day through Labor Day.

c. Streams and Rivers

Federal criteria for E. coli were developed with consideration of risk to the swimming public. All of the data used to establish the federal criteria were collected from swimming beaches. In general, flowing rivers and streams in Wisconsin do not provide comparable recreational activities for full body immersion. For those water bodies, the WDNR utilizes the long-standing water quality criterion for fecal coliform that is reflected in Chapter NR 102.04(5) Wis. Adm. Code, specifically:

> (a) *Bacteriological guidelines.* The membrane filter fecal coliform count may not exceed 200 per 100 ml as a geometric mean based on not less than 5 samples per month, nor exceed 400 per 100 ml in more than 10 percent of all samples during any month.

When a flowing stretch of a river or stream is included on the Impaired Waters List, the pollutant is listed as fecal coliform and the impairment is identified as "Recreational Restrictions – Pathogens." In many instances where fecal coliform counts are high, *E. coli* data or other pathogen data are also collected and may be used in lieu of or supplementary to fecal coliform data to make best professional judgment decisions to list or not list the waterbody as impaired.

3. Fish Consumption

Waterbodies are listed for fish consumption advisories due to atmospheric deposition of mercury, polychlorinated biphenyls (PCBs), Perfluoroctane sulfonate (PFOs), dioxin and furan congeners – along with published consumption guidelines. WDNR typically conducts the fish sampling and fish tissue analysis. More information on the number of fish sampled, frequencies of sampling, and number of sites in Wisconsin is detailed in WDNR's *Water Division Monitoring Strategy.*[37]

The WDNR also includes those water bodies with sediment deposits that are known to have toxic substances that exceed state water quality criteria for ambient water as specified in Chapter NR 105, Wis. Adm. Code. These waters may be identified through various monitoring activities, including routine water quality monitoring, sediment analysis, and collection of fish tissue.

37 WDNR, 2008a.

V. GENERAL SURFACE WATER CONDITIONS IN DANE COUNTY

Water resource conditions are influenced in large part by the physical geography of a watershed (**Map 3**). The western third of Dane County, known as the Valley and Ridge or "Driftless" Area, is the part of the county where glaciation has not occurred. This area is characterized by steep ridges and valleys drained by fast-flowing streams, generally without natural lakes or impoundments. Most of these streams are fed by springs and seeps flowing from water-bearing layers of bedrock exposed on hillsides. Because of steep gradients, cool water temperatures, and high dissolved oxygen levels, most of the county's trout streams are located in this part of the county. Black Earth Creek, Mt. Vernon Creek, and the Sugar River are familiar examples (**Map 1**). These streams generally have fair to good water quality, but are commonly affected by nonpoint source pollution as well as streambank erosion problems. The large valley of the Wisconsin River, also found in the western part of the county, consists of deep sand and gravel deposits and extensive marshes in the floodplain of the river. Fish and Crystal Lakes are located in this area. Fish Lake is a high-quality lake which has begun to suffer declining water quality.

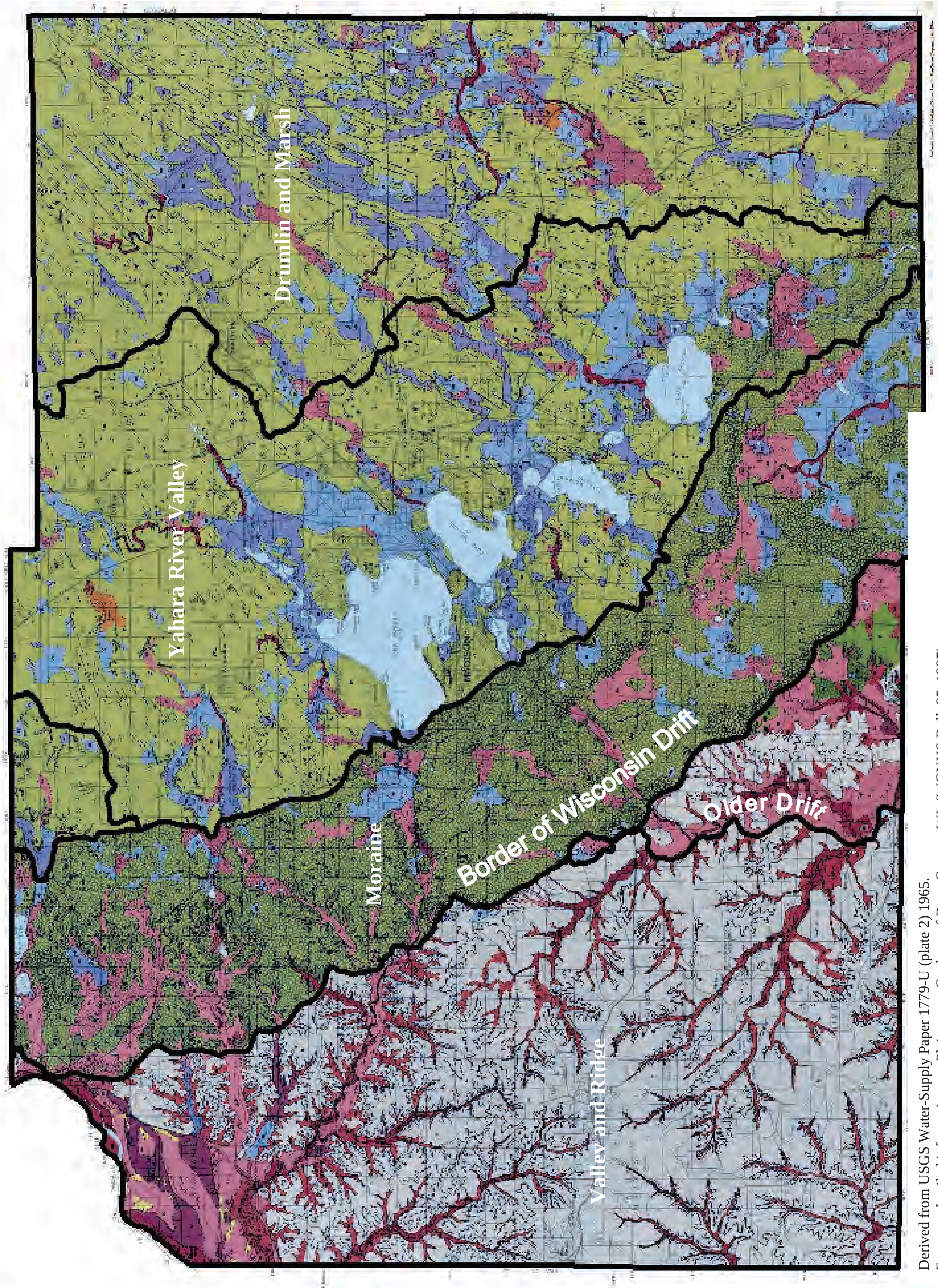
To the east of the Driftless Area is an area of glacial end moraines, located at a major drainage divide where the headwaters of many streams of the Wisconsin, Sugar and Yahara River basins originate. The moraines include hills and mixed deposits of glacial till (mixtures of clay, silt, sand, gravel, and boulders), which were deposited and left behind as the glaciers retreated. The moraines also included large blocks of remnant ice. These blocks melted forming potholes or kettles, some of which remain as small ponds, marshes, and bogs.

East of the moraines, in the center of the county, is the Yahara River Valley. Here deep glacial deposits dammed up large valleys, forming a chain of lakes and wetlands. The four largest and most heavily used lakes in the county are found here. They include Lakes Mendota, Monona, Waubesa and Kegonsa, which are all connected by the Yahara River. These are fertile lakes that support abundant algae and rooted aquatic plant growth, as well as a diverse warmwater fishery including northern pike, bass and panfish. Streams in the Yahara River valley are generally flatter and more sluggish than those in the Driftless Area, and fewer are spring-fed. Token Creek is a notable exception, since it receives a large volume of groundwater discharge from adjacent springs. Extensive ditching and wetland drainage has been done on and near certain water bodies in the region, resulting in water quality impacts and aquatic habitat loss.

The eastern part of the county is known as the Drumlin and Marsh Area. This area includes many small drumlin hills interspersed with shallow glacial deposits that have created an extensive system of interconnected wetlands with poorly defined drainage. Small streams wind slowly through the lowlands and there are few springs supplying streamflow. The only lakes in this area are small stream impoundments (e.g., the Marshall millpond) or shallow, marshy lakes. No trout streams are present. A warm-water fishery predominates in the two major streams in the area -- Koshkonong Creek and the Maunesha River. Extensive ditching and wetland drainage in this area have also affected water quality and habitat conditions.

Historic water quality data, supplemented by more recent monitoring activities, provide enough information to draw some general conclusions about the water quality of streams and lakes in the region. The following section summarizes some of the more important data on water quality.

Map 3. Physiographic Areas Of Dane County



Derived from USGS Water-Supply Paper 1779-U (plate 2) 1965.
For more detailed information see Pleistocene Geology of Dane County, WI. (WGNHS Bull. 95, 1997)

A. Baseflow Stream Water Quality Conditions

Dry-weather stream baseflow water quality data collected as part of the Cooperative Water Resources Monitoring Program[38] is summarized in **Attachment B-1**. The data are representative of all seasons of the year. The table includes the total number of samples collected over the latest sampling period (2007-2010) including mean, minimum, and maximum concentrations recorded for each measured constituent. Historic data for some of the more important parameters for each major stream system are graphed in **Attachments C-1 through C-10**. Because of monitoring program constraints, one station is usually being used to characterize conditions for the entire stream. In actuality, however, water quality can vary significantly in different reaches of a stream.

Baseflow consists of groundwater discharge to streams as well as regular or controlled surface discharges where they exist, such as from wastewater treatment plants, mining operations, and dams. Baseflow does not include streamflow resulting from stormwater runoff. Baseflow represents streamflow conditions under dry-weather conditions, which exist most of the time. In general, many of the water quality concerns associated with dry-weather baseflow have been the result of municipal and industrial wastewater discharges streams as well as agricultural and urban development activities in the watershed. Onsite wastewater systems and agricultural fertilization practices can also contribute nitrogen and phosphorus to streams through groundwater.

Other times, excessive nutrients, oxygen-demanding materials, and toxic substances may not be adequately diluted during low flow conditions and aquatic life can be adversely affected. For example, excessive nutrients can cause nuisance levels of aquatic plants which, through respiration, can lower dissolved oxygen concentrations in streams. Organic pollution can cause a loss of species diversity within a stream and dominance by more tolerant species. Toxic pollution may lead to both a reduction in species and total numbers of organisms.

Streams most affected by pollutants are small streams receiving discharges from major wastewater treatment plants – e.g., Badfish Creek (MMSD discharge) and Koshkonong Creek (City of Sun Prairie discharge). These streams, however, have shown dramatic improvements in water quality over the last 35 years as a result of major wastewater treatment improvements as well as improved land management practices. Recent baseflow monitoring results were compared to results obtained over this time period. Notable comparisons and changes include the following:

1. Ammonia and Organic Nitrogen

Overall, the concentration of ammonia-nitrogen in most streams has decreased (**Attachment C-1**). Baseflow ammonia levels in all monitored streams were found to be below chronic water quality criterion listed in NR 105.06 (e.g., 0.55 mg/L at a pH of 8.5 and temperature of 25º C). These criteria rise with decreasing water temperature and pH. Significant improvements in ammonia levels have been realized primarily as a result of improvements in wastewater treatment technologies as well as agricultural and urban Best Management Practices. Organic nitrogen concentrations have also generally decreased (**Attachment C-2**). Organic nitrogen contributes to ammonia formation and biological oxygen demand.

2. Nitrate Nitrogen

The concentration of nitrate-nitrogen in most county streams, however, has seen an increase over the last 35 years **(Attachment C-3**). This is attributed to the large amounts of nitrogen fertilizer used in the region, one of the most agriculturally productive in the nation. Nitrate nitrogen levels have been recently declining, likely the result of increased agricultural nutrient management planning and practices.

It is important to point out that nitrate in streams is not a particularly significant *surface* water quality concern (note that streams with direct wastewater treatment discharges have been excluded from **Attachment C-3** to reflect groundwater contributions). The baseflow monitoring results indicate that nitrate levels in *groundwater* are continuing to increase. This is a health concern for families using private wells. The state has established 10 mg/L as a drinking water standard for infants younger than six months (NR 809.11(3)). While The more recent reduc-

38 Coordinated by the Capital Area Regional Planning Commission in cooperation with federal, state, and local partners.

tions in nitrates is encouraging, more work is needed to address historically high levels in the region.

3. Total Phosphorus

Baseflow concentrations of phosphorus are typically higher in streams receiving sewage treatment plant discharges, compared to streams that are not (**Attachment C-4**). A large proportion of the baseflow total phosphorus concentration is often dissolved (reactive) phosphorus. Significant decreases in baseflow phosphorus concentrations has occurred, largely attributed to improvements made at municipal wastewater treatment plants since the late 1970s as well as reductions in phosphate used in detergents.

Many of the streams in the region that do not receive wastewater discharges also have relatively high phosphorus levels during baseflow conditions. Increased phosphorus in baseflow can indicate its release from deposited sediments in the stream or groundwater if the clay particles and iron oxides in the soil become saturated. These data are indicative of the locations where potential problems from excess fertility could occur such as algae and aquatic weed growth, along with associated water quality impairments. This phosphorus originates from agricultural and urban nonpoint pollution sources such as fertilizers used on crops and lawns,[39] animal waste, and eroding topsoil from both agricultural and construction site activities. While there have been some improvements due to improved urban and agricultural Best Management Practices, more work is needed. Nearly all of the streams (16 of 22) had mean phosphorus results greater than the state criterion of 0.075 mg/L for streams and 0.100 mg/L for rivers (NR 102.06(3)(b)). In fact, streams in the Rock River Basin have been included in a TMDL established for both phosphorus and sediment. This is because a large portion of the phosphorus that moves from land to water is also attached to sediment particles. In this manner, practices targeted to control sediment may be used to capture phosphorus as well.

4. Suspended Sediment

Baseflow concentrations of suspended sediment have also generally decreased (Attachment C-5). This is attributed to wastewater treatment upgrades as well as construction site erosion control and agricultural Best Management Practices. However, many water bodies in the region are still affected by excess sediment loading. Sediment that is suspended in the water reduces light penetration and photosynthesis, increases water temperature, clogs gills, and covers aquatic habitat with fine silt and clay. Sediment can also carry nutrients, heavy metals, and other pollutants into water bodies. The Rock River TMDL is addressing phosphorus and sediment together because their sources, transport, and management options are so closely linked. While there is no numeric in-stream threshold for sediment currently, WDNR may consider sediment as a pollutant using the narrative criteria (NR 102.04(1)) through sufficient documentation/justification.

5. Dissolved Oxygen

Although <u>mean</u> dissolved oxygen concentrations in monitored streams did not violate state water quality criteria, individual samples for several streams did (6 out of 22), **Attachment C-6**. Since none of the six streams receive wastewater treatment plant discharges directly, low dissolved oxygen concentrations during baseflow periods indicate substantial organic decomposition or possibly other nonpoint sources of pollution. Since dissolved oxygen is more variable than the other parameters and may be affected by daily photosynthesis/respiration cycles, mixing patterns, etc.; more data collection would be needed to substantiate a water quality impairment. Three of the streams are currently listed as Impaired (Dorn, Nine Springs, and Starkweather Creeks).

6. Coliform Bacteria

Coliform bacteria levels have improved since the 1970s, primarily as a result of improved disinfection of treated wastewater effluent (Attachment C-7). However, half of the monitored streams (11 out of the 22) have bacteria counts which exceed the state guideline for body-contact recreation of 1000 colonies/100 ml for a single sample.[40] State water quality criteria exist for point source discharges (NR 102.04(5)(a), however insufficient data was available for making these determinations. Because of limited data, stream and river samples are rarely considered.[41] Since coliform bacteria is a natural component of the digestive systems of both humans and animals,

39 Dane County enacted a ban on phosphorus in lawn fertilizer sold in the county in 2004.

40 Wisconsin Department of Health and Family Services, Bureau of Environmental Health.

41 Wisconsin 2010 Consolidated Assessment and Listing Methodology (WisCALM). WDNR 2009c.

the test is used as an indicator of contamination and increased risk from other, less easily detected pathogenic organisms and viruses. Pollution may be occurring from animal wastes, inadequately disinfected wastewater treatment plant discharges, or other undetermined sources.

7. Chloride

The concentration of chloride in almost all county streams has increased (Attachment C-8). Increases in chloride are associated with continued use of road salt which leaches into groundwater, as well as increased discharges from treatment plants. Increased chloride concentrations are also being found in municipal wells and the Yahara Lakes (Attachment C-9 and C-10). While these levels have been found to be generally below state water quality chronic and acute thresholds (395 mg/L and 757 mg/L, respectively),[42] they do indicate a worsening trend. Short-term pulses may also exceed chronic or acute levels during spring stormflow/snowmelt conditions in some locations, which is an area of increasing concern. Chloride is very soluble and remains in solution. Since there are no current treatment options available at the landscape scale (reverse osmosis or microfiltration being prohibitively expensive), reduction in usage appears to be the best and most effective salt management strategy to-date.

A new perspective on the severity of aquatic toxicity impact of road salt was gained by a focused research effort directed at winter runoff periods.[43] According to the study, dramatic impacts were observed on local, regional, and national scales. In Milwaukee (local scale), samples from 7 of 13 urban-influenced streams exhibited toxicity in bioassays during road-salt runoff. The maximum chloride concentration was 7730 mg/L. In 11 southeast Wisconsin watersheds (regional scale), chloride concentrations exceeded U.S. Environmental Protection Agency acute (860 mg/L) and chronic (230 mg/L) water quality criteria at 55 and 100 percent of the monitored sites, respectively.[44] At the national level, very few samples at southern sites exceeded chronic water quality criteria, and no samples exceeded acute criteria. The latter suggests that salt concentrations in northern streams are more associated with road salt application than other sources (e.g., water softeners). Chloride concentrations exceeded USEPA water quality criteria at 55 percent (chronic) and 25 percent (acute) of the 168 monitoring locations in northern metropolitan areas from November to April. Only 16 percent (chronic) and 1 percent (acute) of sites exceeded criteria from May to October, indicating this is largely a wintertime/snowfall-related problem.

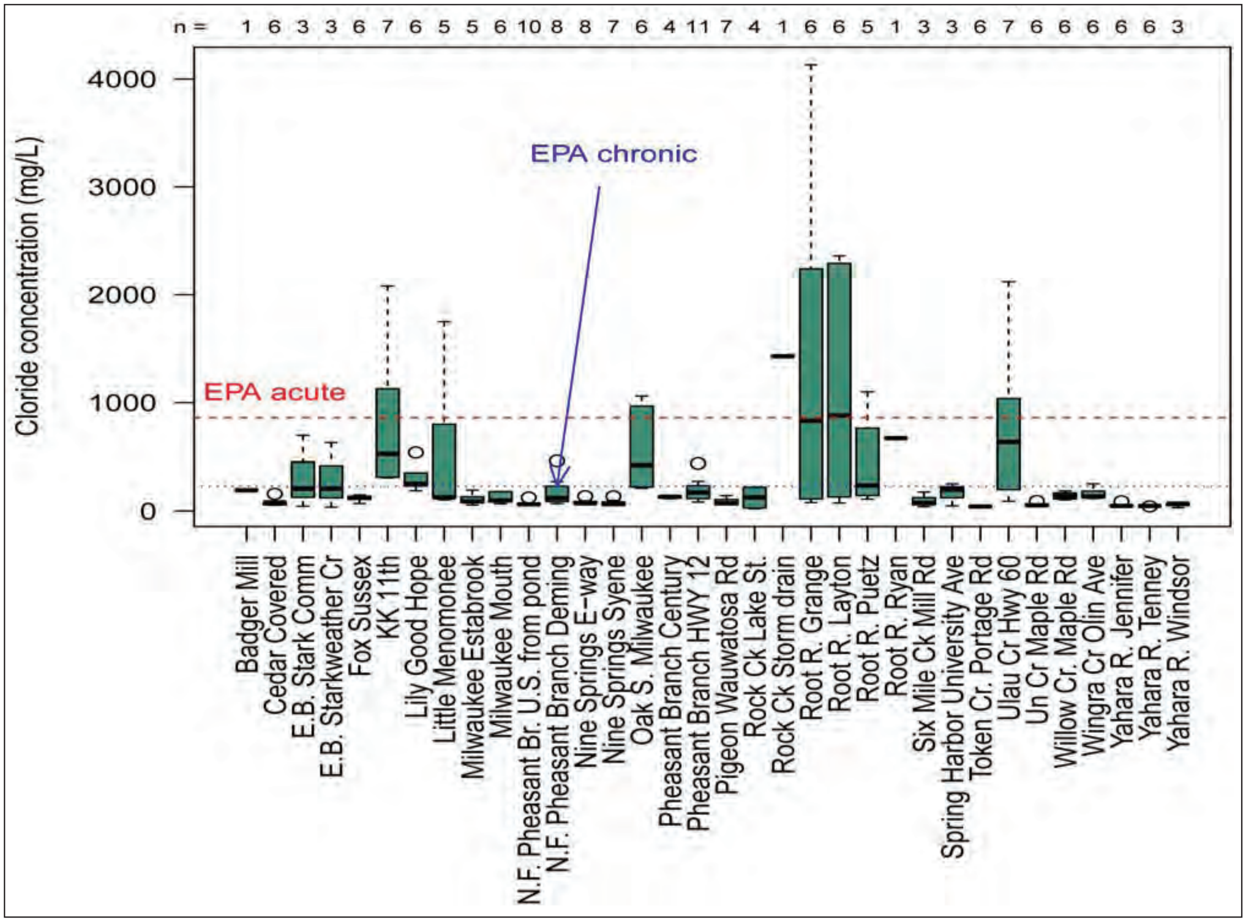
In General, Milwaukee area sites were more impacted than Madison area sites (**Figure 12**).[45] According to 2011 data collected by the Wisconsin Citizen-Based Monitoring Network, in Madison area streams the USEPA chronic standard was exceeded 16 times at 7 sites on 4 streams (Pheasant Branch Creek, Spring Harbor Storm Sewer, Starkweather Creek, and Wingra Creek). There were no exceedances of USEPA's acute standard found in 2011.

In 2007-08, 26 chloride samples were collected from Pheasant Branch Creek and then used to develop a regression model to estimate continuous concentrations of chloride and compute daily chloride loads.[46] The maximum estimated concentration of chloride during the monitoring period was 931 mg/L on March 1, 2007 and exceeded the USEPA acute criterion. Chloride concentrations exceeded the USEPA chronic criterion for at least 10 days during February and March 2007 and for 45 days from December to April during the 2007-08 winter season. The maximum concentration in 2008 reached 680 mg/L twice during February. These high concentrations of chloride occurred in spite of the attenuating effect of the Confluence Pond about 0.3 miles upstream from the gaging station. Following the winter peaks, concentrations of chloride remained elevated above background concentration through April, long after the snow had melted.

Middleton uses a recommended road deicing salt application rate of 300 lbs. per lane mile and used 2,068 tons of salt during the record snowfall season of 2007-08. Middleton used a more normal 1,346 tons of salt during the 2008-09 season. In comparison, the Madison Streets Division utilizes a salt application rate of 150 lbs. per lane mile, and Madison applies a calcium chloride solution as the pre-wetting agent and a sand abrasive that includes 20 percent salt. Deicing salt is also applied to sidewalks, driveways, and parking lots on commercial and residential private property. In a Madison survey, salt application rates to parking lots ranged from about 0.14

42 NR105.06(3)(i) and NR105.05(2)(h)
43 Corsi, S. et. al., 2010.
44 Note, Wisconsin criterion of 757 mg/L (acute) and 395 mg/L (chronic) are specific to Wisconsin waters.
45 http://watermonitoring.uwex.edu/level3/UrbanRoadSaltReports.html
46 USGS, 2012.

Figure 12. Chloride in Southern Wisconsin Streams, 2011



to 0.30 tons per acre for each application. Thus the total salt usage is likely much greater than just the road salt applications.

8. Heavy Metals and PCBs

Heavy metal analyses were also conducted as part of the baseflow monitoring program (**Attachment A-2**). Results were compared to WDNR water quality criteria listed in Chapter NR 105. While earlier (1990) sampling showed the chronic toxicity standard for lead was exceeded on the East Branch of Starkweather Creek, more recent sampling indicates the concentration of lead has declined. Concentrations of other metals, such as cadmium, chromium, copper, mercury, and nickel have also decreased compared to samples taken in 1990. No violations of state or federal criteria were detected.

Moderate to high levels of metals such as mercury, zinc, barium and arsenic, are found in the bottom sediments of Murphy (Wingra) Creek and both East and West Branches of Starkweather Creek. Because of this metal contamination (among other considerations), WDNR, the City of Madison, and Dane County selected Starkweather Creek as a sediment dredging and aquatic habitat restoration project in the 1990s.

Detectable levels of PCBs have also been found in Starkweather Creek and Murphy Creek bottom sediments, as well as along the western shore of Lake Monona indicating widespread contamination there. Compared to other PCB contamination sites across the state, however, the level of PCB contamination is low. DDT by-products have also been detected in bottom sediment in both branches of Starkweather Creek and in Murphy Creek.

9. Temperature

Maximum water temperatures recorded in all monitored streams during baseflow conditions did not violate the state temperature criteria for warmwater fish (86ºF or 30ºC) for coldwater fish (73ºF or 23 ºC), NR 102.04(4).

10. Biologic Indices

Another indicator of stream water quality conditions is the type of insects found on rocks and other stream bottom materials. Certain species of insects will tolerate only undisturbed conditions with limited organic material, while other are able to survive a wider range of habitat and water quality conditions. Tolerance values are assigned to various insect species and an overall Index of Biotic Integrity (IBI) score calculated for the water body. **Map 4 and Attachment A** show the general condition of the named water bodies in Dane County. More detailed information may be found in the corresponding descriptions for each water body later in this report.

Research and monitoring have shown a very positive link between the amount of land in USDA's Conservation Reserve Program (CRP) and improvements in small coldwater streams in southwestern Wisconsin.[47] While water quality problems linked to intensive agriculture were well documented in the 1980s, competition from global commodities markets was gradually changing agriculture in Wisconsin. There has been a long term shift from numerous small farms to fewer larger farms. Coinciding with these trends, conservation practices, such as contour strip plantings and improved manure management, had also become more widespread. As the numbers of farms declined, the total animal unit numbers also declined; along with associated problems such as over-grazing. Ultimately, BOD and nutrient loading to the streams decreased. In addition, as farm practices were gradually improving and intensive agriculture was declining on less productive lands, researchers have found increased baseflows and reduced runoff and peak flow rates in Driftless Area streams. [48, 49, 50] This has been attributed to the higher infiltration rates associated with less intensive agricultural uses.

As agricultural land uses softened across the landscape, the 1985 Farm Bill ushered in a transformative conservation effort know as the Conservation Reserve Program or CRP. The CRP offered farmers USDA rental payments for retiring highly erodible croplands into long term grass cover. Environmental benefits included improved hydrology, reduced soil erosion, reduced nutrient loading, and increased wildlife habitat. Hydrology improved as surface runoff declined by 50 percent or more while infiltration increased inter-lateral groundwater flow to coldwater streams. Sustained spring flow from perched hillside aquifers are important to Driftless Area streams.[51] Grass cover reduced phosphorus and sediment loading by 90 percent while the larger grassland tracts provide essential habitat for some of the most threatened bird populations in the United States: migratory grassland birds.[52]

The relative high densities of these rare bird populations thrive in the Driftless Area in southwest Dane County and southeast Iowa County. This area is known as the Military Ridge Prairie Heritage Area (MRPHA) and lies within the greater Southwest Wisconsin Grassland and Stream Conservation Area (SWGSCA).[53] These projects focus on public-private partnerships designed to protect grasslands, prairie remnants, oak savannas, agriculture, and water quality. The measured improvements in Driftless Area streams reflect the ecological and management connections between the upland ridges and the streams that bisect them. In addition to environmental benefits, in some cases the CRP provided a social safety net that allowed struggling farmers to hold on to their farms, and in return, provide important public benefits.

Without any direct stream management, fisheries in the study area gradually shifted from relatively diverse populations of eurythermal (tolerant) species to populations of stenothermal (intolerant) species more reflective of ecologically healthy trout streams. Over the span of decades, species richness declined in the streams (**Figure 13**) while coldwater IBI scores greatly improved (**Figure 14**).[54] There is a negative correlation between these two indicators of coldwater habitat that may seem counterintuitive or inconsistent at first glance. Actually, healthy trout streams typically support a relatively *low* diversity of fish species adapted to living in perpetually cold water conditions.[55] The changes that occurred in Gordon Creek Watershed streams also occurred in streams across MRPHA but did not occur in areas where CRP participation was substantially lower.[56] Higher IBI scores generally occurred in watersheds where non-cropland uses, particularly grasslands, were higher (**Figures 15 and 16**)

47 Marshal, 2008a.
48 Gebert, 1996.
49 Juckem, 2008.
50 Kochendorfer, 2010.

51 Carter, 2010.
52 Marshall, 2008a.
53 WDNR, 2009b. http://www.swgsca.org
54 Marshall, 2008a.
55 Lyons, 1996.
56 Marshall, 2008a.

The changes in agriculture and streams in the Driftless Area streams is not the end of the story. Since 2002, anticipation of ethanol production and expectation of high corn prices precipitated significant withdrawals from the CRP. At a few locations, factory-style farms replaced former CRP lands with very high animal unit densities that can have catastrophic effects on water quality (e.g., 2005 manure spill in the West Branch Sugar River). In other areas, CRP lands were converted to low density housing. While impervious surfaces do not typically increase substantially under this form of development, potential impacts linked to surface runoff and groundwater contamination cannot be ignored. Low density development also destroys habitat for threatened migratory birds that require large tracts of unfragmented grassland, and can destroy scenic views that are important for the local tourism economy; undermining the goals of MRPHA and SWGSCA, as well as other significant areas around the region.[57]

11. Baseflow Reduction

Several studies have been done looking at municipal groundwater withdrawal in Dane County. Municipal groundwater pumping has lowered the groundwater level in the Madison area by more than 60 feet in some areas (**Map 5**), with additional declines of as much as 20 feet by the year 2030 (**Table 10**).[58] The Yahara lakes and area wetlands were once discharge areas for groundwater. Now they lose water to the groundwater system (groundwater recharge) due to pumping and water diversion.[59] The lower water levels in the shallow groundwater aquifer have led to a decline in the flow of several local springs.[60] The Dane County Regional Hydrologic Study predicted year 2030 stream baseflow reductions of between 3 percent (Spring Creek near Lodi) and 100 percent (E. Branch Starkweather at STH 30 and Koshkonong Creek at Bailey Road) from pre-development conditions for representative Dane County streams.[61] Reduction in stream baseflow can decrease water quality during critical summer months because of higher temperatures (less cold groundwater discharge) and lower dissolved oxygen levels (warmer water holds less oxygen). In extreme cases, small tributary streams and headwater areas can go dry.

57 WDNR, 2009b.
58 DCRPC, 2004b.
59 Hunt, 2001.
60 Lathrop, 2005.
61 DCRPC, 2004b.

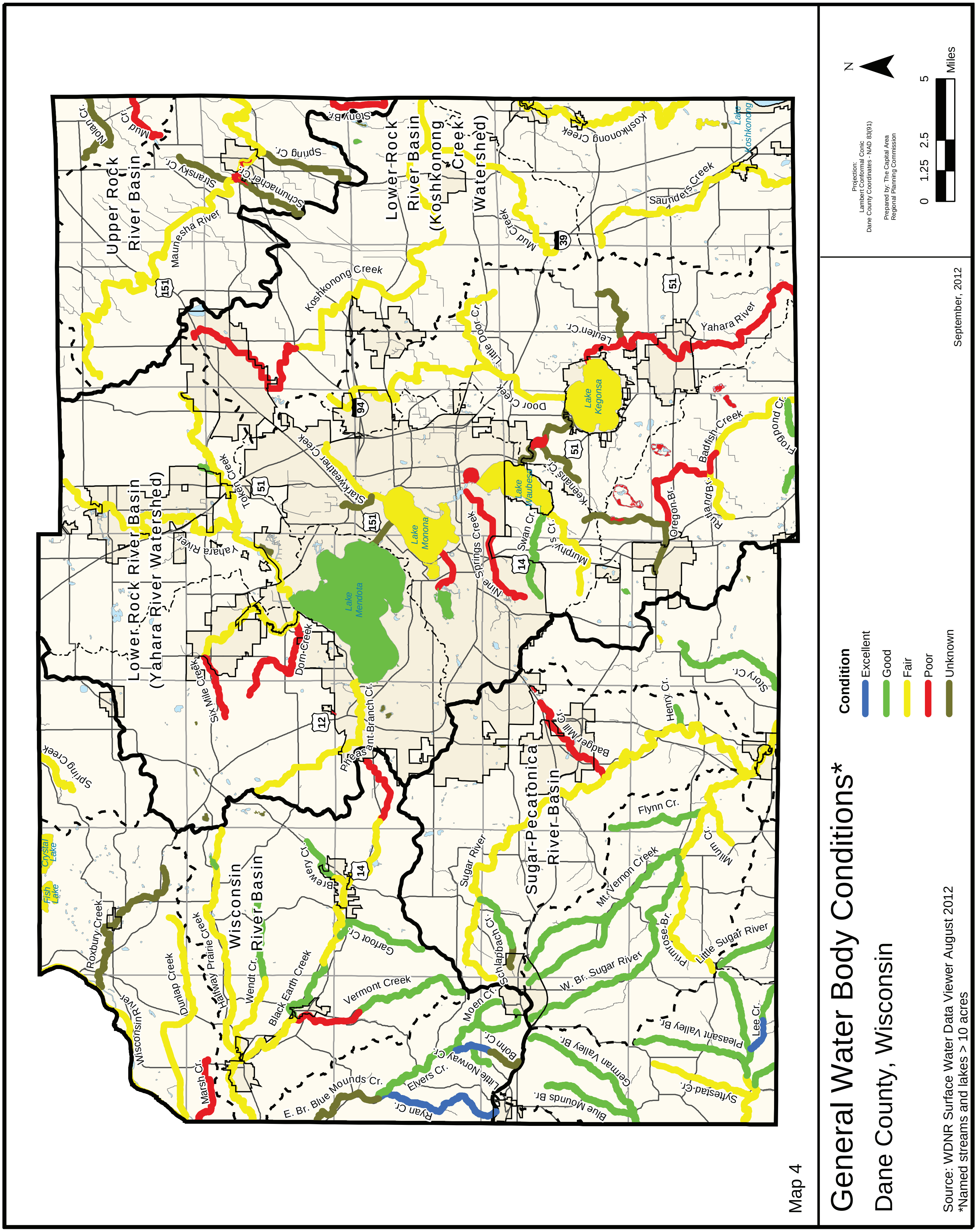

Map 4
General Water Body Conditions*
Dane County, Wisconsin
Source: WDNR Surface Water Data Viewer August 2012
*Named streams and lakes > 10 acres
Condition
Excellent
Good
Fair
Poor
Unknown
September, 2012
Projection:
Lambert Conformal Conic
Dane County Coordinates - NAD 83(91)
Prepared by: The Capital Area Regional Planning Commission
0 1.25 2.5 5 Miles
N
Upper Rock River Basin
Lower Rock River Basin (Koshkonong Creek Watershed)
Lower Rock River Basin (Yahara River Watershed)
Wisconsin River Basin
Sugar-Pecatonica River Basin
Lake Mendota
Lake Monona
Lake Waubesa
Lake Kegonsa
Lake Koshkonong
Crystal Lake
Fish Lake
Yahara River
Koshkonong Creek
Maunesha River
Starkweather Creek
Token Creek
Six Mile Creek
Dorn Creek
Pheasant Branch Cr.
Nine Springs Creek
Badger Mill Cr.
Sugar River
W. Br. Sugar River
Little Sugar River
Mt. Vernon Creek
Black Earth Creek
Vermont Creek
Garfoot Cr.
Brewery Cr.
Wisconsin River
Roxbury Creek
Dunlap Creek
Halfway Prairie Creek
Wendt Cr.
Marsh Cr.
E. Br. Blue Mounds Cr.
Blue Mounds Br.
Ryan Cr.
Elvers Cr.
Little Norway Cr.
Bohn Cr.
Moen Cr.
Schlappbach Cr.
German Valley Br.
Pleasant Valley Br.
Syftestad Cr.
Lee Cr.
Primrose Br.
Flynn Cr.
Milum Cr.
Henry Cr.
Story Cr.
Spring Creek
Oregon Br.
Rutland Br.
Badfish Creek
Frogpond Cr.
Keenans Cr.
Murphy's Cr.
Swan Cr.
Door Creek
Little Door Cr.
Leuten Cr.
Mud Creek
Saunders Creek
Spring Cr.
Schumacher Cr.
Stransky Cr.
Mud Cr.
Nolan Cr.
Stony Br.
151
51
94
39
14
12

Figure 13. Species Richness Changes After Conservation Reserve Program (CRP) Enrollments in Southwest Dane County and Southeast Iowa County. Low species richness reflects healthy trout streams

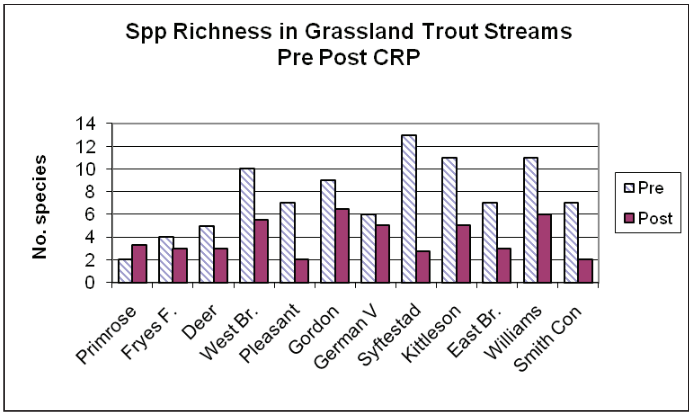


Figure 14. Coldwater Index of Biotic Integrity (IBI) Scores for Southwest Dane County and Southeast Iowa County Before and After Conservation Reserve Program (CRP) Enrollments. Biotic integrity increases with increasing score. "Good" range = 60-80

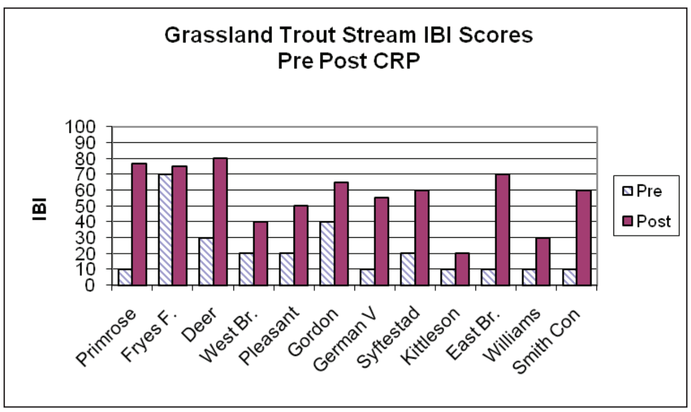


Figure 15. Higher Index of Biotic Integrity Scores (left side) Occurred in Watersheds with Lower Intensity Agriculture

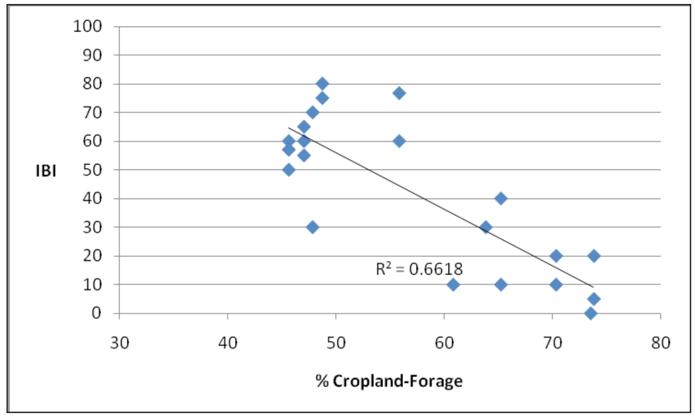
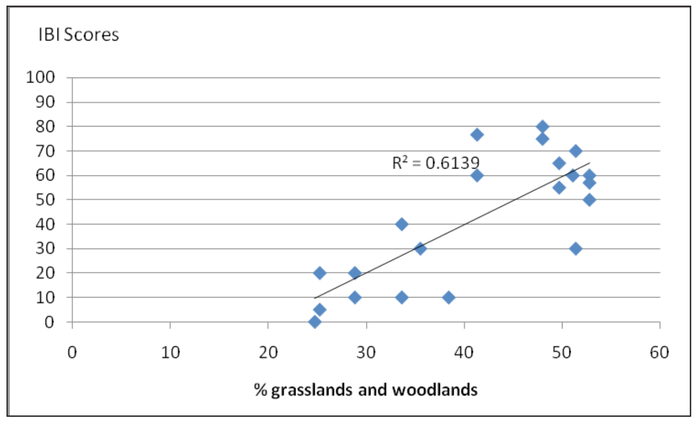
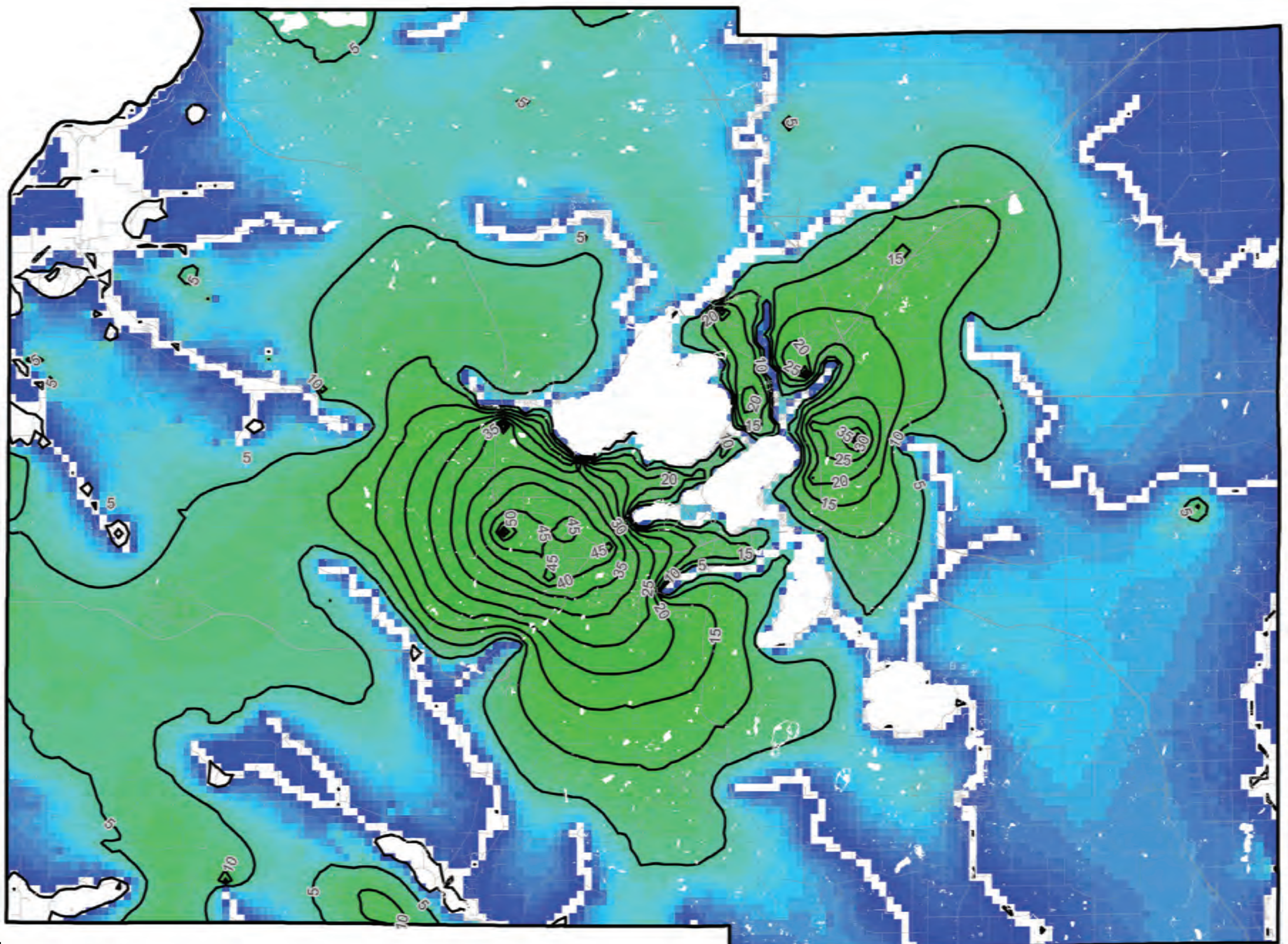


Figure 16. Lower Index of Biotic Integrity Scores (left side) Coincided with Lower Grasslands and woodlands



MAP 5



Cones of Depression (2000)

Dane County, Wisconsin

Graphic output is from Groundwater Vistas model (2004).

Groundwater Table Reduction

Less — More

Feb., 2005

Projection:
Lambert Conformal Conic
Dane County Coordinates - NAD 83(91)

Prepared by: THE DANE COUNTY REGIONAL PLANNING COMMISSION

N

0 0.5 1 2 3 4 5 Miles

Table 10. Summary of simulated Baseflows for Dane County Streams for Different Pumping Conditions (cfs)

Station	Predevelopment Baseflows	Present Conditions (Measured Q_{80})	2030 Baseline Conditions
Spring Creek near Lodi	16.87	16.70	16.48
Black Earth Creek above Cross Plains	1.70	0.60	0.19
Black Earth Creek @ USGS gage above Black Earth	21.18	19.44	18.50
Mt Vernon Creek @ USGS Gage	12.78	12.40	12.12
W Branch Sugar River @ STH 92 near Mt. Vernon	10.70	10.47	10.25
Pheasant Branch Creek @ USH 12 @ Middleton	2.20	0.85	0.29
Badger Mill Creek @ STH 69 south of Verona	5.37	3.50	2.79
Six Mile Creek @ Mill Rd near Waunakee	4.46	3.40	2.77
Yahara River @ Golf Course near Windsor	11.71	10.00	8.14
Token Creek @ USH 51	18.48	15.50	13.33
E. Branch Starkweather Creek @ Milwaukee St.	2.10	0.30	0
W Branch Starkweather Creek @ Milwaukee St.	5.44	0.60	0.57
Murphy (Wingra) Creek @ Beld St.	4.94	2.30	1.93
Nine Springs @ Hwy. 14	7.31	5.60	5.24
Badfish Creek @ Co. Hwy. A	6.59	5.17	4.47
Koshkonong Creek @ Bailey Rd. near Sun Prairie	0.95	0.24	0
Koshkonong Creek near Deerfield at STH 73	11.56	9.00	7.40
Koshkonong Creek @ Hoopen Rd. near Rockdale	21.90	18.39	16.43
Door Creek	4.64	3.20	2.50
Maunesha River south of USH 151	2.48	2.10	1.68
Yahara River outlet of L. Waubesa	127.28	70.00	54.21
Yahara River below Stoughton	223.42	161.06	142.51

B. High Flow Stream Water Quality Conditions

Nutrients, sediment, oxygen-demanding materials, and various other pollutants are washed from rural and urban lands into streams and lakes during periods of precipitation and runoff. This often causes long-term pollutant loading concerns that are associated with fertility and sedimentation problems in receiving waters. Concentrations of certain constituents such as ammonia and dissolved oxygen in runoff can pose immediate toxicity concerns for aquatic life. The difficulty in monitoring for these relatively infrequent and episodic events is the significant cost of instrumentation needed to catch these events at both the right time and place. Research also shows that by the time water quality problems become evident, in many cases, the stream has already been degraded by water *quantity* impacts or altered hydrology, such as ditching and draining, urban development, and associated "flashier" streamflow patterns. This can result in channel incision, widening, stream bank erosion and sedimentation, along with associated destruction of aquatic habitat, and transition to more tolerant biological communities.

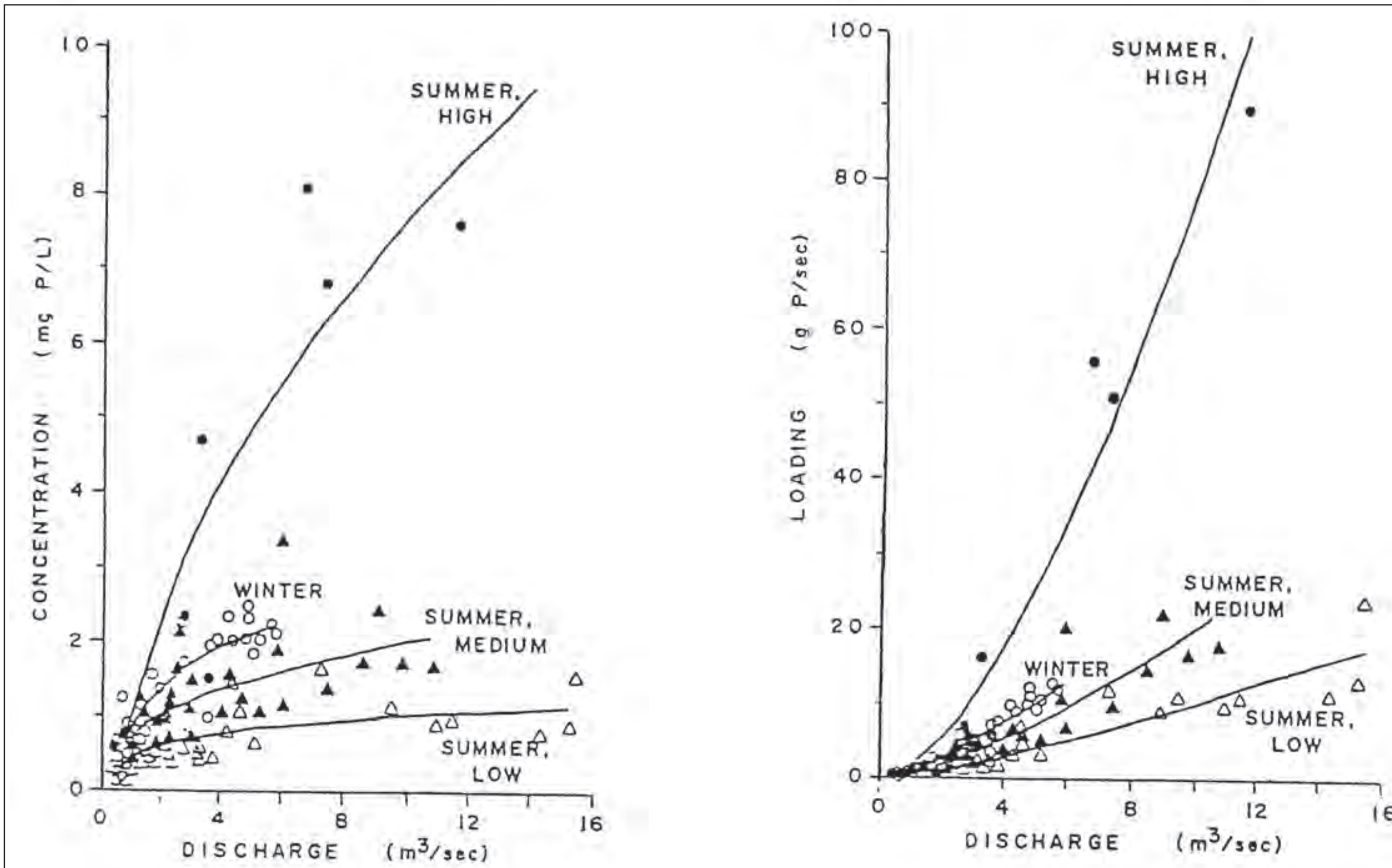
Sediment delivery to water bodies from agricultural and urban areas is frequently a concern during high-flow conditions. Depending on the intensity and duration of a storm event, the resulting high flow in a stream may cause either sediment deposition or scouring of the stream bed. Small, intense storms may deposit more sediment and keep turbidity higher than longer storms.[62] Sediment deposited after such storms can smother bottom fauna important as fish food. More significantly, sediment can smother fish spawning sites and fill pools used for cover, thereby reducing reproduction and surviv-

62 DCRPC, 1992.

al. In addition, the fine sediment deposited after a storm may be subject to erosion under low-flow conditions, which can cause extended periods of turbidity. Phosphorus loading associated with storm events can also pose water quality concerns. Phosphorus is recognized as the primary constituent causing excessive eutrophication or fertility problems (e.g., nuisance algae blooms, decomposition, and low dissolved oxygen) targeted for control through various watershed management efforts. Monitoring data have indicated a strong correlation between phosphorus and suspended sediment. Eroded soil particles are composed of organic matter rich in phosphorus. Phosphorus also attaches to clay surfaces, which make up a large portion of the suspended sediment load carried in runoff water. Phosphorus concentrations and loads during storm events are highly variable and depend on the intensity of the event and time of year (**Figure 17**).

Phosphorus has been continuously monitored on two principal tributaries to Lake Mendota (the Yahara River and Pheasant Branch Creek) for more than two decades. Long-term continuous monitoring is necessary for establishing statistical relationships and trends associated with otherwise highly variable conditions. While phosphorus loads are quite variable from year to year, much of the phosphorus loading occurs during periods of stormwater runoff and not during periods of dry weather flow (**Figures 18 and 19**). Almost all of the mass loading of phosphorus and sediment was found to occur during major runoff events. Pollutant concentrations also vary dramatically during the course of a storm event. The timing and size of storms during the year are particularly important factors influencing phosphorus loads. Monitoring data indicate that a large proportion of annual phosphorus and sediment loads are delivered during a few major storms, often in February, March, and April.[63]

Figure 17. Total Phosphorus Discharge Models for the Yahara River



○△ Open circles/triangles = low intensity winter/summer events ●▲ Solid circles/triangles = high intensity winter/summer events

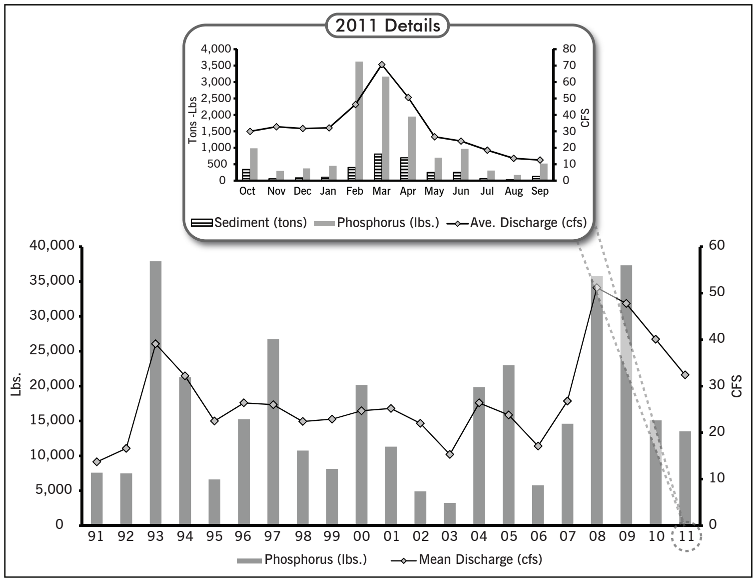
(Source: WDNR Bureau of Research-Dick Lathrop)

63 Lathrop, 2007.

In addition to phosphorus and sediment impacts, recent monitoring indicates that short-term, in-stream water quality problems can also occur from precipitation events. For example, monitoring of Black Earth Creek indicates that dissolved oxygen concentrations were lowered as a result of summer rainfall to levels that violated minimum WDNR standards (**Figure 20**). These violations typically occur during storm events. Chronic low dissolved oxygen levels in the stream has been documented.[64] Oxygen reductions are believed to be caused by a combination of factors, including high oxygen demand from organic materials in runoff, from both rural and urban sources, and high water temperatures. Low dissolved oxygen concentrations can also increase the toxicity of ammonia to fish. An expanded monitoring program has been directed to the creek to try and discern the source of impairment.

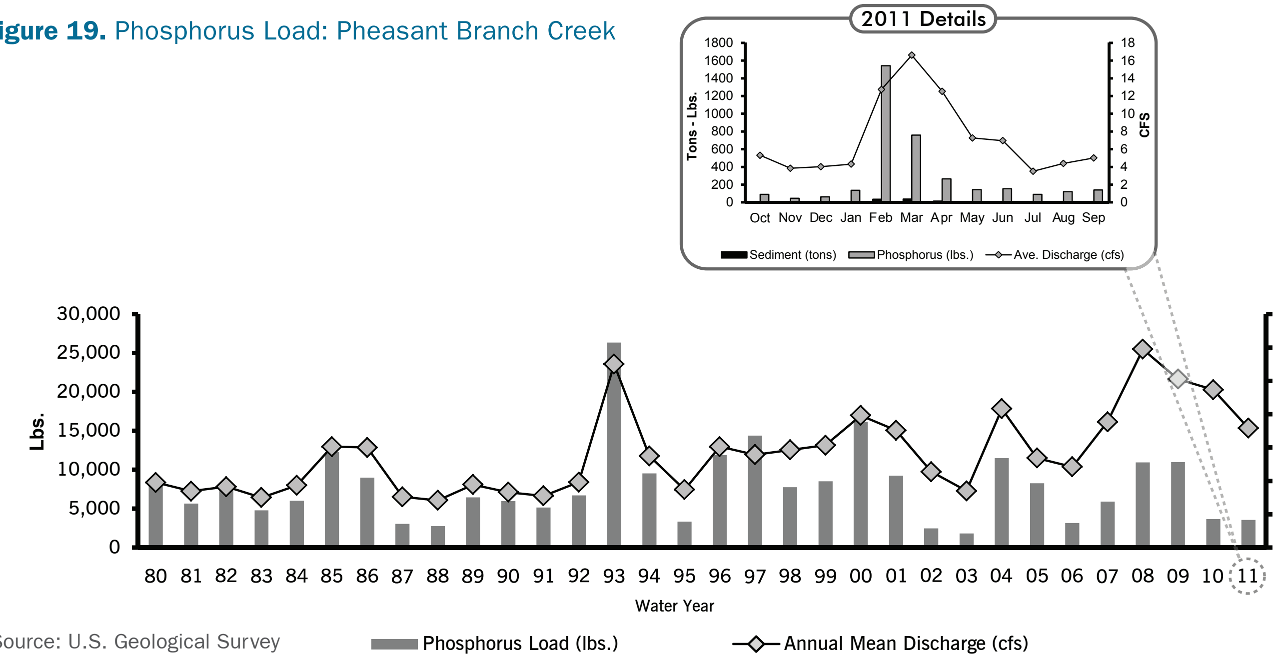
In more urban areas of the county, monitoring of runoff by USGS and WDNR has shown concentrations of heavy metals, pesticides and PAHs (polycyclic aromatic hydrocarbons) at levels that often exceed federal and state chronic and acute toxicity criteria for aquatic life. For example, A significant amount of monitoring data has been collected at the Monroe Street detention basin west of Lake Wingra. Results show the detention basin is effective in controlling much of the heavy metals in runoff from this predominantly residential area.

Figure 18. Phosphorus Load: Upper Yahara River



Source: U.S. Geological Survey

Figure 19. Phosphorus Load: Pheasant Branch Creek

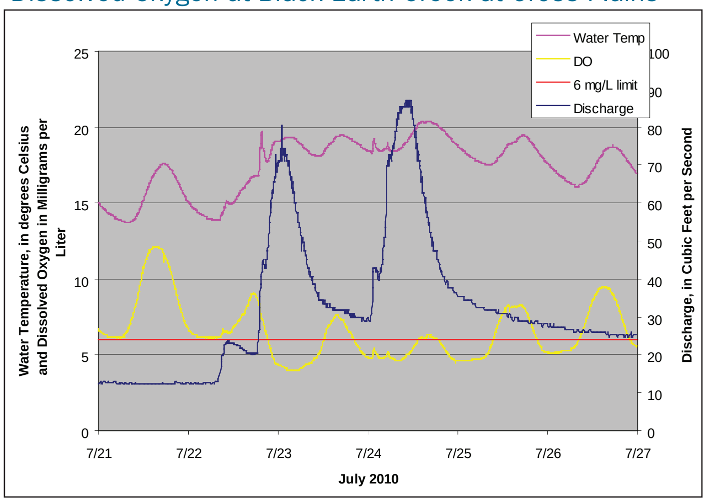


Source: U.S. Geological Survey

64 Walker, 2001.

Water quality during high-flow conditions has been extensively monitored in the state and around the nation. This information provides the basis for various stormwater runoff models (e.g., SLAMM, SWAT, among others) routinely used by water resource professionals in place of actual in-stream monitoring, which can be prohibitively expensive. Results of the monitoring and modeling show the concentrations of suspended sediment, total and reactive phosphorus, among other pollutants, increase with stream discharges.

Figure 20. Streamflow, Water Temperature, and Dissolved Oxygen at Black Earth Creek at Cross Plains



Source: U.S. Geological Survey

The agencies responsible for regulating stormwater runoff (U.S. EPA and WDNR) use Total Suspended Solids (TSS) as a water quality surrogate or indicator in two ways: 1) as the regulatory criteria used to indicate the amount of pollutants in runoff, and 2) as a measure of effectiveness of Best Management Practices (BMPs) in removing those pollutants. TSS is used as an indicator because its relationship with other pollutants is known, and it can be consistently simulated by computer models. However, TSS is not a measure of all pollutants carried by stormwater runoff. Coarse materials such as street sand, trash, and dissolved chemicals like chloride are not included in the definition of TSS. Only fine particles of sediment, and the pollutants that attach to them, are measured by TSS. While TSS is not a perfect measure for all types of stormwater pollution, there is enough experience using TSS to design urban and agricultural BMPs that can be employed to help protect our lakes and streams.

C. Lake Water Quality Conditions

The Yahara River lakes (Mendota, Monona, Waubesa and Kegonsa) are among the highest valued and most extensively studied and used water resources in the county. They also provide a spectacular setting for the county's central urban area and enjoyment by both the resident population and visitors alike. However, the Yahara Lakes experience substantial algae and rooted aquatic plant growth in summer that is fueled by nutrients, particularly phosphorus. Because of their high fertility, the lakes are classified as eutrophic. While a major change occurred in the 1960s with the invasion and dominance by the exotic Eurasian water milfoil, more recent field surveys indicate that water milfoil is on the decline and native plant species are becoming more abundant. While this is good, overfertilization of the lakes from activities on the land surface is still a problem.

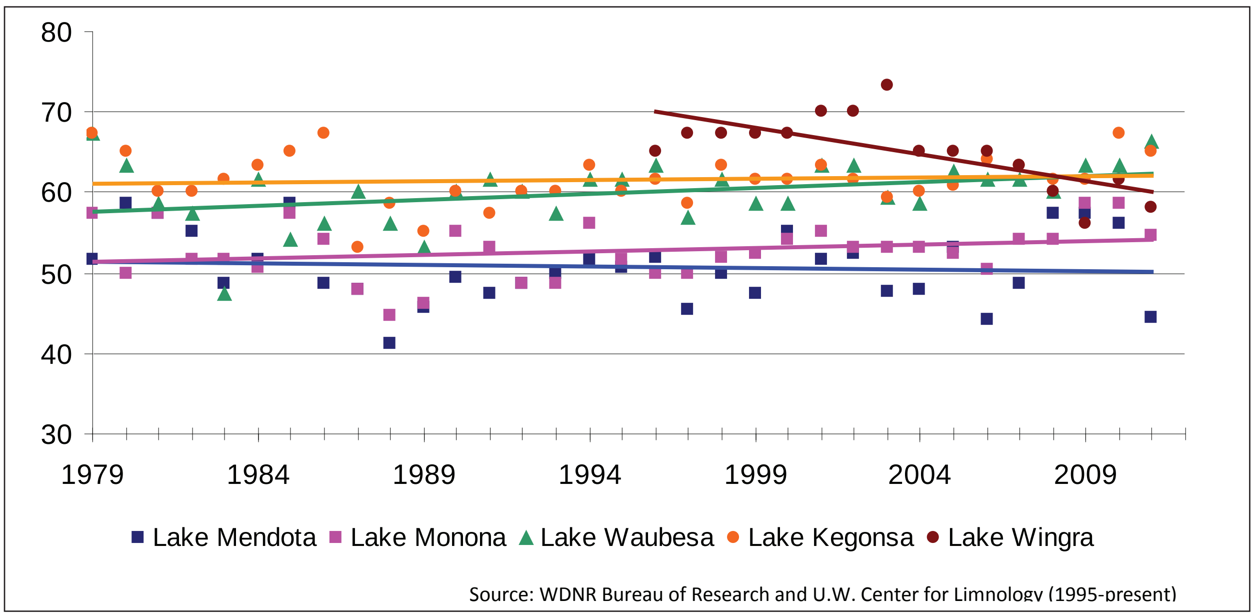
The assessment of the water quality conditions of lakes can sometimes be out of sync with public perception of conditions, especially if the use is impaired. Extensive rooted aquatic plant growth (macrophytes) restricting swimming, fishing, and boating activities in near-shore areas are frequently identified as an indication of poor lake water quality. However, macrophytes are generally not the result of high in-lake concentrations of nutrients, but rather the presence of accumulated nutrients in near-shore sediments. Certain areas of macrophytes are actually recognized as important for maintaining habitat for fish spawning and feeding (although small lakes dominated by dense stands of macrophytes can have stunted fish populations).

Phytoplankton or algae blooms *are* a direct response to excessive in-lake nutrient concentrations, originating from external pollutant sources or in-lake recycling from bottom sediments. Blue-green algae blooms of certain species, such as *Aphanizomenon* or *Microcystis,* render the water "green" and unsightly for swimming and often accumulate on shorelines and decay, causing offensive odors and (in rare cases) possible toxicity to pets and humans.

In many lakes, an antagonistic relationship may exist between macrophytes (large rooted aquatic plants) and phytoplankton (small floating plants). In lakes where macrophyte growth is a major portion of the total lake area (e.g., Fish Lake), macrophytes may remove phosphorus from the lake water to levels low enough to prevent excessive phytoplankton blooms. In lakes where the area of macrophyte growth is minor in relation to the whole lake (e.g., Lakes Mendota and Monona), phytoplankton blooms can occur, and may restrict light penetration sufficiently to reduce the depth-distribution of macrophytes. In these lakes, the effects of change in nutrient loadings from external sources will be most apparent. In most cases, phosphorus is cited as the limiting or most important nutrient governing phytoplankton growth in lakes. In addition, lakes that thermally stratify and have a flushing rate less than six times/year generally are more sensitive to external phosphorus loadings than lakes that have high flushing rates and/or do not stratify.

WDNR has continued a basic water quality monitoring program on the Yahara Lakes since the Dane County Water Quality Plan was first completed in 1979. Except for Fish Lake, other lakes in the region have not been as extensively or consistently monitored as the Yahara Lakes. Based on observations and limited monitoring data, most of the named lakes and ponds in the region are considered *eutrophic* (nutrient rich and overly fertile). Fish Lake has been classified as *mesotrophic* (medium fertility), although current monitoring indicates the lake is becoming eutrophic. Recent monitoring results for specific lakes are summarized in later sections of this report.

Figure 21. Median Summer Trophic State Index (TSI) Values Based on Secchi Disk Results



TSI	TSI Description
TSI>80	Algal scums, summer fishkills, few plants, rough fish dominant. Very poor water quality
TSI 70-80	Becoming very eutrophic. Heavy algal blooms possible throughout summer, dense plant beds, but extent limited by light penetration (blue-green algae block sunlight).
TSI 60-70	Blue-green algae become dominant and algal scums are possible, extensive plant overgrowth problems possible.
TSI 50-60	Lakes becoming eutrophic: decreased clarity, fewer algal species, oxygen-depleted bottom waters during this summer, plant overgrowth evident, warm-water fisheries (pike, perch, bass, etc.) only.
TSI 40-50	Water moderately clear, but increasing chance of low dissolved oxygen in deep water during the summer.
TSI 30-40	Deeper lakes still oligotrophic, but bottom water of some shallower lakes will become oxygen depleted during the summer.
TS< 30	Classical oligotrophy: clear water, many algal species, oxygen throughout the year in bottom water, cold eater, oxygen-sensitive fish species in deep lakes. Excellent water quality.

Source: Wisconsin DNR

Yahara Lakes

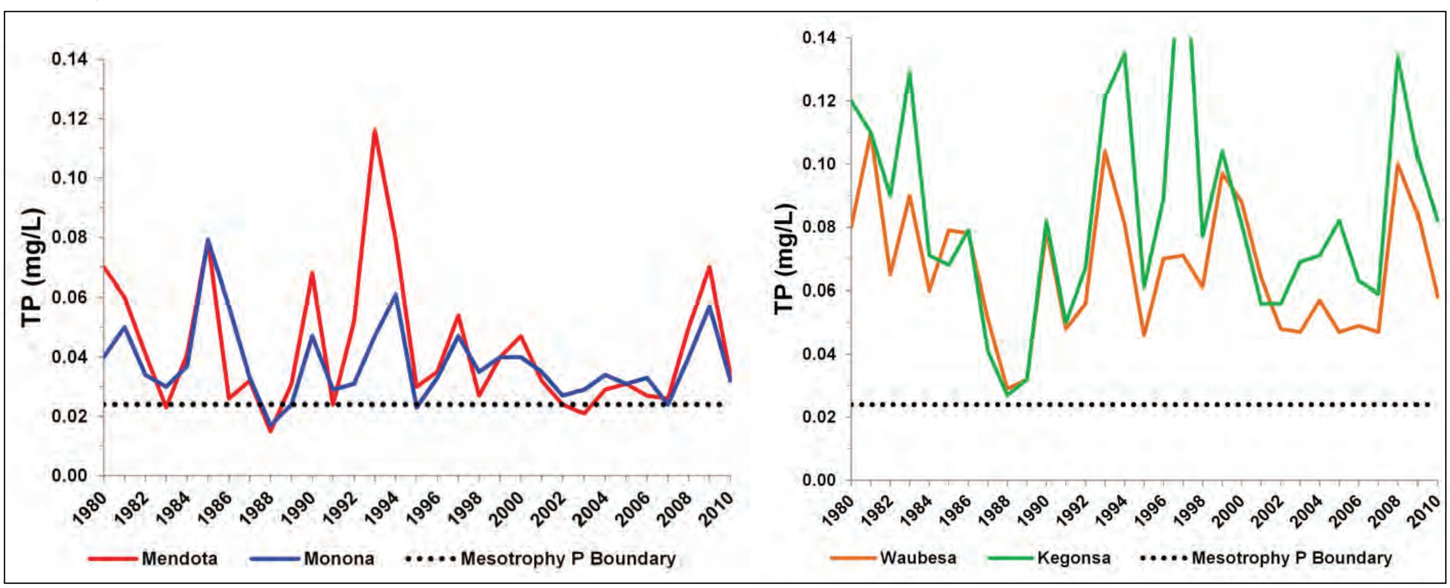
As part of the cooperative water resources monitoring program coordinated by the Regional Planning Commission, the USGS conducts stormwater monitoring on the Upper Yahara River, Pheasant Branch Creek, and Spring Harbor storm sewer. Phosphorus is monitored on two principal tributaries to Lake Mendota (the Upper Yahara River and Pheasant Branch Creek) because it is the key nutrient fueling algae and plant growth. Annual phosphorus loads and mean discharges are illustrated for those two stations (**Figures 18 and 19**).

Monitoring data indicates that most of the nutrient loading occurs during the late winter and early spring months when spreading manure on frozen ground occurs.[65] In addition, much of this phosphorus is in the dissolved form and therefore biologically available or reactive. This has a cascading effect since about two-thirds of the phosphorus loading to the lower Yahara Lakes comes from upstream lakes (See **Figure 45** Section VI).[66] According to researchers, Lake Mendota's water quality could improve relatively quickly if the amount of phosphorus flowing into the lake can be significantly reduced. The significance of this is that phosphorus load reductions to Lake Mendota could produce cascading water quality improvements in the downstream Yahara Chain of Lakes as well.[67] More detailed information is contained in the Yahara Lake Chain of Lakes section of this report.

Phosphorus and water clarity measurements for the Yahara lakes have been regularly recorded by the WDNR since the mid-1970s, and more recently by the U.W. Center for Limnology. Summarized water clarity results are displayed in **Figure 21**. Median summer TSI values based on water clarity in the lakes is determined by the maximum depth to which a black and white secchi disk can be seen from the lake's surface.

Water clarity is strongly influenced by precipitation, nutrient loading and associated algae growth. For example, during the drought in 1987 and 1988, nutrient loadings dropped and water clarity generally improved (lower TSI values). Following the flooding in 1993, nutrient levels increased and water clarity declined (higher TSI values). The more algae there is in a lake, the "greener" the lake appears, and water clarity is diminished. On the other hand, when there is less algae, sunlight can penetrate deeper and stimulate the growth of rooted aquatic plants.

Figure. 22. Total Phosphorus Concentrations in the Surface Waters of Lakes Mendota, Monona, Waubesa, and Kegonsa, 1980-2010



TP represented as median July-August summer values during 1980-2010.
TP <0.024 mg/L signifies mesotrophy; TP >0.024 mg/L signifies eutrophy.
Source: Lathrop and Carpenter 2011

65 Lathrop, 2007.
66 Lathrop, 2011.
67 Lathrop, 2010.

The water clarity of each of the Yahara Lakes varies seasonally and annually. In general, long-term water quality shows declining trends (higher TSI values) in Lakes Monona, Waubesa, and Kegonsa. The good news is that water quality in Lake Mendota is showing some improvement, possibly the result of the Lake Mendota Priority Watershed Project and other conservation activities being conducted in the watershed. Considerable improvement in Lake Wingra's water quality has resulted from the removal of carp in 2008, in addition to other conservation practices being promoted in the watershed by the Friends of Lake Kegonsa and the City of Madison. Despite existing programs to control nutrients and stormwater runoff, more effort is needed to improve water clarity in the Yahara Lakes.

Plots of median July-August total phosphorus (TP) concentrations for 1980-2010 indicate that lakes Mendota and Monona were highly correlated as were Waubesa and Kegonsa (**Figure 22**). While Mendota and Monona often had median TP concentrations well into the eutrophic region, TP in some summers was occasionally low enough to reach the mesotrophic boundary of 0.024 mg/L. Both lakes notably exhibited mesotrophic conditions in 1988 in response to the two-year drought. Even though summer TP concentrations in Waubesa and Kegonsa were much higher than in Mendota and Monona, TP dropped close to the mesotrophic boundary in response to the late 1980's drought. Conversely, when the lakes were "shocked" with extreme phosphorus loads (e.g., 1993 and 2008), July-August TP concentrations returned to more normal levels in 1-2 years. The implications of this is that the relatively rapid TP response of lakes to either high or low phosphorus loads provides strong evidence the lakes will respond positively to <u>major</u> loading reductions efforts.[68]

Lake response modeling indicates the probability of July-August days with mesotrophic water quality conditions in Lake Mendota would increase if average distribution of phosphorus loads to the lake were to decline (**Figure 23**). Modeling results also indicate that food web dynamics, particularly grazing by *Daphnia* zooplankton had a strong influence on the probability of mesotrophic conditions in Lake Mendota. For example, under current loading conditions <u>and</u> with the lake dominated by the *D. pulicaria* zooplankton grazer, the probability of lake TP being in the mesotrophic state was slightly less than 20 percent, or almost 2 out of 10 July-August days on average over many years (arrow A). If average P loads were reduced by 50 percent in the future with the same grazer dominance, then the probability of mesotrophy during July-August is predicted to be almost 4 out of 10 days (arrow B).

Prior studies indicate that when *D. pulicaria* were effectively eliminated due to predation by large densities of planktivorous fish, then the lake was only populated for short periods by the smaller-bodied *D. galeata mendotae* – a zooplankton species that had significantly reduced grazing pressure on algae.[69] Researchers found under current P load conditions and <u>without</u> the presence of the large grazer, the probability of lake TP being in the mesotrophic state is only about 5 percent, or 1 out of 20 days (arrow C). Under the same scenario but with a 50 percent P load reduction, the TP mesotrophic probability increases to about 15 percent, , or 3 out of 20 days (arrow D). This is close to the probability under the current distribution of P loads with the large grazer present (i.e., 20 percent). In other words, the modeling results indicate that a 50 percent P load reduction could be negated by a food web shift causing the loss of the large-bodied *D. pulicaria* grazer in the lake.

Given that a significant number of agricultural and urban Best Management Practices have been installed in Mendota's watershed in recent decades – especially the implementation phase of the Lake Mendota Priority Watershed Projects in 1998-2008 – "the lack of a significant decline in long-term average P loads and associated water clarity is disconcerting."[70] One explanation is that the pollution reduction gains from the installed practices were offset by an increased frequency of extreme precipitation events as well as a worsening manure management problem in the watershed. On the positive side, if the management practices had not been installed, then P loadings would likely have been much higher in recent years.

The Yahara Lakes are currently included in the Rock River Basin TMDL for phosphorus and sediment. It is believed that efforts to reduce phosphorus and sediment loading to waters in the watershed will improve water quality conditions in the Yahara Lakes. As part of this effort,

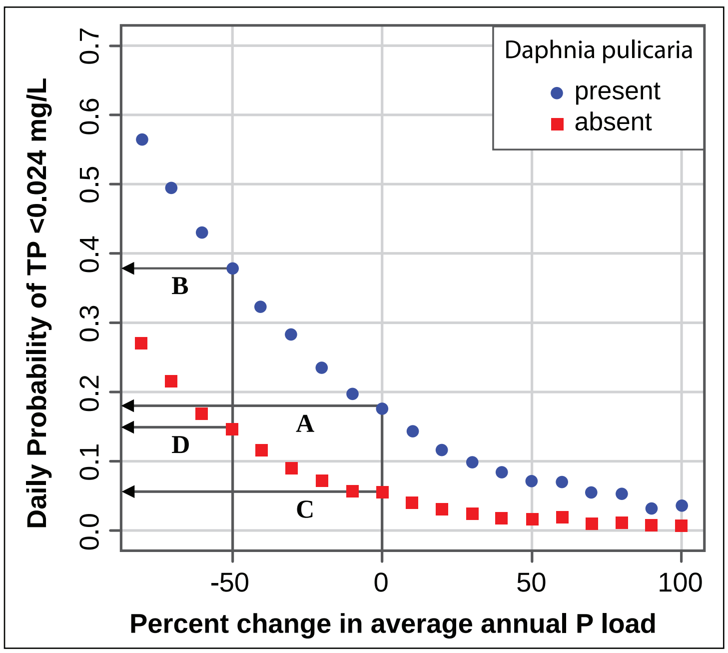
68 Lathrop, 2011.

69 Lathrop, 1996, 1999, 2002

70 Lathrop, 2011

models have been developed characterizing the quantity and quality of stormwater runoff and pollutant loadings from representative land uses in the watershed. This information will be used to help identify the areas with the greatest reductions needed as well as determining cost/benefit ratios (e.g., nutrient trading) for targeting and installing urban and agricultural Best Management Practices. A companion project "Yahara Clean" was launched in 2008 as a joint partnership among local communities in the region to help achieve that end.

Figure 23. Daily probability of Lake Mendota having a surface water Total Phosphorus concentration <0.024 mg/L (mesotrophy) during July-August and the presence/absence of the large bodied Daphnia grazer



Source: Lathrop and Carpenter 2011

Chlorides

Another water quality concern is chloride from road salt. According to the Madison Department of Public Health, chloride levels in the Yahara Lakes have risen an average of 94 percent since 1972 (Attachment C-9 and C-10). The lakes most affected by street drainage from the City of Madison are Lakes Wingra and Monona. Although Lake Mendota is the least affected by Madison runoff, a monitoring station situated upstream has shown comparable results. This illustrates the need for countywide participation in controlling salt usage.

One of the most detrimental effects of heavy salt runoff may be the establishment of density gradients that prevent lake mixing. This leads to stagnation of bottom layers and aggravates the effects of decomposing organic matter on oxygen levels. Other effects may include pH increases and changes in ecological communities, including encouragement of blue-green algae.

Heavy Metals and PCBs

Sediment surveys in Lake Monona have revealed elevated copper and arsenic concentrations associated with the past use of herbicides to control algae and rooted aquatic plants. These herbicides are no longer used, but the metallic residues have accumulated in the sediments. There are also concerns that sediment containing metals such as mercury can be scoured from tributary streams into Lake Monona from peak flows caused by large rainstorms. Mercury can then accumulate in fish in the lake. This may have already occurred since large walleyes in both Lake Monona and Lake Waubesa contain levels of mercury exceeding the public health standard (0.5 parts per million) and have been added to the Wisconsin Fish Consumption Health Advisory List.

Sediment samples reveal a buildup of several heavy metals above background levels in Lake Monona. Except for mercury, heavy metals found in Lake Monona have a low potential for bioaccumulation in fish, and do not pose a human health threat. However, deposition of heavy metals and other contaminants can restrict future lake management options, particularly dredging, due to regulatory limits on sediment disposal.

Some white bass and carp are contaminated with PCBs. Both Lakes Mendota and Monona are listed by the WDNR as 303(d) Impaired Waters because of PCBs, although the priority is considered "low." WDNR advises citizens to restrict their consumption of these fish.

Other Lakes

Other lakes in the region have not been as extensively or consistently monitored as the Yahara Lakes. Fish Lake is a high quality deep lake in northwestern Dane County showing signs of accelerated eutrophication. There have also been water quality concerns for small impoundments such as Lake Belle View in the Village of Belleville and Stewart Lake in the Village of Mt. Horeb. These kind of impoundments are usually shallow and eutrophic and also suffer from extensive sedimentation, largely as a result of nonpoint pollution and high natural fertility levels. Significant dredging and associated restoration efforts have been conducted on these two lakes to help reverse and restore the water quality conditions there, along with the public's use and enjoyment.

Most other lakes and impoundments in the region are generally shallow and quite small relative to their watershed area. Accelerated sedimentation and eutrophication can occur as a result of erosion and runoff from their watersheds. Based on observations and limited monitoring data, most of the named lakes and ponds in the region are considered eutrophic.

D. Climate Change.

A consensus is forming among most environmental scientist studying climate that global climate change is occurring. The climate change is driven in part by the emission of green-house gases (GHG) that traps heat in the atmosphere resulting in global warming. The Wisconsin Initiative on Climate Change Impacts (WICCI)[71] temperature modeling projects an annual average temperature increase of 6-7^0 F between 1980 and 2055 for Dane County.

The climate warming may affect surface and groundwater resources of Dane County in several ways. John Magnuson of the UW-Madison Center for Limnology notes that the average duration of ice cover on Lake Mendota and lakes in the northern hemisphere has decreased over the last 50 years while the average fall-winter-spring air temperature has increased.[72] A trend of more intense precipitation events (i.e. the one-, two-, and three-inch storms) is developing. Modeling shows an increased frequency of intense storms with greater than 3 inches of precipitation in a 24-hour period for Dane County.[73] Climate change is anticipated to impact every aspect of the water cycle, and many of the underlying assumptions that stormwater managers use for runoff and storm design might become outdated if these predictions become a reality.[74] Climate change will therefore necessitate a reappraisal of existing approaches for stormwater management. For example, if the number and intensity of warm weather storm events increases as predicted, habitat and water quality improvements already gained may be lost. This is because these more frequent and intense storms could overwhelm implemented land conservation measures, increasing sediment and nutrient loading to surface waters.

In addition, a DNR fisheries biologist working with WICCI predicts that "climate change will likely cause reductions in all cold water habitats and coldwater fish species in Wisconsin…."[75] Lyons et.al. [76] used water temperature models to predict the possible impacts of stream water temperature increase on certain fish species. Of the 50 species examined, 23 are predicted to decline in distribution in Wisconsin, 23 species would increase in distribution, while four fish species would see no change. The most dramatic decline of coldwater fish species would occur in small coldwater streams such as Fryes Feeder, Deer Creek, Schlapbach Creek, and Garfoot Creek. The Lyons study suggests that small increases in summer air and water temperature will have major effects on the distribution of fish in Wisconsin streams. Additional modeling and vigilant monitoring will be needed to better understand and meet the challenge, or adapt to a warming climate.

The WICCI effort focuses on adaption and its Working Groups are the key components in those efforts. Each Working Group focuses on a particular issue, activity, ecosystem, or geographic area to identify potential vulnerabilities and impacts, and to develop recommendations to increase resilience in the face of change. A few examples of adaptive measures include redesigning stormwater management systems to handle increasing volumes of stormwater; targeting land, riparian, and water management and stream restoration activities to offset rising air temperatures and changes in precipitation; planting vegetation more suited for longer, warmer growing seasons; among other strategies.[77]

71 See the WICCI website for more information on the effects of climate change on Wisconsin. http://www.wicci.wisc.edu/
72 Magnuson, 2009.
73 Potter, 2010.
74 Hirschman, 2001.
75 Pomplum, 2011
76 Lyons, 2010.
77 Wisconsin Initiative on Climate Change Impacts (WICCI), 2011.

VI. Water Quality Conditions in Specific Streams and Lakes

The amount and quality of data available to characterize the conditions of streams and lakes in the region varies considerably from one water body to another. A need to update this appendix has arisen to reflect more recent water quality monitoring results and current resource conditions. This information is presented in the following section, organized by river basin.

The sources of data and information used for this summary are too numerous to list here, but some of the more comprehensive sources are noted to illustrate the scope of available information on water resources in the region. For example, the USGS and the WDNR have carried out substantial surface water quality monitoring in the county. The USGS has conducted baseflow water chemistry monitoring of various streams in the county for over the last 30 years. They have also conducted continuous discharge and storm event pollutant monitoring at selected streams and storm sewer outfalls. USGS monitoring results can be found on-line at the Wisconsin USGS website (http://wi.water.usgs.gov/data/waterquality.html). State USGS staff have also authored several professional reports and papers pertaining to water resources in the county and southern Wisconsin.

The WDNR also conducts on-going water resources and fisheries monitoring programs that assess water quality, instream and riparian habitat, macroinvertebrates and fish assemblages. Much of that data can be found on the WDNR Surface Water Integrated Monitoring System (SWIMS) database (http://dnr.wi.gov/org/water/swims/). Much of the data and related information has been summarized in State of the Basin Reports, or basin plans, for the four water basins covering Dane County, including the Lower Wisconsin, Sugar-Pecatonica, and Upper and Lower Rock River Basins. However, these basin plans have not all been updated recently. More up to date information can be accessed via WDNR's Water Data Viewer (http://dnr.wi.gov/water/basin/), which is currently under development. Nonpoint source (NPS) pollution abatement priority projects and reports also provide additional data and information for those watersheds that had projects. Another important source of information were the water resources and fisheries management files and biologists at the WDNR South Central Region Office.

The Madison Metropolitan Sewerage District (MMSD) has also been conducting water chemistry, fish, and macroinvertebrate monitoring of streams that receive its treated effluent. The Dane County Office of Lakes and Watersheds and Land and Water Resources Department (LWRD) have also provided information and conducted studies and reports. Given the wealth of information available (and sometimes gaps), the following information is not intended, nor can it possibly be an exhaustive treatment of water quality conditions for every water body in the county. But it does provide useful reference to the kind of information that is available to help us understand the condition and history of a particular water body and, more importantly, help direct our resource protection/restoration efforts more effectively in the future.

A. Lower Wisconsin River Basin

The Dane County portion of the Lower Wisconsin River Basin encompasses about 141,620 acres that include the Roxbury Creek Watershed, Black Earth Creek Watershed, a portion of the Mill and Blue Mounds Creek Watershed and a portion of the Lake Wisconsin Watershed. This part of the county holds a wealth of water resources and diverse aquatic habitats that span both glaciated and Driftless Area landscapes. Water resources in the Dane County portion of the basin include a regionally popular trout stream (Black Earth Creek), upland Driftless Area trout streams, agricultural ditched streams, seepage lakes, impoundments, and cut-off channel oxbow lakes that are part of a biologically diverse and recreationally important large river system known as the Lower Wisconsin State Riverway.

Lower Wisconsin State Riverway

While the longest river in the state finds its origin in Lac Vieux Desert, some 338 miles upstream in Vilas County, the Lower Wisconsin State Riverway remains one of the most biologically diverse large river systems remaining in the United States[78]. The river also lies within the Western Coulee and Ridges Ecological Landscape that provides opportunities to protect and manage floodplain forests and large river ecosystems along with the significant assemblages of fish, herptiles and invertebrates.[79] In 1989, Act 31 established the Lower Wisconsin State Riverway to protect the scenic beauty and natural character of

78 Marshall, 2008b.
79 WDNR, 2005b.

the 92-mile Lower Wisconsin River from Prairie du Sac to the confluence with the Mississippi River. This unique public-private partnership was established as an alternative to the proposed federal Wild and Scenic Rivers Act designation that was publicly controversial.[80] That same year, DNR staff recommended Outstanding Resource Water (ORW) designation for the Lower Wisconsin River to reflect the high biodiversity (including 98 species of fish, rare aquatic insects, diverse and rare mussel beds, and herptiles), tremendous sport fisheries, and recreation use by over 400,000 visitors a year. The alternative designation of Exceptional Resource Water (ERW) was ultimately adopted in Wisconsin Administrative Code NR 102.

2009 marked the 20-Year Anniversary of the Lower Wisconsin State Riverway. Coinciding with the anniversary, an educational poster was designed by Flying Fish Graphics and was sponsored by numerous public and private partners to celebrate the tremendous biodiversity of the river. The high biodiversity reflects the braided river channel system with diverse habitats within a floodplain that is unimpeded by dams. The Lower Wisconsin River was also spared the severe water quality problems that plagued the upper reaches prior to the Clean Water Act, due to the long distances from the industrial and municipal wastewater point sources. Nonetheless, the Lower Wisconsin River was somewhat degraded by the pulp and paper mill industry throughout the 1970s as organoleptic compounds (relating to taste and smell) tainted fish flesh and rafts of foam floated downstream from the Prairie du Sac dam. By the early 1980s, the Lower Wisconsin River benefitted from the implementation of the Clean Water Act as organic loading from pulp and paper mills and other point sources had declined by 95%. Coinciding with reduced point source pollution, land uses within the surrounding Driftless Area improved along with increased tributary and upland groundwater flows to the floodplain.[81]

The Dane County reach of the Lower Wisconsin River is about 14 miles long. M-IBI sampling conducted in 2009 the vicinity of USH 12 indicated generally "Fair" biotic integrity (range = 0.74-7.54, average = 3.01, n=8).[82] Some of the most environmentally sensitive habitats and aquatic life forms are found within the Dane County portion of the State Riverway including the reach below the Prairie du Sac Dam and floodplain lakes. The dam functions as a migration barrier and numerous rare fish and mussels are found within this reach of river including State Endangered crystal darter, State Threatened blue sucker, State Threatened paddlefish, State Endangered shoal chub, State Threatened pistolgrip mussel and State Endangered Higgin's Eye mussel. The endangered species within this reach of river are often exposed to low dissolved oxygen levels due to organic loading from hypereutrophic Lake Wisconsin and anoxic hypolimnetic releases from the Prairie du Sac dam.[83]

Cutoff channel oxbow lakes are found in several locations within the Dane County reach. Floodplain lakes have been the least surveyed and understood waterbodies in the state and their invaluable ecological functions had been largely overlooked for decades. A 2009-10 small-scale lakes planning grant survey of Dane County floodplain lakes helped bridge the information gap.[84] The surveys demonstrated that the floodplain habitats support rare fish species such as the State Endangered starhead topminnow, State Special Concern pirate perch, State Special Concern lake chubsucker and State Special Concern mud darter. The late George Becker (1983) described the starhead topminnow as imperiled and recommended establishing a "topminnow sanctuary" for the rare fish. However, the recent floodplain surveys in Dane County and other State Riverway counties demonstrated that the starhead topminnow is more abundant than previously thought and that the State Riverway may actually function as the sanctuary that Dr. Becker had envisioned. While floodplain lake data were scarce until recently, the USGS documented long term trend of increased Driftless Area baseflows, coinciding with higher groundwater levels, may have improved the habitat for starhead topminnows. The rare fish appears to thrive in backwater habitats that contain abundant aquatic plants and upland or hillslope groundwater discharge.

Recent surveys of floodplain habitats included cutoff channel oxbows, creek bottoms, side channels that are intermittently cutoff from the river during low flows and beaver ponds. The floodplain lake habitats that support fish populations are often sustained by upland groundwater flow but are also vulnerable to groundwater

80 Matthews, 2009.
81 Marshall, 2009.
82 WDNR Water Data Viewer 2012.
83 Marshall, 2004b.
84 Marshall, 2010.

contamination and runoff pollution.[85] These waterbodies also display variable conditions in response to changing river stages and groundwater sources. For example, in 2010 high river flow rates altered the floodplain hydrology significantly when compared with the daily median flow rates (**Figure 24**). In Sauk County, very low dissolved oxygen levels in numerous oxbows coincided with high river stages. When river stage rises, nutrient rich alluvial groundwater typically displaces upland groundwater.[86]

The entire Lower Wisconsin State Riverway floodplain is vulnerable to groundwater pollution and recent research had demonstrated that fish and aquatic life are no less susceptible to high nitrates than human infants.[87] In Sauk County, an oxbow that intercepted upland groundwater also contained higher nitrate levels than nearby wetlands and other floodplain waterbodies that are influenced more by alluvial groundwater and river stage.[88] Recommendations from the Dane County small-scale lake planning grant study include:

(1) Dane County should work with the Lower Wisconsin State Riverway Board and Department of Natural Resources to reevaluate existing State Riverway boundaries. Environmentally sensitive floodplain lakes would benefit from expanded buffer zones to protect both upland groundwater and reduce surface runoff pollution.

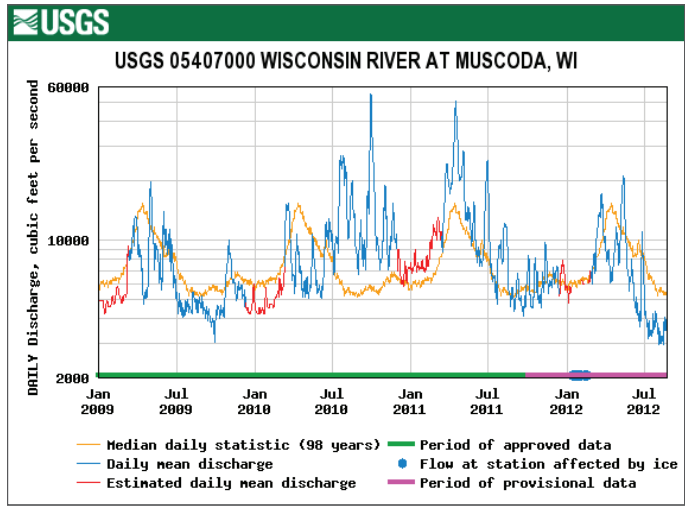
(2) Given the environmental sensitivity and important ecological functions of the floodplain lakes, the Department of Natural Resources should classify these waterbodies as Outstanding Resource Waters (ORW).

(3) The pre-1994 State Stewardship fund for the Lower Wisconsin State Riverway should be restored.

(4) Future research should focus on a few floodplain lakes over a wide range of river stages and flows. Upland groundwater and alluvial groundwater inputs will likely fluctuate, along with floodplain lakes water quality, over a range of river stages. More detailed biological inventories are also needed.

(5) Consider restoring the lower reaches of Dunlap Creek and Marsh Creek to characteristics and habitat of natural floodplain creek bottoms.

Figure 24. Lower Wisconsin River Flow Rates in 2009-10 demonstrate variable conditions within the river floodplain



85 Marshall, 2010.
86 Amoros, 2002.
87 Carmago, 2005.
88 Pfeiffer, 2005.

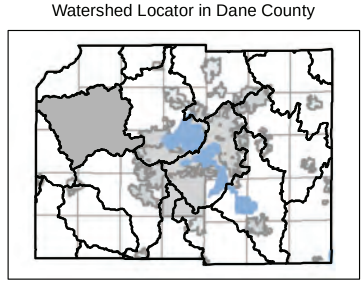
Black Earth Creek Watershed

0 1 2 3 Miles

Explanation

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland
- Impaired Water
- Outstanding Resource Water
- Exceptional Resource Water
- Wetlands > 2 acres
- Perennial Stream
- Intermittent Stream
- Constructed Drainage
- Lakes and Ponds
- City
- Village
- Town
- Major Lake

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Black Earth Creek Watershed (LW17)	
Land Cover	**Acres**
Residential	3,257
Transportation	2,506
Industrial	468
Commercial	102
Institutional/Governmental	175
Communication/Utilities	43
Other Lands*	5,588
Agricultural	30,183
Outdoor Recreation	884
Woodland	21,259
Open Water	140
Wetlands	1,511
Hydric Soils**	4,790
Size of Watershed in Dane County	66,117

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Black Earth Creek Watershed encompasses 103 square miles in Dane County including 72 miles of streams and 27 miles of classified trout habitat. The upper reaches of Black Earth Creek and Halfway Prairie Creek drain glaciated landscapes. Otherwise, streams in the southern border of the watershed benefit from the Driftless Area geology as groundwater discharges sustain cold and cool water fish populations and reduce water quality problems linked to intensive agriculture and urbanization. Land uses in the watershed have limited the potential ecological integrity of most streams in this watershed. Previous studies had identified water quality problems due to cropland erosion, channel ditching, barnyard runoff, construction site erosion, and increased impervious surfaces; the latter two reflecting development pressures.[89] Most of the streams in the watershed flow through rural and agricultural land, except for the lower reach of Brewery Creek in Cross Plains, and Black Earth Creek from Middleton downstream to below the Cross Plains wastewater treatment plant. The Black Earth Creek watershed was a DNR nonpoint source pollution abatement Priority Watershed Project between 1989 and 2001. Over $125 million was spent on a variety of Best Management Practices including wetland restoration, grassed waterways, LUNKER (instream habitat) structures, and vegetated filter strips. Partners in the watershed project included the Dane County Land Conservation Department, Black Earth Creek Watershed Association (BECWA), Trout Unlimited, and USGS.

89 Dane County OLW, 2008.

Black Earth Creek

Black Earth Creek rises in the Johnstown terminal moraine west of Middleton and flows about 27 miles to the confluence with Blue Mounds Creek in Iowa County. Most of the watershed is dominated by thick deposits of glacial outwash and alluvium, materials that form an excellent aquifer for sustained stream flow.[90] Black Earth Creek is a regionally popular trout stream and trout enthusiasts had rated it one of the top 100 trout streams in the nation. The sustainable habitat for a productive brown trout fishery reflects springflows that originate as wooded hillslope groundwater recharge areas with additional groundwater flow originating in the Sugar River Watershed.[91] Under NR 102, Black Earth Creek is designated Outstanding Resource Water (ORW) from the headwaters downstream to the Village of Cross Plains wastewater treatment plant. This designation reflects the well established Class 1 trout fishery when the anti-degradation rule (NR 207) was adopted in 1989.

The best trout habitat extends from just above Cross Plains downstream to the Village of Black Earth. The upper reaches of the ORW designation near Middleton support mixed stenothermal cold and eurythermal warmwater populations of fish; likely reflecting channel modifications and altered hydrology. Below the Village of Black Earth to the confluence with Blue Mounds Creek, Black Earth Creek again supports mixed populations of stenothermal cold and eurythermal warmwater fish. While Black Earth Creek supports high densities of wild brown trout, coldwater IBI scores from 2001-08 indicated “fair” environmental conditions with a mean score of 38 (range = 20-70, n=16). Below the Village of Black Earth, coldwater IBI scores indicated “poor” conditions and reflect the mixed stenothermal–eurythermal fish populations. IBI scores were “Good” between the Villages of Black Earth and Cross Plains. Forty-seven M-IBI samples taken between 2002 and 2011 also indicated “Fair” biotic integrity overall. Broken down into sections, biotic integrity averaged “Poor” at one site in the headwaters below the City of

90 DCRPC, 1992.
91 Potter, 1995.

Middleton, "Fair" at four sites near Cross Plains, "Fair" at two sites below Cross Plains, "Good" at two sites above Black Earth, and "Fair" at two sites between Black Earth and Mazomanie. Below the confluence with Blue Mounds Creek and within the Lower Wisconsin State Riverway, rare fish species such as State Threatened starhead topminnow, State Special Concern mud darter, State Special Concern pirate perch and State Special Concern weed shiner thrive within the floodplain habitats.

While the popularity of the Black Earth Creek reflects a relatively long history for producing abundant brown trout, Black Earth Creek is threatened by more environmental problems than other high quality streams in Dane County. Environmental problems that threaten Black Earth Creek include agricultural ditching, the Refuse Hideaway Landfill U.S.EPA Superfund Site, gravel mining thermal discharges, cropland runoff, two municipal wastewater treatment plants, manure runoff, and expanding urbanization. The Black Earth Creek Priority Watershed Project (1989-2001) addressed many of these issues with partial success, including Best Management Practices that exceeded pollution reduction goals.[92] Restoration efforts did not end with the Priority Watershed Project as continued habitat improvement and water pollution control activities reflect ongoing federal programs such as the Conservation Reserve Program (CRP), Wetland Reserve Program (WRP) and nutrient management. In spite of these successes, frequent dissolved oxygen criterion violations and periodic fish kills occur. Expanding urban development and impervious surfaces discharging excess stormwater flows are thought to be the cause of these problems. Urbanization continues to pose long term threats to Black Earth Creek.

Dissolved oxygen levels frequently drop below trout stream criterion limit of 6 mg/L. Chronic low dissolved oxygen in the stream had been previously well documented.[93] These violations typically occur during storm events when specific conductance levels are lower, reflecting soft rain water inputs, and when creek levels rise (**Figures 25 and 26**). In addition to the frequent low dissolved oxygen levels, fish kills occasionally occur and sometimes result in significant trout mortality. In June of 2001, a storm related fish kill reduced trout densities from 64 to 86 percent west of Cross Plains.[94] The specific cause(s) that occurred during the June 5-inch storm event is still unknown. However, WDNR reported potential sources including manure management, WPDES permitted dairy farms, urban runoff, and tile drains from former wetlands (now cropped) that could potentially discharge pesticides and commercial fertilizers to the stream. It is unknown whether the fish kill was the result of a single factor or cumulative effect from many sources. The impacts of the fish kill on trout populations appeared to be relatively short-lived. Electroshocking survey results from 2002 and 2003 demonstrated that the wild brown trout are resilient in Black Earth Creek. Both sizes and densities in the creek west of Cross Plains were found at levels that preceded the 2001 fish kill.[95] Macroinvertebrates sampling immediately after the fish kill revealed no measurable impact of the pollution.

92 Dane County OLW, 2008.
93 Walker, 2001.

In October 2009, USGS and WDNR set up a continuous water quality monitoring system consisting of four "real-time" monitoring stations from Cross Plains to Black Earth. These stations provide automated alerts if diagnostic water quality parameters are exceeded. This allows water quality managers to follow up on watershed conditions and potential threats to the stream when they occur. Diagnostic water quality chemistry results for ammonia, chloride, conductivity, pH, turbidity, and suspended sediment are collected at these stations and are used to measure and document changing stream conditions through the full range of wet- and dry-weather periods. As of August 2012 no alerts have occurred.

Additional information gleaned from the USGS monitoring station in Black Earth revealed that Black Earth Creek flow has been gradually increasing (**Figure 27**).[96] This trend is consistent with other Driftless Area streams where long term base flow rates have increased and may reflect conservation efforts.[97], [98] Good stream health and resiliency have been found to be very much related to maintaining more natural hydrologic conditions or flow regimes.[99] Urban and agricultural Best Management Practices that increase groundwater recharge and reduce stormwater runoff and pollutant loading can help maintain and possibly even *improve* water quality conditions in Black Earth Creek.

94 WDNR, 2001b.
95 WDNR Water Files, 2003.
96 Krohelski, 2002.
97 Gebert and Krug, 1996.
98 Juchem, 2008.
99 Poff, 2010a.

Figure 25. 2010 Dissolved Oxygen and Specific Conductance Data from the Cross Plains Realtime Monitoring Site (USGS)

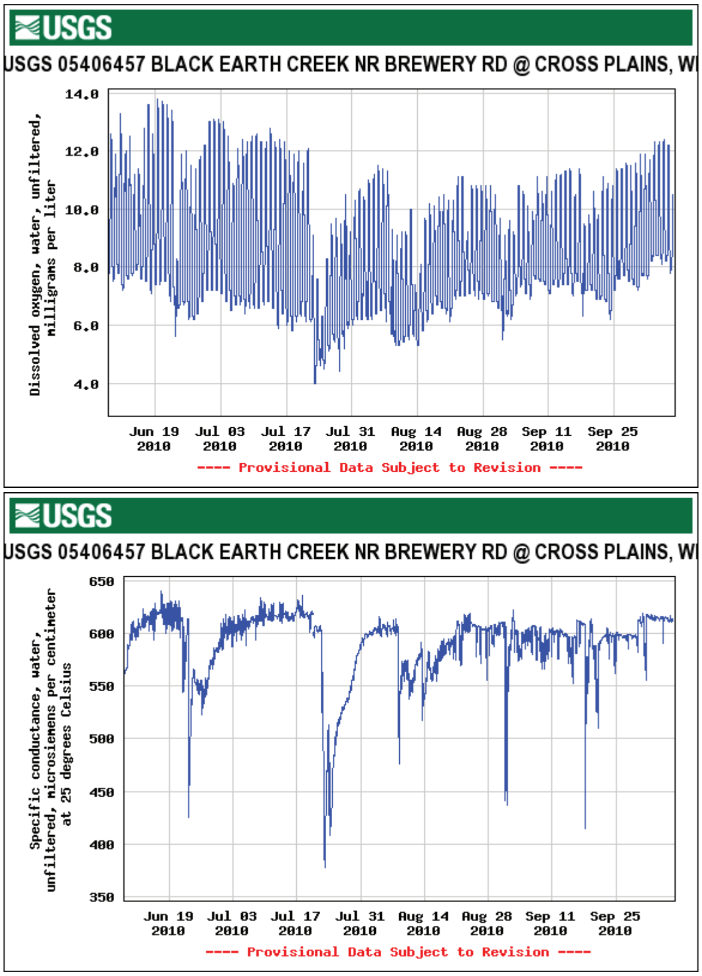


Figure 26. 2010 Dissolved Oxygen and Gage Height from the Black Earth Realtime Monitoring Site (USGS)

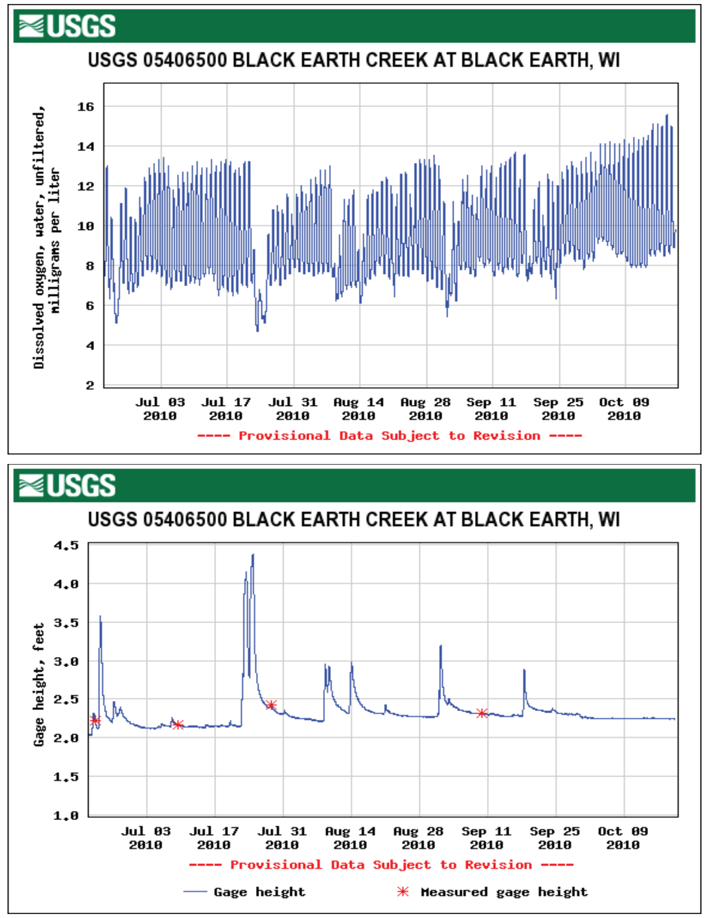
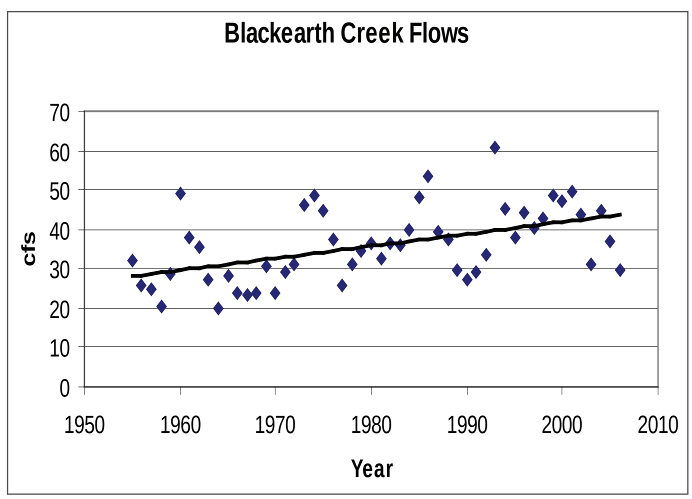


Figure 27. Black Earth Creek Mean Annual Stream Flow Trend (R^2=0.71)



Even though the Priority Watershed Project ended in 2001, the numerous partners continue to seek management strategies to protect and improve the popular trout stream. The *Black Earth Creek Resource Area Plan*,[100] prepared with input from a diverse steering committee, recommended 10 specific actions that will help protect the trout stream and associated natural resources within the Black Earth Creek Valley:

1. Protect/promote cost-share funding and other incentives to acquire lands or property rights for priority areas identified in the Resource Area Plan.
2. Encourage/promote participation in the farmland preservation programs offered by various public and private groups, such as the American Farmland Trust, Pheasants Forever, etc.
3. Protect upland wooded areas, especially steep slopes to prevent soil erosion, promote infiltration, provide wildlife habitat, resource connectivity and scenic beauty, such as through easements along ridgelines and hilltops.
4. Promote trail linkages between various sites and across jurisdictional boundaries, such as a trail along the length of the creek corridor between Middleton and Mazomanie, connecting with the Ice Age Trail as well as neighboring communities.
5. Use public access areas as stepping stones connected with and along the trail to enhance outdoor recreation and educational opportunities, including exhibits and displays.
6. Restore glacial Mud Lake west of the Middleton business park as a controlled surface and groundwater management facility to help protect Black Earth Creek.
7. Promote infiltration practices as a means of protecting groundwater discharge to Black Earth Creek (e.g., grass swales, retention areas, and rain gardens; rooftop storage/runoff directed to lawns and other more pervious areas instead of driveways, parking lots and streets).
8. Incorporate natural resource elements as specific conservation design features in new development and re-development projects.
9. Provide advice to farmers, developers and homeowners on opportunities they can take to help protect Black Earth Creek.
10. Investigate the feasibility of pumping more water from municipal wells located closer to the Yahara Lakes (Middleton and Madison) resulting in less groundwater being captured from the Black Earth Creek watershed.

100 DCRPC, 2003.

Brewery Creek (Enchanted Valley Creek, Dry Run Creek)

Brewery Creek is a small tributary of Black Earth Creek that enters from the north in the Village of Cross Plains in Dane County. The stream is 2.7 miles long and drains a 10.5 sq. mile watershed. Brewery Creek currently supports a diverse Fish and Aquatic Life (FAL) community with the potential of supporting a coldwater community. The creek provides important habitat for forage fish and for small brown trout. This habitat, however, is affected by modifications such as dredging and ditching. The creek is subject to flooding and low summer flows. These problems may be exacerbated by increasing development in Cross Plains where additional stormwater runoff could contribute a larger volume of stormwater and pollutants to the creek, and increased municipal pumping could reduce baseflow conditions further. Also as a tributary to Black Earth Creek, nutrient and organic enrichment to Brewery Creek adds to Black Earth Creek's nonpoint source pollution problems.

Brewery Creek has a long history of water quality degradation. In the 1980s, manure management problems had eliminated environmentally intolerant macroinvertebrate populations in the creek. In August 1990 dissolved oxygen actually dropped to 0 mg/L during a storm event. Since then biotic integrity has shown some improvement. A study conducted between 1999 and 2002 revealed improved conditions in Brewery Creek and demonstrated that staged subdivision development with stormwater management and erosion controls can minimize impacts to a receiving stream during the construction phase.[101] As part of that study biological indicators indicated that the stream had improved from a watershed perspective and that it now supports numerous brown trout that migrate upstream from Black Earth Creek. The stream's improvement may reflect the Best Management Practices completed as part of the Priority Watershed

101 Selbig, 2004.

Project (1989-2001), conservation measures, and more environmentally-friendly land use management that had been occurring within the Driftless Area.[102] M-IBI monitoring has shown biotic improvement since 1986 when the creek suffered from harmful land use practices in the watershed. Average M-IBI results between 1986-1989 indicated "Poor" biotic integrity compared to "Fair" biotic integrity results between 2001-2012 (range = 0.58-3.56, average = 2.37, n=6). M-IBI sampling indicated "Good" biotic integrity in 2012 above CTH P (range = 4.17-7.13, average = 5.65, n=2). Water quality has also shown an improvement. HBI values have gone from "Poor" water quality in 1985 to scores indicating "Good" water quality between 1995-2002.

While the macroinvertebrate data indicated improved conditions in the stream, fish community data indicated that Brewery Creek is "Poor" trout habitat. From 1999 through 2003, the fish community was dominated by tolerant species such as creekchubs, fathead minnows, golden shiners, white suckers, yellow bullhead and green sunfish. However, the common occurrence of brown trout in the small creek is a significant improvement compared to no trout previously and 100 percent tolerant fish assemblage that were found in the stream during the 1980s.

The improved fish and macroinvertebrate communities in the stream appear to contradict another study. Graczyk and others demonstrated that pre- and post-Priority Watershed Project storm related sediment and nutrient loads were not significantly different at the 0.05 probability level.[103] This information suggests that perhaps the biological improvements may reflect changes in hydrology such as increased baseflows that Black Earth Creek and other Driftless Area streams have displayed. Increased baseflows related to higher groundwater discharge may provide more hospitable conditions for fish and aquatic life especially during critical late summer periods. The maximum daily mean temperatures recorded from 2000-02 in Brewery Creek now indicate coldwater or trout habitat and reflect groundwater inputs. With these improvements in mind, it is important to minimize the potential impact that increased urban development could have on the stream. Increased stormwater runoff could potentially reverse the improvements that have been experienced in the creek as well as diminish its future prospects.

102 Juchem, 2008.
103 Graczyk, 2003.

Garfoot Creek

Garfoot Creek is a 4.3 mile long tributary that enters Black Earth Creek from the south, approximately 0.5 miles upstream of Salmo Pond. It has a relatively high gradient of 32 ft/mile. Garfoot is classified as a Class II trout stream and is designated as an Exceptional Resource Water (ERW). As part of the Black Earth Creek Priority Watershed Project, event monitoring indicated significant BOD, sediment, and nutrient loading in the stream.[104] More recently, Graczyk determined that levels of ammonia nitrogen during storm events was statistically lower following completion of Best Management Practices in the watershed.[105] Levels of phosphorus and suspended sediment were not statistically different before or after implementation of Best Management Practices. Recent WDNR baseline electroshocking surveys indicated that Garfoot Creek displays the best trout habitat in the entire watershed. From 2001-03, coldwater IBI scores ranged from 20 to 90 with a means score of 67 (n=7) or "Good" trout habitat. An experimental brook trout stocking effort is underway to determine if this environmentally sensitive native Salmonid can thrive in the stream. The stream is under consideration for Class I trout fishery management. M-IBI scores between 1996-98 reflected generally "Good" biotic condition (range = 3.66-7.32, average = 5.64, n=7). However, more current sampling is needed.

Vermont Creek

Vermont Creek arises in Section 25 of Vermont Township and flows 9.6 miles north to the confluence with Black Earth Creek in the Village of Black Earth. The creek flows through a relatively broad valley floodplain and most of the channel had been ditched and straightened. Some of the springheads that feed groundwater to the creek have been impounded. As a result, it displays marginal Class III trout habitat and was added to the 303(d) Impaired Waters list in 2004. Recent habitat restoration efforts, involving Dane County LWRD, Southern Wisconsin Chapter Trout Unlimited, WDNR, and the Natural Heritage Land Trust, have focused on box elder removal, channel sloping, cattle fencing and installation of instream habitat structures. The partners anticipate improved trout production and recruitment in the stream. WDNR baseline coldwater IBI scores (range = 10-50, average = 27, n=12) reflect the "Poor" habitat in the stream. Future WDNR electroshocking surveys will document effectiveness of

104 DCRPC, 1992
105 Graczyk, 2003.

the habitat restorations. From 2002-06 M-IBI scores reflected generally "Poor" biotic integrity in the downstream segment (range = 1.27-2.78, average = 2.23, n=5) and "Good" biotic integrity in the upstream segment (score = 7.35).

Halfway Prairie Creek

The headwater of Halfway Prairie Creek is located at the outlet of hypereutrophic Indian Lake. The stream flows 11.6 miles before entering Black Earth Creek in the Village of Mazomanie. Halfway Prairie Creek is in the state's 303(d) Impaired Waters list. Most of the stream channel had been ditched with minimal riparian buffers. As a result, the stream displays very poor habitat and supports a predominantly pollution tolerant fishery. While a few brown trout are occasionally found in the stream, WDNR baseline electroshocking surveys (2006) demonstrated very poor coldwater IBI scores (range 0-20, average = 8.3, n=6) and reflected the degraded habitat. The stream had been identified for potential trout management if buffers are expanded and habitat improved. 2006 HBI scores (average = 4.1, n=4) reflected "very good" water quality and influence of groundwater inputs. 2006 M-IBI samples indicated overall "Fair" biotic integrity (range = 0.98-4.25, average = 2.85, n=4). M-IBI samples taken below Indian Lake in 1986 also indicated "Fair" biotic integrity (range = 3.99-6.13, average = 4.91, n=4).

Wendt Creek (Spring Brook)

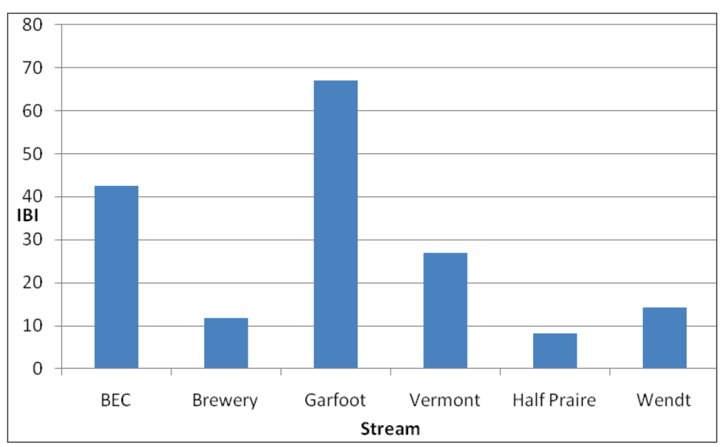
Wendt Creek arises from wetlands in Section 15 in the Town of Berry. The stream flows eight miles to join Halfway Prairie Creek in Section 16 in the Town of Mazomanie. Wendt Creek had a brief history of trout management in the early 1950s but agricultural channel ditching and water quality problems rendered these efforts unsuccessful. The stream is now listed as a 303(d) Impaired stream, but may have potential for trout management if buffers are expanded and habitat improved. Poor coldwater IBI scores (range 10-20, average = 14.3, n=7) from electroshocking surveys performed in 2003 and 2006 reflect fish populations dominated by environmentally tolerant and other eurythermal species. Consistent with Halfway Prairie Creek, HBI monitoring from 2006 indicated "Good" water quality (range = 4.3-5.5, average = 4.6, n=5). M-IBI samples indicated overall "Fair" biotic integrity (range = 2.63-5.40, average = 3.81, n=5), and "Good" in the headwaters.

Indian Lake

Indian Lake is a 66 acre shallow kettle lake that is maintained by groundwater and surface runoff. The entire lake is surrounded by the Indian Lake County Park and recreational uses include fishing, bird watching, canoeing and other types of boating that do not involve gas engines. The lake is primarily managed for largemouth bass and panfish. An aeration system is frequently used during late winter months to avoid anoxia and fish winterkill conditions. The small lake had a long history of severe blue-green algal blooms. During the early 1980's, WDNR Bureau of Research conducted an experiment to determine if adding nitrogen to the lake would trigger a shift from nitrogen fixing Cyanobacteria species to non-bloom species.[106] The findings indicated that nitrogen applications were not effective due to short-term responses and other complicating factors. Since then, blue-green algal blooms in the lake have declined as a response to sustained dense aquatic plant growths and perhaps other factors.

Consistent with the hydrology of nearby Fish and Crystal lakes, Indian Lake water levels have increased over time. The maximum recorded depth during the 1970s was 6 feet.[107] In 2006, the maximum water depth had increased to 8.5 feet. The water levels in all three lakes may reflect increased regional groundwater recharge associated with agricultural conservation land use practices.[108] The lake area also expanded significantly.

Figure 28. Mean coldwater Index of Biotic Integrity Scores for Black Earth Creek Watershed Streams

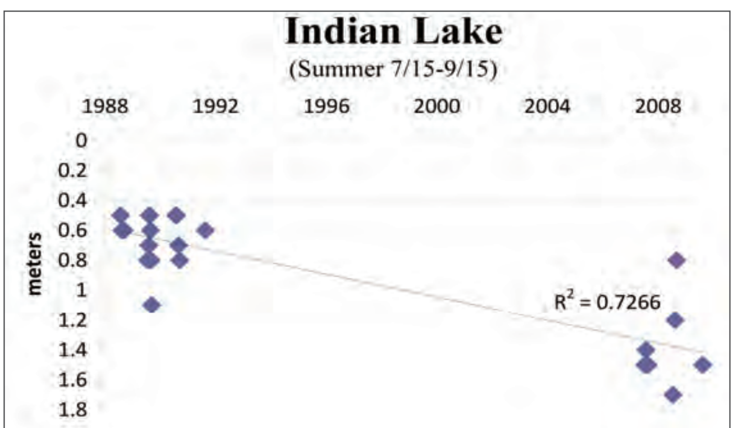


106 Lathrop, 1988.
107 Day, 1985.
108 Gebert, 1996.

More recently, eurasian water milfoil (EWM) and coontail had become established in the lake and apparently suppress phytoplankton blooms. Harvesting the dense beds of aquatic plants had become the primary management focus in the shallow lake. Dane County has been operating mechanical harvesters to create navigation channels for non-motorized boating access in the lake. These efforts also have potential to improve predator prey interactions.[109] Median July-September Lake volunteer secchi measurements (SWIMS database) taken from 1987-09 ranged from 0.5 meters to 1.7 meters. More recent data (2007-09) had a median July-September TSI = 54, indicating generally "Good" condition. Longer term secchi trends indicated improved water clarity and likely reflect increased macrophyte densities in the lake (**Figure 29**).

Fish species richness has been limited by periodic winterkills in the past. Species identified in the past surveys include fathead minnows (*Pimephales promelas*), bluntnose minnow (*Pimephales notatus*), white suckers (*Catostomus commersoni*), black bullhead (*Ameiurus melas*), green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), black crappie (*Pomoxis nigromaculatus*), largemouth bass (*Micropterus salmoides*), and yellow perch (*Perca flavescens*). Following winterkills, bullhead populations periodically exploded and exacerbated turbidity and internal phosphorus loading in the lake. This occurred when dense bullhead populations disturbed bottom sediments when feeding. Currently, bluegill and largemouth bass populations are sustained by late winter aeration while aquatic plant harvesting improves the habitat.

Figure 29. Water Clarity Trend in Indian Lake



Source: WDNR volunteer monitoring data

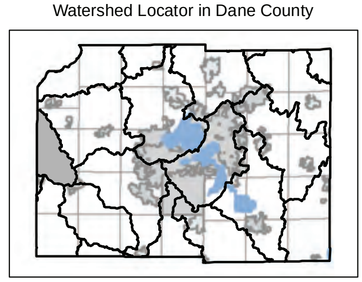
A point intercept aquatic plant survey was performed on the lake in 2006 and that information was used to prepare an aquatic plant management plan for the lake.[110] The goals for managing Indian Lake macrophytes include: (1) improving non-motorized boat access within dense coontail, Eurasian watermilfoil and curly-leaf pondweed beds, (2) sustaining lake-wide aquatic plant beds in desirable densities to prevent blue-green algal blooms that had historically occurred (3) managing aquatic plants to enhance the largemouth bass and bluegill fisheries, and (4) enhancing native floating-leaf plant populations.

109 Marshall, 2007c.

110 Marshall, 2007c.

Mill and Blue Mounds Creek Watershed

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Mill and Blue Mounds Creek Watershed (LW15)	
Land Cover	**Acres**
Residential	592
Transportation	651
Industrial	41
Commercial	29
Institutional/Governmental	22
Communication/Utilities	2
Other Lands*	2,859
Agricultural	6,835
Outdoor Recreation	639
Woodland	10,574
Open Water	11
Wetlands	507
Hydric Soils**	825
Size of Watershed in Dane County	22,762

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Dane County portion of the Mill and Blue Mounds Creeks Watershed encompasses 35.7 square miles of predominantly Driftless Area broad-leaf deciduous forest and agriculture. The percentage of agriculture is relatively low compared to many Driftless Area watersheds. Of concern are the relatively high urban growth rates in the Village of Mt. Horeb and Village of Blue Mounds with associated impacts of impervious surfaces runoff. Other concerns have included overtopping manure storage pits near streams and polluted runoff. The streams in this watershed typically display good trout habitat based on resident fish communities.

Moen Creek

Moen Creek originates in Section 2 of Blue Mounds Township and flows northwest about two miles to its confluence with Bohn Creek to form Elvers Creek. The gradient is very steep at 103 ft/mi. with a discharge of approximately 4 cfs near the confluence with Elvers Creek.[111] The headwaters are impounded to form Stewart Lake. A 2006 study of the creek near the dam by the Dane County LWRD determined that thermal impacts from the lake are minimal and did not alter the coldwater fish community. 2002 biological monitoring indicates that the stream is supporting its Class II trout fishery with a "Fair" coldwater IBI score of 40 and "Very Good" water quality HBI value of 4.0. A cursory habitat evaluation in 2001 found the creek to have fair to good instream habitat. An M-IBI sample taken in 2001 indicated overall "Good" biotic integrity (score = 5.83).

Elvers Creek

Elvers Creek is formed by the confluence of Moen and Bohn Creeks. It flows north approximately 10 miles to the confluence with Ryan Creek forming the East Branch Blue Mounds Creek. WDNR manages about 105 acres of public fishing grounds along the classified trout stream that is also designated an Exceptional Resource Water (ERW). Portions of the upper stream reach had been ditched and is considered marginal Class III trout habitat. Polluted runoff from farmlands is also considered a problem limiting full potential of the stream. The WDNR has given it a high nonpoint source pollution ranking. WDNR biologists recommended the stream for polluted runoff abatement efforts since lower 3 miles of the stream has potential for Class I trout management.[112] WDNR electrofishing surveys conducted from 2002 to 2008 indicated "Fair to Good" trout conditions in the stream with coldwater IBI scores ranging from 50 to 70 (average = 58.3, n=6).

Bohn Creek

Bohn Creek rises in Section 9 of Blue Mounds Township and flows north 3.5 miles to join Elvers Creek in Vermont Township. The lower part of the creek is managed as a Class II trout stream. The portion of Bohn Creek above the confluence with Little Norway Creek is considered marginal trout habitat. WDNR electroshocking surveys performed in 2002 and 2205 along the lower reaches of the stream revealed "Excellent" trout conditions with an average coldwater IBI score of 93 (n = 3). The very high scores reflected in part the presence of native brook trout in the creek.

111 Dane County OLW, 2008.
112 WDNR, 2002c.

Little Norway Creek

Little Norway Creek is a small 1.3-mile tributary to Bohn Creek and arises in Section 4 of Blue Mounds Township. The creek has a very steep gradient with an elevation change of 92 feet/mile. While the small creek is not currently managed, a WDNR electroshocking survey performed in 2008 revealed "Good" trout conditions with a coldwater IBI score of 70.

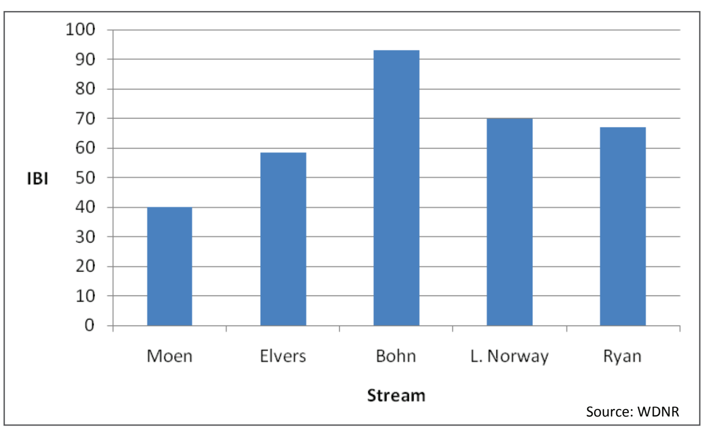
Ryan Creek

Ryan Creek is a 6.4-mile long Class II trout fishery that is also designated an Exceptional Resource Water (ERW). While problems in the creek have been linked to channel ditching and cattle grazing, coldwater IBI scores from WDNR electroshocking surveys in 2002, 2003, and 2009 revealed "Good" conditions (range = 50–80, average = 67, n=6). HBI monitoring in 2003 indicated "Excellent" water quality conditions (scores = 1.98 and 2.88). M-IBI samples collected in 2003 and 2009 indicated overall "Excellent" biotic integrity (scores = 11.60 and 8.03). The stream is ranked high for polluted runoff abatement funding.

East Branch Blue Mounds Creek

The East Branch Blue Mounds Creek begins at the confluence of Ryan and Elvers Creek. It is a class II trout stream in Dane County. It has a relatively low gradient and portions have been ditched. It is a flashy stream that often floods during snow melts and heavy rain events. Instream habitat is affected by sedimentation.

Figure 30: Comparative Coldwater Index of Biotic Integrity Scores from Mill and Blue Mounds Creek Watershed



Stewart Lake

The Dane County LWRD initiated a study of Stewart Lake in the spring of 2006 to assess the water quality conditions in the lake and determine if the management recommendations in a previous (1995) plan were still viable.[113],[114] Results indicated that excessive lake fertility continued to undermine the ecological and recreational potential in the lake. The data suggest that most of the fertility problems were linked to sediment deposits, although sediment depths had not changed significantly over the past decade. These results indicated that the Best Management Practices installed after 1995 had been effective at reducing additional sedimentation in the lake. Consistent with the 1995 lake management plan, dredging was recommended to prevent internal phosphorus loading from the lake sediments.

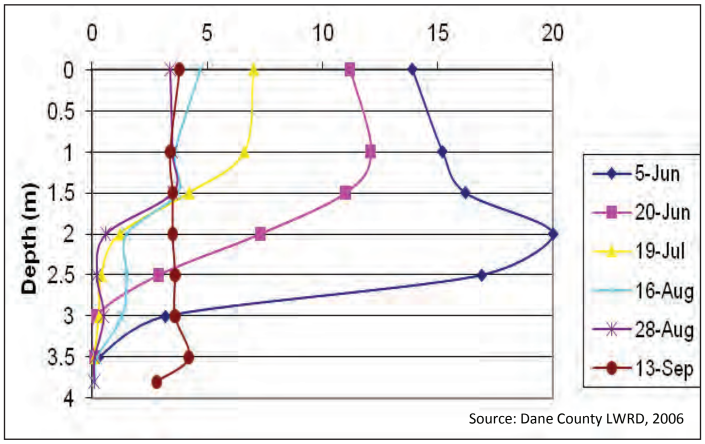
The 1992-93 lake study concluded that stormwater runoff was a major source of nutrients in the lake as well as internal phosphorus loading from bottom sediments. The combined nutrient sources resulted in heavy algal growths in the lake. In this study it was concluded that lake fertility was also linked to sediment nutrients. However, in 2006 the fertility produced excessive rooted aquatic plants instead of algae. Whereas chlorophyll-a concentrations were relatively high in 1992-93 and reflected typical eutrophic conditions, in 2006 dense growths of non-native curly-leaf pondweed (*Potamogeton crispus*), common waterweed (*Elodea canadensis*) and coontail (*Ceratophyllum demersum*) had apparently suppressed phytoplankton growth. As a result, chlorophyll concentrations were lower and water clarity was generally better in 2006 than in 1992 or 1993.

During both study periods, low dissolved oxygen near the bottom of the lake was prevalent, indicating poor habitat for trout and other sportfish. However, in 2006 low dissolved oxygen levels were more pronounced than in 1992 or 1993. Following the seasonal decline of very dense common waterweed, August and September dissolved oxygen levels were lower than the minimum water quality criterion concentration of 5 mg/L throughout the entire water column. The data suggested that the suppression of algal photosynthesis continued even as the rooted plants were decaying. The decomposition of the aquatic plants also contributed to dissolved oxygen

113 Dane Co. LWRD, 2006.
114 DCRPC, 1995.

deficits. When the aquatic plants were growing in early June 2006, supersaturated dissolved oxygen levels were evident and reflected photosynthesis (**Figure 31**). Coinciding with low dissolved oxygen in late summer, Stewart Lake had unusually high conductivity readings. The high conductivity readings can be an indicator of high fertility, including nutrients that were likely released from the decaying plants and ultimately from the sediment. High conductivity can also reflect high chlorides found in wastewater or road salt.

Figure 31. 2006 Dissolved Oxygen Profiles in Stewart Lake (ppm)



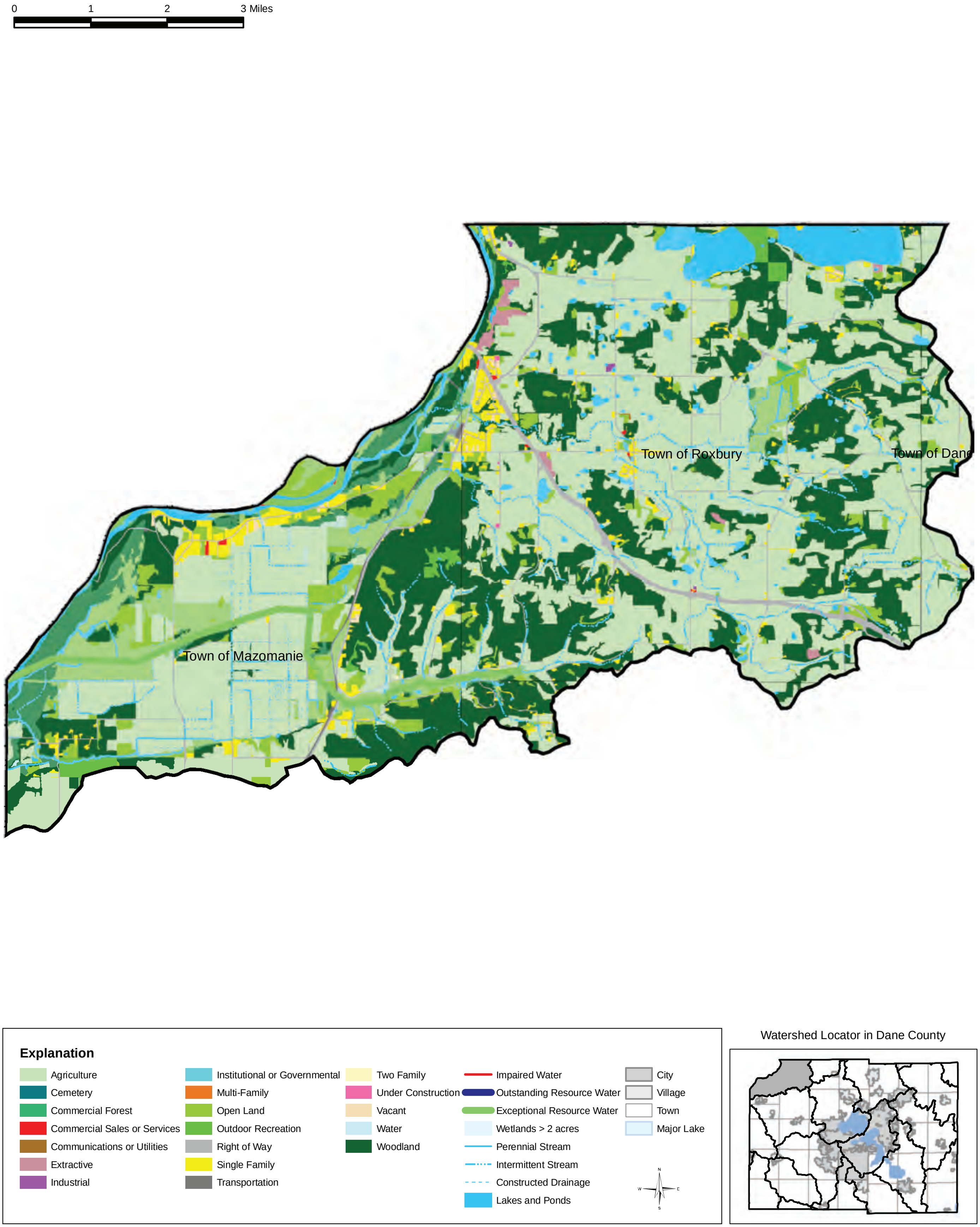
The ecological effects of the dense rooted aquatic plants found in 2006 included undermining fish predator-prey relationships. Abundant very small bluegills were easily observed near the surface during the 2006 study, particularly when dissolved oxygen levels were low. The dense plant canopy likely created a refuge, resulting in large numbers of stunted panfish.

2006 lake cross sectional data indicated that the water depths had not decreased since 1993 and that the watershed best management strategies were working. No significant change in water depths indicated that there were no additional sediment sources. Sediment chemical analysis revealed that the material is relatively clean and would not pose an environmental problem for drawdown, dredging, and disposal.

Water quality and thermal impacts of the lake were minimal below the dam. Groundwater flow to the stream rapidly increased below the dam and data loggers indicated water temperatures were typical of Driftless Area trout streams. The aquatic insect community reflected a healthy stream and fish populations were dominated by mottled sculpin (Cottus bairdii) and brown trout (Salmo trutta). Therefore, a restored lake was considered compatible with a healthy trout stream below the dam.

In 2009, the lake was drained and sediments were allowed to compact before hydraulic dredging began. A total of 19,000 cubic yards were removed from the lake before it was refilled in 2010. Dane County LWRD staff will monitor lake water quality responses to the restoration project, including potential for curly-leaf pondweed and Elodea growths that are common in Driftless Area impoundments.

Roxbury Creek Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Roxbury Creek Watershed (LW18)	
Land Cover	**Acres**
Residential	1,061
Transportation	1,220
Industrial	156
Commercial	18
Institutional/Governmental	8
Communication/Utilities	2
Other Lands*	2,625
Agricultural	17,754
Outdoor Recreation	349
Woodland	10,016
Open Water	1,311
Wetlands	3,628
Hydric Soils**	7,081
Size of Watershed in Dane County	38,150

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Dane County portion of the Roxbury Creek Watershed encompasses about 59.6 square miles with agriculture being the dominant land use. The principle water quality problems within this watershed are polluted agricultural runoff and channel ditching. Of particular concern to lake property owners in the watershed is the long term trend of rising lake water in two seepage lakes: Fish Lake and Crystal Lake. The trend of rising lake levels coincides with increased baseflows in Driftless Area streams.

Dunlap Creek (Dunlap Hollow Creek)

Dunlap Creek originates at the base of the terminal moraine in Section 33 of Roxbury Township. The stream flows about 10 miles to the confluence with the Wisconsin River. A wetland along the upper reaches of Dunlap Creek is composed of sedge meadows, fens, low prairies and shallow marshes.[115] The upper portion of Dunlap Creek is managed as a Class II trout stream and is designated Exceptional Resource Water (ERW). The WDNR has given it a high nonpoint source pollution ranking. It was the focus of a small-scale priority watershed project in 1991 with Best Management Practices designed to reduce gulley erosion. Between 1992 and 2003, coldwater IBI scores from electroshocking surveys in the upper reaches of Dunlap Creek indicated "Poor" trout conditions (range 20-30, average = 24, n=10). These results reflect sedimentation from cultivated fields and grazing.[116] M-IBI samples between 1991-93 indicated "Fair" biotic integrity (range = 1.04-5.24, average = 3.14, n=9), however, more current sampling is needed.

Downstream of Hwy 78, extensive channel straightening and lack of buffers significantly reduces instream habitat until the stream enters the Lower Wisconsin State Riverway public lands. In 2010, an electroshocking survey, performed at the confluence with the Wisconsin River, revealed poor habitat in the stream. Typical floodplain fish were not found, but instead, species that reflect a degraded coldwater stream.[117] Recommendations from that study include restoring a meandered floodplain creek that should provide habitat for rare fish species found elsewhere along the Lower Wisconsin State Riverway. The existing ditched channel appears to inject cold water into the floodplain and may function as a thermal barrier to typical floodplain fish species. Brown trout should not be managed in the floodplain since the nonnative piscivore often threatens native and rare nongame fish species.

Marsh Creek (Marsh Valley Creek)

Marsh Creek rises in Section 4 of Mazomanie Township and flows four miles to the confluence with the Wisconsin River. The small low gradient stream had been ditched and lacks favorable fish habitat. Recently, Dane County purchased lands along Marsh Creek as part of the Walking Iron Park. The public acquisition offers potential for plugging lateral ditches and restored hydrology and habitat in the stream. Riparian and channel restorations could benefit a number of floodplain eurythermal fish species including the State Special Concern pirate perch that had been collected from the stream. Nonnative brown trout management is not recommended for the stream.[118] An M-IBI sample taken in 2007 indicated overall "Poor" biotic integrity (score = 1.03).

115 DCRPC, 1992.

116 Dane County OLW, 2008.
117 Marshall, 2010.
118 Unmuth, 2010. Personal communication.

Roxbury Creek (Blums Creek)

Roxbury Creek rises in Section 24 of Roxbury Township and flows eight miles west to the confluence with a Wisconsin River side channel oxbow. The primary land use along the creek is intensive agriculture and most of the headwaters had been ditched. The stream is considered a Fish and Aquatic Life (FAL) water. The downstream portion of the stream beginning in Section 17 is considered a Warmwater Forage Fishery (WWFF) with a moderately diverse aquatic community that includes the State Special Concern pirate perch. In 2009, Roxbury Creek received emergency water pumping from hypereutrophic Crystal Lake. A survey that year demonstrated some degradation to the Wisconsin River slough near Roxbury Creek. Given the ecological importance of floodplain habitats to the Lower Wisconsin State Riverway, efforts to improve Roxbury Creek are recommended to protect the side channel and associated nongame fish.[119]

Fish Lake

Fish Lake (252 acres) is a moderately eutrophic lake located in the Town of Roxbury. The lake is relatively undeveloped with significant parklands adjoining the east and west shorelines. The public land acquisitions and the creation of Lussier County Park have been great additions to this unique deepwater seepage lake in southern Wisconsin. The acquisitions have also benefitted the water quality by reducing surface runoff pollution and protecting wildlife habitat. Recreational uses include swimming, fishing and boating. There is a town ordinance prohibiting gasoline motors on the lake.

The Fish Lake watershed is approximately 1680 acres including the lake surface. The primary land use is agriculture. Top soils are fine silty loam and are nutrient rich from manure and fertilizer applications. Most of the watershed is rolling farmland with steep wooded hills. Just northwest of Fish Lake is Mud Lake (74 acres). Mud Lake was historically a northwest bay of Fish Lake that was mostly disconnected when Fish Lake Road was constructed. The bay is currently connected to Fish Lake via a culvert.

Major changes had occurred in Fish Lake over the last several decades including declining water quality and reduced native aquatic plant beds. Detailed information on Fish Lake can be found in a comprehensive lake management plan[120] and in numerous articles focusing on ecology of macrophytes and fish. The comprehensive lake management plan was based on a U.S. Environmental Protection Agency (USEPA) Clean Lakes Phase I Diagnostic and Feasibility Study and incorporated significant findings of the cooperative research effort known as the "Integrated Management of Macrophytes and Fish."

Prior to the recent water quality decline, Fish Lake had been classified mesotrophic based on chlorophyll-a, phosphorus, and Secchi data. During the 1970's, the lake was considered to have the best water quality in the county however other indicators suggested gradual water quality decline. Hypolimnetic dissolved oxygen levels had been declining since the late 1950's while poor survival of stocked rainbow trout (*Oncorhynchus mykiss*) ended any efforts to manage a two story fisheries by 1969.[121] Cisco (*Coregonus artedii*) populations are native to the lake and, like trout, also require deep cool water habitat with sufficient dissolved oxygen. Over the past several decades, periodic cisco kills have been documented and coincided with low dissolved oxygen levels in the upper hypolimnion and thermocline.

Fish Lake historically supported diverse floating-leaf and submersed aquatic plant beds but significant declines in abundance had occurred. Native plant declines coincided with three long term changes in the lake: eutrophication, Eurasian water milfoil (EWM) invasion, and rising water levels.

Approximately 60 percent of the Fish Lake watershed was agricultural, primarily in the forms of croplands and dairy farms. Even though the watershed to lake ratio is relatively low at 4.4:1, high phosphorus loading was documented during the 1990's. The estimated annual phosphorus loading to the lake was 1690 lbs/year. Winter manure spreading and feedlots were identified as principal watershed sources of phosphorus and nitrogen at that time. More recently, the predicted phosphorus loading to the lake has declined and reflects a feedlot closure near Mud Lake and expanded parkland around both Fish and Mud lakes.

Within the last few decades, rising Trophic State Index (TSI) values indicated that Fish Lake had shifted from

119 Unmuth, 2010. Personal communication.

120 Marshall, 1996.

121 DCRPC, 1979.

mesotrophic to moderate eutrophic condition. The long term water quality decline in the lake had been linked to watershed nutrient sources.[122] Nutrient loading linked to barnyard runoff was particularly severe in Mud Lake, that had become hypereutrophic.

Evidence of declining water quality included reduced Secchi measurements, higher chlorophyll and higher hypolimnetic phosphorus and ammonia levels in Fish Lake. In addition to increasing (TSI) values, Fish Lake littoral zone sediments also reflected nutrient enrichment. Shallow water sediment core sampling revealed very high levels of both phosphorus (1142 mg/kg) and ammonia (128 mg/kg). Sediment testing indicated that polluted runoff was deposited within littoral areas of the lake, particularly along the west shorelines adjacent to most of the agricultural runoff. Sediment fertility has been linked with EWM growth and phosphorus transport from the littoral zone.[123] Deep water sediment core sampling was also conducted and revealed significant water quality decline in recent years. Analyzing sediment cores is a way of determining a history of nutrient input into a lake. Upper portions of sediments reflected recent deposition.

While detailed lake and watershed monitoring studies were initiated in 1988 to address the declining water quality, lake users were generally more aware of the "dense weed beds" in the lake. Eurasian watermilfoil was first identified in 1967 and rapidly expanded throughout the 1980s. By 1991 dense growths of EWM covered 99 acres of the lake bottom area.[124] During the EWM expansion period, numerous native species declined substantially as EWM established monotypic stands beyond one meter depth - a typical pattern of EWM invasions.[125] With the exception of coontail, the remaining native macrophytes occupied near-shore areas.[126] The near-shore native plant beds can be more vulnerable to shoreline development and rapid water level decline.

In 1994, EWM declined by approximately 40% across the lake. The decline coincided with weevil damage.[127] Native weevils can reduce the viability of EWM by boring into the stems.[128] Boring into the stem results in loss of plant buoyancy and the plant basically sinks. This either kills the plant directly or severely weakens the plant due to reduced photosynthesis. Coinciding with reduced macrophyte density that year, Secchi depths declined and chlorophyll-a concentrations increased. Higher chlorophyll levels may have reflected nutrient release from decaying EWM, reduced alleopathy or both. These conditions were temporary since EWM rebounded in 1996. The temporary EWM decline did not expand the distribution or abundance of native plants and may reflect sediment nutrient effects. The EWM decline and resurgence suggested that a lake-wide chemical eradication may not expand native plants and could result in severe Cyanobacteria blooms.

The EWM invasion had altered the habitat chemically in Fish Lake.[129] Very low dissolved oxygen levels were found near the bottom of the beds. The effects of dense plant beds on predator-prey interactions had been reported as well.[130] Local efforts to develop new methods for improving habitat within dense EWM beds began in 1989.[131] Scuba divers used manual cutting tools in Fish Lake to cut deeper growths of EWM at the sediment surface. The deep cutting technique held promise since the channels created by the SCUBA divers persisted for four years. Aerial photographs of the lake during this period clearly revealed where the channels were cut. Modest growths of curly-leaf pondweed and coontail had replaced EWM within the channels. Deep cutting to stress deeper EWM stands was ultimately tested by teams of researchers seeking management tools for improving EWM habitat and predator-prey interactions.[132] The Dane County Public Works Department modified one of the county harvesters in order to conduct a series of deep cutting experiments in Fish Lake and in other lakes as well. While the mechanical channels did not persist as long as the manual cut channels, the results demonstrated increased growth rates for particular year classes of both bluegill and largemouth bass populations. "Cruising lanes" became available to largemouth bass. Predation on stunted bluegills occurred, followed with increased growth rates of specific year classes for both species.

In addition to eutrophication and EWM expansion in Fish Lake, long-term rising water levels[133] was likely a third factor contributing to redistribution of native plants. As

122 Marshall, 1996.
123 Smith, 1990.
124 Lillie, 1996.
125 Madsen 1991.
126 Lillie, 1996.
127 Lillie, 2000 and Creed, 1998.
128 Mazzei, 1999.

129 Unmuth, 2000.
130 Engel, 1987 and Savino, 1992.
131 Marshall, 1990.
132 Unmuth, 1999; Olson 1998 and Trebitz, 1997.
133 Krohelski, 2002.

the water level rose, emergent and floating-leaf plants moved to newly submersed shorelines while EWM also migrated toward shore as well. The result had been a gradual shift of all plants, emergent, floating-leaf and submersed, toward the perimeter of the lake. In 2006, the lake management district began pumping water from the lake to reduce water levels. Many of the relatively scarce native species became desiccated as water levels rapidly dropped. More recently, pumping water from hypereutrophic Mud Lake had become a controversial issue given the uncertainty of pumping effectiveness and negative impacts of pumping hypereutrophic water to the Lower Wisconsin State Riverway. Impacts of the pumping in 2009 had included shoreline erosion of public land, loss of a diverse mussel bed that included State Threatened species, and water quality degradation.[134] WDNR is currently monitoring the water quality of the hypereutrophic Mud Lake where phosphorus levels ranged from 0.235 to 0.292 mg/L (TSI = 72) in 2010.

Bluegill and largemouth bass comprise the dominant fisheries in the lake but numerous other species are found in the lake as well. Environmentally sensitive nongame species identified in Fish Lake include banded killifish (*Fundulus diaphanous*), blackchin shiner (*Notropis heterodon*) and blacknose shiner (*Notropis heterolepis*) and Iowa darter (*Etheostoma exile*). These species can typically be found in dense aquatic plant communities near shore.[135] The banded killifish is classified as State Special Concern and the other three species are classified as environmentally sensitive to degraded habitat.[136] Abundant overhanging trees ring the lake and create another important habitat feature for fish populations and herptiles. In 2002, WDNR and Dane County Parks cooperated in a habitat improvement project along the Lussier Park shore. Large dead trees were pushed into the water and American lotus seed and nursery seedlings from Mud Lake were planted as well. The goal was to improve habitat for game fishes and intolerant nongame species that can be vulnerable to near-shore habitat loss. The current status of nongame fishes in the lake is unknown.

Fish Lake continues to be the focus of lake monitoring since it is part of the University of Wisconsin Center for Limnology Long Term Ecological Research (LTER) program. **Figures 32a and 32b** display recent Trophic State Index (TSI) values and data for total phosphorus and secchi.[137] Median July-September TSI values of 51 and 54, respectively, indicate generally "Fair" conditions since 2000.[138] A median TSI secchi value of 59 over the last five years indicates a recent decline in condition. A TSI(TP) > TSI(Secchi) indicates zooplankton grazing, nitrogen, or some factor other than phosphorus is limiting algal biomass. The highly variable phosphorus levels and TSI data in general reflect complex factors including lake morphology (a deep seepage lake), dense Eurasian watermilfoil beds, seasonal variability, internal loading, and agricultural runoff.

Point intercept macrophytes surveys were performed on Fish Lake in 2006-07 to gather information needed to prepare an aquatic plant management plan for the lake,[139] a requirement of NR 109.04. The recommendations listed in that plan include:

1. Consider longer term efforts to sustain boating lanes and improved fish habitat using methods such as deep cutting - harvesting. Methods could include modified large scale harvesting or manual cutting involving SCUBA.
2. Protect important habitat features including floating-leaf plant beds and coarse woody habitat. Residents should be discouraged from manually removing high values species such as watershield, floating-leaf pondweed, and water lilies.
3. Recommend Sensitive Areas Designations to WDNR based on criteria established in Wisconsin Administrative Code NR 107 and other important ecological features. Sensitive Areas would encompass plant beds with high value native species including watershield, floating-leaf pondweed, and water lilies. Use of herbicides and large-scale mechanical harvesting is prohibited in these areas. Encourage local land use planning and management to reduce nutrient runoff into the lake. Watershed runoff had contributed to littoral zone sediments rich in nutrients, a factor contrib-

134 Friends of the Lower Wisconsin Riverway, 2009.
135 Becker, 1983.
136 Lyons, 1992.

137 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.
138 Whereas Carlson 1977 provides an equation to convert phosphorus concentrations to TSI, the WDNR is not currently using that equation for General Condition Assessments. It is used for 303(d) listing.
139 Marshall, 2007c.

uting to high EWM growth in the lake. Potential sources of polluted runoff should be re-evaluated given reductions linked to surrounding park land acquisitions.

4. Consider sampling nearshore fish populations, including blackchin shiner, blacknose shiner and banded killifish. These species may be affected by rapid habitat changes including rising water levels.

Figure 32a. Recent Surface Total Phosphorus Trends in Fish Lake (Trophic State Index > 50 = eutrophic)

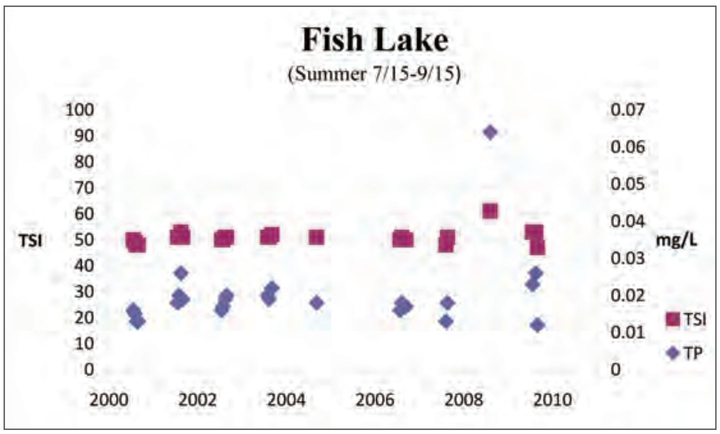
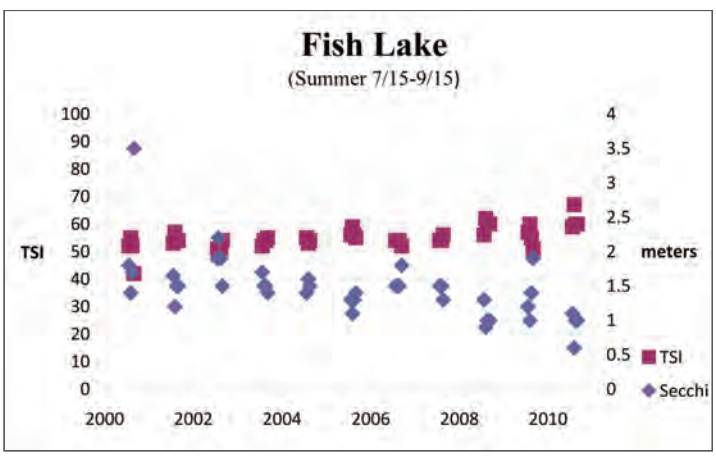


Figure 32b. Recent Secchi Measurements in Fish Lake (Trophic State Index > 50 = eutrophic)



Crystal Lake

Crystal Lake is a 525 acre shallow seepage lake located just 1,950 feet east of Fish Lake. Recreational uses include gasoline motorized boating, fishing, water skiing and swimming. In recent years, Crystal Lake has been a popular attraction for anglers due to the fast growing bluegill, crappie, and largemouth bass populations. Additional recreational opportunities are located at a large commercial park located on the Columbia County side of the lake.

Unlike the relatively deep Fish Lake, Crystal Lake is shallow and it does not thermally stratify. Crystal Lake is classified as hypereutrophic due to high concentrations of Cyanobacteria. The WDNR lake database indicated that recent Secchi depth measurements had ranged from 1.5 feet (TSI = 72) to 2.8 feet (TSI = 63), indicating "Fair" conditions. Total phosphorus measurements from 2010 ranged from 0.117 to 0.121 mg/L (TSI = 65). The surrounding watershed is very similar to the Fish Lake watershed with agriculture the dominant land use. Predominant sources of phosphorus to Crystal Lake include feedlots, crop fields, and internal loading as the lake mixes throughout the summer. During the 1980s, WDNR conducted animal waste management (NR 243) investigations on several shoreline feedlots that were located on the Columbia County side of the lake. Internal loading in Crystal Lake is much greater than in Fish Lake due in part to the shallow basin.

Crystal Lake and Fish Lake are connected to a common aquifer and rising water levels have been occurring in both lakes for decades.[140] Maximum water depths were only 6 feet in the 1940s and increased to 9 feet by 1960. Frequent winter fish kills had been documented from the 1940s through the 1960s. Aeration and frequent stocking were necessary to create recreational fishing during that period. When fish kills had occurred, bullheads were often the only survivors.
In recent years the trend of increasing water levels continued and the maximum water depth is now 14 feet. Consistent with the Fish Lake shoreline, trees had become inundated in past years and dead trees now line the perimeter of Crystal Lake. The dead trees are an important habitat feature for fish and herptile populations. Coinciding with the rising water levels, sustainable

140 Krohelski, 2002.

largemouth bass and panfish populations in the lake indicate that winterkills had diminished. In spite of continued hypereutrophic conditions, greater water volume has apparently increased the total oxygen mass within the lake. Potential water level declines in the future, whether natural or from pumping, could reverse the long-term trend of sustainable winter dissolved oxygen levels in the lake.

Dense growths of macrophytes had been reported decades ago including common waterweed (*Elodea canadensis*), sago pondweed (*Struckenia pectinatus*), duckweed (*Lemna*), and white water lily (*Nymphaea odorata*). There are no historical quantitative records on Cyanobacteria blooms or how the blooms might have affected the maximum rooting depths and distribution of macrophytes in Crystal Lake.

In recent years, EWM had become established in the lake and the formation of dense monotypic stands created recreational use problems. Management had included private herbicides applications around the two commercial mobile home parks in Columbia County while Dane County operated mechanical harvesters to provide boating access from the public boat ramp and elsewhere.

Fish populations had fluctuated over the years due to previous winterkills and also reflected restocking efforts. Bluegills (Lepomis macrochirus), largemouth bass (Micropterus salmoides), and black bullhead (Ameirus melas) had been the most common species reported. Other species reported from the lake include golden shiner (Notemigonus crysoleucas), fathead minnow (Pimephales promelas), pumpkinseed (Lepomis gibbosus), and orangespotted sunfish (Lepomis humilis). No environmentally intolerant fish species have been reported from the lake. Since about 1980, higher water levels have coincided with sustainable populations of largemouth bass, bluegill, black crappie (Pomoxis nigromaculatus), and to a lesser extent yellow perch (Perca flavescens). Panfish growth rates had been exceptionally fast compared with most Wisconsin lakes.[141] Blue-green algae blooms and outbreaks of Columnaris bacteria are factors that periodically have negative impacts on the fisheries.

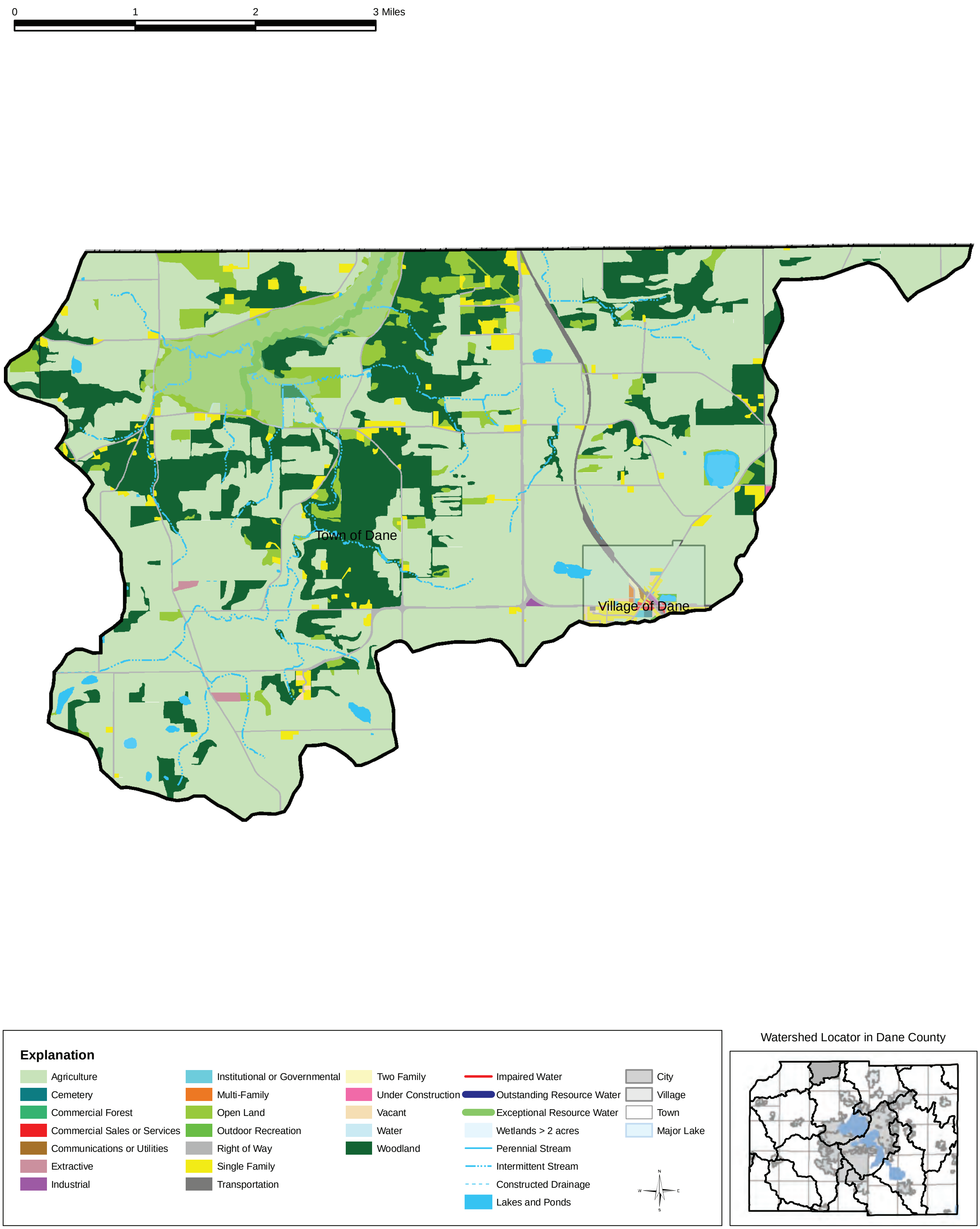
In 2006-07, point intercept macrophyte surveys were performed to collect information needed to prepare an aquatic plant management plan for the lake,[142] a requirement under Wisconsin Administrative Code NR 109.24. The surveys demonstrated that Eurasian watermilfoil was a minor component in an aquatic plant community already limited by heavy blue-green algal blooms and poor water clarity. Recommendations from Crystal Lake aquatic management plan include:

1. Mechanical harvesting should be conducted during periods when EWM densities are high to improve boating access.
2. Modest levels of native macrophytes provide important fish habitat and should not be the focus of eradication efforts. These conditions may change and Eurasian watermilfoil could expand under different water level conditions, warranting management.
3. Recommend Sensitive Area designations to WDNR including bays supporting white water lily beds.
4. Protect coarse woody habitat around the lake for fish and herptile populations.
5. Encourage local land use planning and management to reduce nutrient loading into the lake. (Reducing blue-green algal blooms could ultimately improve native plant growth in the lake.)
6. Consider coordinating the preparation of a comprehensive lake management plan with Columbia County.

141 Unmuth, 1999.

142 Marshall, 2007c.

Lake Wisconsin Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Lake Wisconsin Watershed (LW19)	
Land Cover	**Acres**
Residential	338
Transportation	484
Industrial	23
Commercial	6
Institutional/Governmental	11
Communication/Utilities	2
Other Lands*	659
Agricultural	9,248
Outdoor Recreation	5
Woodland	2,757
Open Water	14
Wetlands	698
Hydric Soils**	835
Size of Watershed in Dane County	14,244

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.

Source: Capital Area Regional Planning Commission 2005 Land Use Data

Dane County captures a small portion (22.3 square miles) of the Lake Wisconsin Watershed that also occurs in Columbia and Sauk Counties. The watershed is named for Lake Wisconsin, an impoundment of the Wisconsin River created by the Wisconsin Power & Light dam at Prairie du Sac, approximately one mile upstream from the Dane County border. Population growth in the watershed is high, most likely the result of the watershed's proximity to the City of Madison.[143] Municipalities include the Villages of Dane in Dane County, and the Villages of Merrimac, Poynette, and the City of Lodi in Columbia County. As with virtually all the other watersheds in the basin, agriculture predominates. Other land cover in the watershed consists of broad-leaf deciduous forest, and grassland. Development in the watershed is a concern since it could impact natural plant communities, habitat, and cause water quality problems if not controlled. The principal stream in Dane County is Spring Creek.

143 WDNR, 2002c.

Spring Creek (Lodi Creek)

Spring Creek originates in the Town of Dane and flows north into Columbia County. It is a Class II trout stream and the Dane County portion is also designated an Exceptional Resource Water (ERW). In Dane County, Spring Creek flows through Lodi Marsh, a State Natural Area. The WDNR describes the Natural Area as: a large wetland complex with numerous springs and spring runs, southern sedge meadow, and cattail marsh. The large, mostly open wetland borders the headwaters and upper two miles of Spring Creek. Cattails, bulrushes, and sedges comprise most of the vegetation. Shrubs include pussy willow, red-osier dogwood, and bog birch. On the south side of the marsh is a knob hill rising 240 feet from the marsh bottom. Its north slope supports a dry-mesic forest of red oak, sugar maple and basswood while a small dry prairie is located on the south slope. Along the base of the hill is an extensive seepage area with an abundance of skunk cabbage, marsh marigold, marsh fern, northern bedstraw, swamp loosestrife, spring-cress, wild iris, and mountain mint. Two large springs, one on each hill, provide a steady water flow. Of interest is the presence of 14 species of Papaipema moths, which are regarded as indicators of high-quality prairie and wetland habitat. In addition, many significant wetland-restricted moths are also found here. Breeding birds include great-blue heron, Sandhill crane, common snipe, willow and alder flycatcher, sedge wren, marsh wren, yellow warbler, blue-winged warbler, and a large number of red-winged blackbirds. Rare species include the silphium borer moth (*Papaipema silphii*), Newman's brocade (*Meropleon ambifuscum*), and ottoe skipper (*Hesperia ottoe*).

WDNR manages brook trout in the Dane County portion but the stream is difficult to survey within the extensive marsh. Beaver dams impound portions of the creek within the marsh. Most of the survey work had been completed in Columbia County and coldwater IBI scores range from 40 to 60 (mean = 52.5, n = 8) and reflect generally "Fair" biotic integrity. M-IBI samples taken in the Village of Lodi between 1996-2002 also indicated "Fair" biotic integrity (range = 3.05-4.72, average = 3.88, n=7). The Friends of Scenic Lodi Valley had conducted River Planning Grant studies on the Columbia County portion of the creek over concern for polluted runoff from agriculture and impervious areas within Lodi.

B. Sugar-Pecatonica River Basin

The Sugar-Pecatonica River Basin in Dane County lies in the Driftless Area of Wisconsin. The Driftless Area lies in the southwestern third of Dane County and the southwestern part of the state. This area was not covered by the continental glaciers during the Wisconsin glaciation period of the Ice Age that began some 25,000 years ago and lasted about 15,000 years.[144] The Sugar River is a tributary of the Pecatonica River. They join in northern Illinois approximately five miles south of the state line.

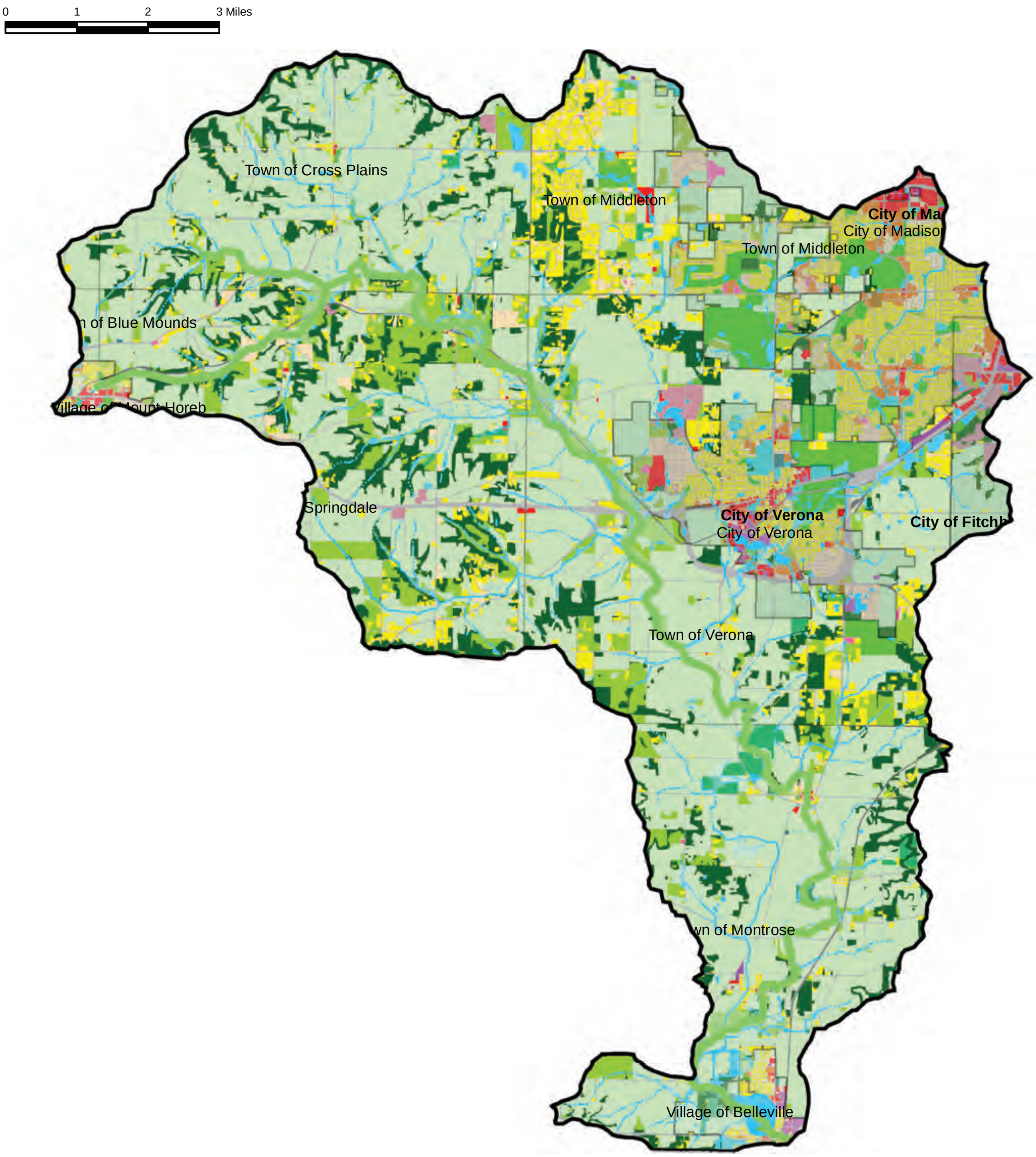
The north boundary of the Sugar River sub-basin is Military Ridge, the top of the Platteville-Galena cuesta. Streams flowing south from Military Ridge do not have as steep a stream gradient as those flowing north to the Wisconsin River. The Driftless Area topography of the western portion Sugar River sub-basin has dissected uplands with a well developed dendritic drainage pattern consisting of steep wooded slopes and narrow stream valleys with alluvial deposits. Hills are generally flat topped and commonly used for pastures and growing row crops such as corn and soy beans. The primary streams of the sub-basin, the Sugar and the West Branch Sugar River, were glacial meltwater streams carrying and depositing large amounts of sand and gravel in their floodplains.[145] Bedrock is close to the surface on the hills and ridgetops or is occasionally exposed or overlain by thin soils. Soils in stream valleys are usually alluvial. There are few wetlands and no naturally occurring lakes in the driftless area. The streams are fed by groundwater from springs and seeps. The groundwater dominated baseflow contributes to temperature and habitat conditions suitable for trout and cold and cool water fisheries.[146]

The eastern part of the Sugar River sub-basin in Dane County, while not glaciated during the Wisconsin glacial period, was covered by a continental ice sheet during an earlier glacial period. This area is roughly east of a line between Verona and Belleville. Parts of the Johnstown terminal moraine, the Milton recessional moraine, the Sugar River outwash valley, and rolling drumlin till are in this part of the basin. The drainage pattern is poorly developed with several internally drained areas. Streams in this part of the basin do not have as steep a gradient as those in the western part of the basin. There are four watersheds totally or partially in the Dane County portion of the Sugar River sub-basin. They are the Upper Sugar River watershed, the Mt. Vernon and West Branch Sugar River watershed, small portions of the Little Sugar River watershed, and the Allen Creek and Middle Sugar River watershed.

The Gordon Creek watershed in extreme southwest Dane County flows west and south to join the Upper East Branch of the Pecatonica River in Lafayette County. There are no named streams within the Upper East Branch Watershed in Dane County, consisting of 1,172 acres located on the extreme west-central boundary. Surface waters are limited to an intermittent stream and small tributary that carries treated municipal wastewater from the Village of Blue Mounds to Williams-Barneveld Creek, a trout stream in Iowa County.

144 Mickelson, 2007 and Schultz, 1986.
145 Martin, 1965.
146 DCRPC, 1992.

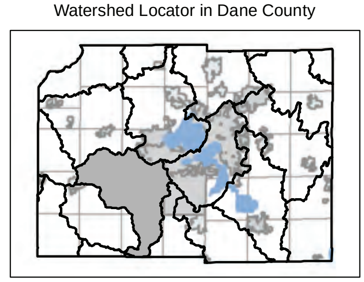
Upper Sugar River Watershed



Explanation

Agriculture	Institutional or Governmental	Two Family	Impaired Water	City
Cemetery	Multi-Family	Under Construction	Outstanding Resource Water	Village
Commercial Forest	Open Land	Vacant	Exceptional Resource Water	Town
Commercial Sales or Services	Outdoor Recreation	Water	Wetlands > 2 acres	Major Lake
Communications or Utilities	Right of Way	Woodland	Perennial Stream	
Extractive	Single Family		Intermittent Stream	
Industrial	Transportation		Constructed Drainage	
			Lakes and Ponds	

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Upper Sugar River Watershed (SP15)	
Land Cover	**Acres**
Residential	7,444
Transportation	4,448
Industrial	759
Commercial	716
Institutional/Governmental	438
Communication/Utilities	58
Other Lands*	7,696
Agricultural	34,111
Outdoor Recreation	2,262
Woodland	6,735
Open Water	297
Wetlands	2,271
Hydric Soils**	4,433
Size of Watershed in Dane County	67,234

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Upper Sugar River Watershed is in the unglaciated southwestern Dane County. It has an area of 105 square miles. Approximately 21 percent of its area is developed (residential, commercial, industrial or institution/government), while 51 percent of its area is devoted to agriculture, 10 percent is in woodlands, and 11 percent is in other land uses (other open or vacant land). The remaining 3% of its area is outdoor recreation and wetlands. While the primary land use in the watershed is rural in nature, it does include the rapidly growing City of Verona, southwest side of the City of Madison and the northwest corner of the City of Fitchburg. The watershed also includes the community of Paoli, and all or parts of the towns of Verona, Middleton, Montrose, Springdale, and Cross Plains. The only municipal wastewater discharge in the watershed is MMSD's discharge to Badger Mill Creek (more on this in the Badger Mill Creek narrative below).

The Upper Sugar River Watershed has nearly 35 named stream miles, all of which are classified as being either Trout Waters and/or Exceptional Resource Waters. The named streams include the Sugar River, Badger Mill Creek, Henry Creek, and Schlapbach Creek. The water quality of streams in the watershed is generally good. However, the potential adverse effects of rapid urbanization on water quality are a concern, particularly for Badger Mill Creek.

Badger Mill Creek

Badger Mill Creek begins in a wetlands complex along USH 18-151 between Madison and Verona and flows about 5 miles to join the Sugar River south of the 18-151 Verona bypass. It drains an area of about 34 square miles. It has a moderate stream gradient of 10.7 ft/mi.[147] Badger Mill Creek's drainage area includes much of the southwest side of Madison as well as most of Verona. Both areas are intensely developed or are rapidly developing. The most significant threat to water quality in Badger Mill Creek is from urban stormwater runoff from historic development in the watershed. Impervious surfaces are estimated to cover about 20 percent of the Badger Mill drainage area.[148] These areas are subject to varying levels of stormwater management as standards have improved over the last decade. New development projects are currently required to meet strict infiltration standards, as well as temperature controls for coldwater streams. Retrofitting stormwater management practices in areas built before the current standards were put in place presents an opportunity to improve water quality and the health of Badger Mill Creek.

MMSD Treated Effluent Discharge to Badger Mill Creek

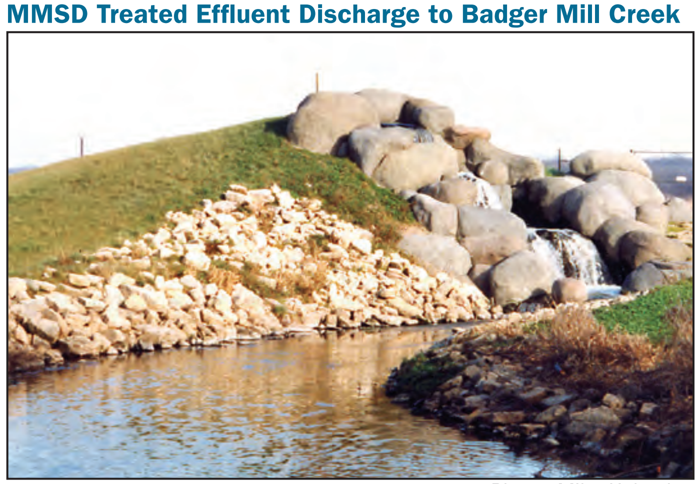


Photo: Mike Kakuska

147 DCRPC, 1992.
148 DCRPC, 2005.

At one time water quality in the creek was considered poor due to inadequately treated municipal and industrial wastewater being discharged to it. Badger Mill was added to the state's 303(d) Impaired Waters list in 1998. These discharges have since been eliminated resulting in improved water quality and instream habitat. The creek was removed from the state's 303(d) list in 2002. In 1998 MMSD began discharging about 3.3 mgd of highly treated effluent back to Badger Mill Creek as a means of maintaining baseflow in the creek. The purpose of the treated effluent return project is to compensate for the amount of groundwater being taken out of the Sugar River basin by municipal well withdrawals. After use, the wastewater is diverted to MMSD's Nine Springs treatment plant and discharged to Badfish Creek in the adjacent Rock River basin. This effort was conducted to restore the water balance between these two basins and, more importantly, improve aquatic habitat in Badger Mill Creek by removing low baseflow as a limiting condition caused by the well water withdrawals.[149]

Badger Mill Creek at STH 69 South of Verona

Photo: Steve Fix

Badger Mill Creek is classified as a Class II trout fishery upstream from the Sugar River to the perennial outflow in Section 13.[150] Water quality and instream habitat have improved significantly in Badger Mill Creek since 1978, but more work is needed. A stream assessment done in 1989 indicated the stream's formal designation as a Limited Forage Fishery (a water quality variance stream[151]) should be upgraded to full Fish and Aquatic Life.[152] DNR fish monitoring done in 1994 and 1995 found brown trout (Salmo trutta) reproduction and abundant mottled sculpin (Cottus baiardi), a pollution intolerant coldwater forage fish species.[153] A reclassification study in 2005 recommended that Badger Mill be classified as a Class II trout stream based on the presence of brown trout at all sample locations, multiple ages of trout, and occurrence of young-of-the-year trout, indicating natural reproduction.[154] Temperature and dissolved oxygen data also supported this reclassification, although the situation seems tenuous.

Data from the USGS station at Bruce Street show that dissolved oxygen levels exhibit typical diurnal (24 hour) oscillation for a stream that contains a high density of macrophytes. DO levels drop to less than 6 ppm during the night and rise to over 12 ppm during the day. The duration of these DO "sags" is generally limited to a few hours in the early morning before photosynthesis begins again. The DO levels tend to sag below 6 ppm more frequently during the mid-summer months than later summer or fall (**Figure 33**). The fishery community appears able to tolerate these sags, but the situation should continue to be monitored.

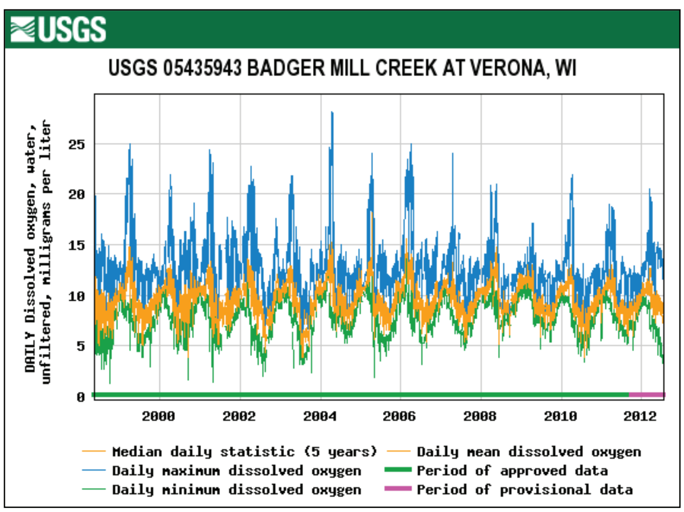
Badger Mill Creek is located in the thermally sensitive part of Dane County. Thermally sensitive areas are areas tributary to existing or potential coldwater stream.[155] Urban stormwater usually has a higher temperature than nearby receiving waters. A sudden or longer term increase in temperature can adversely affect coldwater fisheries and the aquatic ecosystem needed to support these fisheries. Both the cities of Madison and Verona have stormwater master plans. Both have been active in constructing stormwater facilities (e.g. ponds and infiltration basins) to attenuate the potential problems caused by increased urban runoff. While these ponds do retain stormwater, reducing downstream peak flows and pollutant loading, they release water that is often warmer than ambient stream water temperatures over a longer time frame. For example, summertime (June-August) daily mean temperatures immediately downstream of the Nesbitt Road stormwater retention ponds range between 20°C and 26.3°C, with a maximum daily high temperature

149 DCRPC, 1997.
150 Welke, 2005a.
151 NR 102.04 and NR 104.02.
152 Marshall, 1989.
153 Stewart, 1996.
154 Welke, 2005a.
155 To see a map of thermal sensitive areas, go to the Dane County LWRD webpage http://www.countyofdane.com/lwrd/landconservation/cws/index3.html

mean of 30°C.[156] These high stormwater temperatures in Badger Mill Creek's headwater reach appear to be moderated by the MMSD discharge and the springs at the Military Ridge bike trail parking lot.

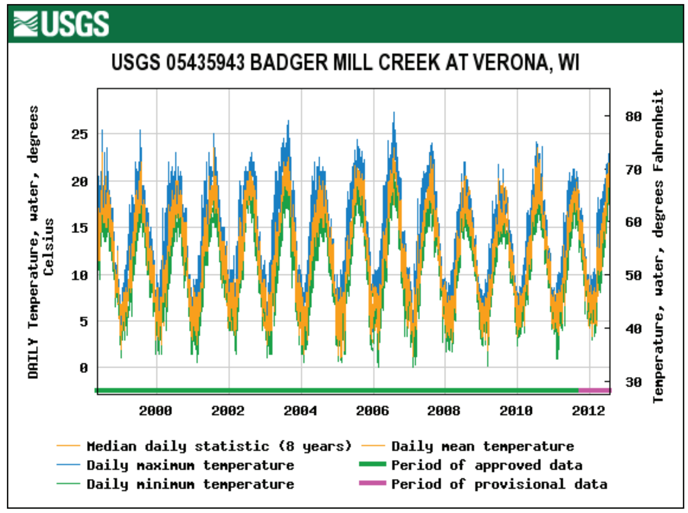
Further downstream, continuous temperature readings between 1998-2012 measured at Bruce Street have exceeded WDNR's guidelines for coldwater streams[157] only 11 times (**Figure 34**). However, continued increases in summertime stormwater flows from Verona and Madison could alter the creek's temperature regime and lead to reduction or elimination of trout and other cold and cool water species from the creek, changing the creek to a warmwater ecosystem. In addition, a recent study of stormwater ponds in Mount Horeb also indicated that while the ponds may reduce peak flows and somewhat moderate stormwater first flush temperatures, they release suspended sediments and associated nutrients to receiving waters.[158]

Figure 33. Daily Dissolved Oxygen in Badger Mill Creek at Verona



HBI monitoring conducted at four sites on Badger Mill between 1996-1999 indicated water quality conditions ranging from "Fair" (fairly significant organic pollution) to "Very Good" (slight organic pollution).[159] More recent sampling by MMSD (2003) showed HBI values ranging from "Fair" at the Lincoln Street footbridge to "Good" at Bruce Street and STH 69. Marshall reported that HBI values did not change significantly with the introduction of the MMSD effluent and generally indicated "Good" water quality. [160] In general, the invertebrates did not reflect major benthic community changes after the wastewater return because both urban and agricultural polluted runoff had previously limited healthy populations.

Figure 34. Daily Temperature Values in Badger Mill Creek at Verona



Coldwater IBI monitoring conducted by the DNR in 1997 at three sites on Badger Mill found "Poor" biotic integrity at all three sites indicating major environmental degradation has occurred and biotic integrity had been severely reduced. Subsequent DNR coldwater IBI monitoring done in 2000 and 2005 at several locations found "Poor" or "Very Poor" biotic integrity. M-IBI samples taken between 1996-1999 supported this finding, also indicating generally "Poor" biotic integrity (range = 0.74-3.43, average = 2.35, n = 13). While there are also brown trout present upstream from the Lincoln Street footbridge, their numbers as well as the number of intolerant, coolwater species drops dramatically. This may be due to the change in stream morphology and habitat in this section of the stream where the channel is straight, wide, shallow, with a silt and sand bottom that offers little habitat.
MMSD has also been conducting fish and aquatic invertebrate monitoring on Badger Mill since 1994. Seventeen years of coldwater IBI results at two Badger Mill Creek sites shows virtually no variation in coldwater IBI scores, represented as being "Poor." HBI monitoring indicates "Fair" water quality with fairly significant organic pollution.

156 USGS data accessed 2010.
157 Maximum daily mean of 22°C and instantaneous maximum temperature of 25°C.
158 Marshall, 2007a.
159 WDNR South Central Region Water Resources Files, 2010.

160 Marshall, 2001.

Fisheries data and temperature readings collected by MMSD have shown that the diversion has not prevented the creek from its ability to support a coldwater classification and trout population. Actually, the increased flow of cold or cool water from the MMSD discharge has stabilized flows and undoubtedly increased the habitat for top level predators such as brown trout and subsequently boosted their population. While the increase in numbers of trout in the creek can likely be attributed to an increase in habitat because of the increase in flow, the presence of more pollution intolerant coolwater indicator species such as mottled sculpin and brook stickleback (*Culaea inconstans*) have declined since the diversion. The specific reasons for the declines are not known. Water quality monitoring has shown increased levels of chlorides, total phosphorus, dissolved phosphorus, and ammonia.[160]

Overall, water quality in Badger Mill Creek has improved since 1978 to the point that the DNR considers and manages it as a Class II trout stream. The return of 3.3 mgd of treated effluent to augment flows in the creek does not appear to have seriously affected water quality and instream habitat, and has actually improved it. The greater concern at this point relates to the long-term, cumulative impacts of increased urbanization on the creek and its ecosystem. Without adequate measures being taken, the increase in impervious surfaces could lead to increased stormwater volume getting to the creek to the point the creek would no longer be able to support a trout fishery. Accompanying problems such as channel alteration, habitat modification, and low dissolved oxygen levels resulting from urban runoff would all adversely affect the existing aquatic ecosystem of Badger Mill Creek. Innovative stormwater management measures to maximize stormwater infiltration to recharge local groundwater supplies and reduce volumes of stormflow are needed in the Badger Mill Creek subwatershed for both new and previously existing development. Commonly used stormwater measures include infiltration basins, bioretention facilities, and rain gardens. These measures are being use to address stormwater runoff issues in other parts of the county as well.

However, a recent resource assessment and development report done for the southwest side of Verona highlighted some of the challenges of locating infiltration features in the Driftless Area.[161] Those challenges include shallow/fractured bedrock and fine-grained soils, and shallow depth to groundwater in some areas. The report by Montgomery Associates and a technical paper by Gaffield and others focused on the issues of new development in this part of Verona and specified measures that could be taken to reduce peak flows, protect the thermal condition of the stream, and maintain or increase recharge for baseflow maintenance.[162] Detailed stormwater management planning and activities will continue to be needed in the watershed so as not to lose the gains that have been made or otherwise limit future prospects.

Henry Creek

Henry Creek is a small spring-fed tributary to the Sugar River near the community of Basco south of Verona. The creek is about one mile long and has a moderately steep gradient of 27.8 ft/mi. There is evidence of past stream straightening. In 1998 Henry Creek was placed on the state's 303(d) Impaired Waters list due to habitat impairments caused by sedimentation. Since that time, land use improvements have resulted in good water quality and habitat.[163] In 2006 Henry Creek was taken off the impaired water list. A USDA Environmental Quality Improvement Project (EQIP) completed in 1999 with the assistance of the Dane County Land and Water Conservation Department mitigated much of the sedimentation problem leading to improved stream quality.[164] Improved land has resulted in a well-buffered corridor flowing mainly through wet meadow. Farm properties near the headwaters have also employed conservation practices to reduce erosion. This has improved baseflow, stabilized event flows, reduced streambank erosion, and allowed the stream to meet its potential as a cold water resource.

Henry Creek is currently considered a Class II Trout stream. Although the stream still contains some silted areas, there are many hard bottom areas of gravel and many undercut banks for fish habitat. Monitoring in 2002 indicated a healthy population of mottled sculpin, along with stickleback and several brown trout. The water temperature is being monitored to determine if the stream can support brook trout. If so, brook trout may be introduced to the stream.

161 Montgomery Associates, 2008.
162 Gaffield, 2008.
163 Amrhein, 2006. WDNR Water Data Viewer.
164 WDNR, 2005a.

Coldwater IBI monitoring conducted in 2002 found "Fair" biotic integrity (score = 50) as did an M-IBI sample (score = 4.44). HBI sampling indicated "Very Good" water quality with possible slight organic pollution (score = 3.97). Two coldwater IBI samples in 2005 indicated "Good" stream biotic integrity (score = 60).

While conditions in Henry Creek have improved, sedimentation from agricultural activities in its headwaters is still a concern. Maintaining an adequate stream buffer, coupled with sound agricultural conservation practices, is needed to reduce sediment loading to the stream and further improve water quality and habitat conditions.

Schlapbach Creek

Schlapbach Creek rises on the east edge of Mount Horeb and flows four miles east to join the Sugar River near the community of Klevenville. It has a drainage area of about five square miles and has a moderate stream gradient of about 24 ft/mi.[165] Much of its drainage area is agricultural with wooded steep-sided ridges on either side of its narrow valley down to CTH P. There the gradient flattens and the stream is buffered by wetlands, part of the Sugar River wetlands complex. A large portion of the east side of Mount Horeb is in Schlapbach's headwaters drainage area. Increased stormwater flows may be affecting the creek's ecosystem. Schlapbach is in the DNR's Southwest Wisconsin Grassland and Stream Conservation Area. A primary goal of this project is to protect, restore and manage priority natural communities and associated rare species including coldwater communities.[166]

Schlapbach Creek is a spring-fed, thermally sensitive coldwater stream and is considered to have good water quality. It is designated an Exceptional Resource Water (ERW) stream having been added to the state's ERW list in 1991. Instream habitat has been negatively affected by intense grazing of streambanks and runoff from cropland.[167] Thirty years ago the stream supported mostly eurythermal (pollution tolerant) nongame fish, but now supports predominately stenothermal (pollution intolerant) coldwater fish species. The fish community change from eurythermal to stenothermal coldwater reflects a regional trend of changing land uses in Dane County including fewer animal units, more conservation-based agriculture, and better infiltration of rainwater and snowmelt.[168] One recent study linked watersheds with high Conservation Reserve Program participation, resulting in a shift from a warmwater, more tolerant fish community to a cool and coldwater community.[169]

165 DCRPC, 1992.
166 WDNR, 2009b
167 Dane County OLW, 2008.

Schlapbach Creek at Sletto Road

Photo: Steve Fix

Schlapbach Creek is considered as an excellent candidate for brook trout introduction by DNR fisheries staff.[170] Ten breeding pairs were stocked in 2002. Follow-up monitoring in 2005, however, found only brown trout. A year 2000 aquatic invertebrate sample taken at Sletto Road had an HBI score of 1.91 indicating "Excellent" water quality with no apparent organic pollution. Earlier HBI monitoring done in 1997 found "Good" water quality conditions at Klevenville-Riley Road (some organic pollution evident) and "Very Good" water quality conditions (slight organic pollution evident) at Sletto Road.[171] Coldwater IBI monitoring done at Sletto Road between 2000-2005 consistently resulted in "Fair" biotic integrity (Coldwater IBI score = 30-50) indicating the stream has experienced moderate environmental degradation and the biotic integrity has been reduced. M-IBI samples taken in 1997 and 2000 indicated "Good" biotic integrity (range = 4.41-9.85, average = 6.79, n=3). The 2000 sample at Sletto Road indicated "Excellent" biotic integrity. Marshall and others collected aquatic invertebrates and did a Family-level Biotic Index (FBI) analysis in 2007. The FBI score (4.13) indicated good water quality. That same study noted phosphorus and nitrogen levels exceeded USEPA recommended standards (0.70 mg/L and 2.0 mg/L, respectively).[172]

168 Marshall. 2007a.
169 Marshal, et.al. 2008a.
170 Fetter, 2005a.
171 Data from WDNR SWIMS water resources data base accessed in 2010.
172 Data from WDNR SWIMS water resources data base accessed in 2010.

Citizen Based Stream Monitoring done at two locations on Schlapbach by the Upper Sugar River Watershed Association has shown dissolved oxygen levels and water temperature levels within the range to fully support coldwater communities.[173] Temperature data collected during the summer of 2005 indicated the upper reaches of Schlapbach suffered from thermal stress due to urban runoff.[174] However, the water temperature increases appear to be localized and brief in duration.[175] Redside dace (Clinostonmus elongates), a pollution intolerant coolwater forage fish on the DNR species special concern list, is no longer found in Schlapbach and has likely been extirpated from it. This is part of a general decline in some non-game species in small streams in southern Wisconsin.[176]

Overall, Schlapbach Creek is a coldwater stream with the potential to support brook trout, and is designated as an Exceptional Resource Water (ERW). It has good water quality and fair fisheries biotic integrity. Its primary threat is from urban stormwater from the Village of Mount Horeb that could result in increased thermal loading, and loading of suspended solids and associated nutrients to Schlapbach Creek. More aggressive stormwater management measures are needed to improve protection. Additional regional and smaller distributed detention facilities, as well as distributed infiltration measures where possible, are needed in developing parts of Mount Horeb to reduce the thermal spikes and provide some local groundwater recharge. Agricultural nonpoint sources are also a threat to water quality and habitat. Improved or increased use of agricultural conservation measures should alleviate that threat. Changes in land use in the upper part of the watershed from farming to recreation have increased baseflow to streams in the region. More recently, several landowners in the Sletto Road area have indicated an interest in returning a portion of the riparian corridor to prairie, which should help increase infiltration and buffer the creek against nonpoint source pollution.

Sugar River

The Sugar River originates in section 33 in the Town of Cross Plains and flows 25 miles southeast where it enters Lake Belle View and leaves Dane County south of the Village of Belleville. The river's direct drainage in this watershed is approximately 72 square miles excluding the major tributaries of Badger Mill Creek and the West Branch Sugar River. The Upper Sugar River is a dominantly spring-fed system with extensive riparian wetlands. Unlike the stream valleys in most of the driftless area, which are narrow and steep, the valley of the Sugar River is fairly broad and flat. The upper portion of the watershed is of particular interest because it drains unglaciated, rougher terrain to the west, and glacial outwash and moraines to the east.

Overall, the river has good dissolved oxygen concentrations, enough to support both a warm and coldwater fishery. The Sugar River has been designated an Exceptional Resource Water (ERW). Water quality is generally good and has gradually improved.[177] In 2008 the stream was re-classified as a Class II trout fishery from its headwaters to the Frenchtown Road above Lake Belle View. Class II trout streams have good survival of adult trout and some natural reproduction. The portion of the river below Frenchtown Road is classified as a Warmwater Sport Fishery. In 2011 the Lake Belle View millpond was separated from the Sugar River by means of a berm as part of a large-scale restoration project. The project is designed to reverse decades of sedimentation from upstream land uses, including selective dredging and reintroduction of native plants and fish.

Agriculture is the primary land use in the watershed with row crops and dairying including some larger animal operations adjacent to the river. Sections of the river have been channelized, particularly north of USH 18-151. It is also located on the outskirts of the expanding Madison metropolitan urban area including the City of Verona. Though historically (and still) predominantly agricultural, this portion of the watershed is experiencing a gradual change in land use. Growth and development in the Cities of Verona and Madison have put pressure on the ground and surface water resources in the Upper Sugar River watershed. Since this area encompasses the headwaters of the Sugar River, changes in land use, hydrology, and sediment/nutrient transport here will have particularly pervasive impacts on all downstream areas.

The only municipality with a direct wastewater discharge to the Sugar River in Dane County is the Village of Belleville. A new treatment plant was completed in 2007, which has helped alleviate past problems with biological

173 UW-Extension, 2008.
174 Fetter, 2005a.
175 Marshall, 2007a.
176 Marshall, 2004a.
177 Welke, 2005b

oxygen demand and suspended solids downstream. Upstream, MMSD discharges to the Sugar River via Badger Mill Creek. This discharge was designed and constructed to help replace water being lost to municipal well water withdrawals. Drawdown of groundwater levels by high capacity municipal wells in Madison and Verona and subsequent diversion to MMSD for treatment results in water being transferred from the Sugar River sub-basin to the Yahara River sub-basin where the wastewater is discharged via Badfish Creek.

In order to offset the groundwater losses, MMSD constructed a pipeline in 1998 to return 3.3 mgd of highly treated effluent back to the Sugar River sub-basin via Badger Mill Creek. This project was specifically designed to return the amount of water being pumped from the basin. The innovation being promoted here is one of treating wastewater as a resource and not something simply flushed down the drain. Aggressive stormwater management efforts by Madison, Verona, and Dane County to infiltrate more runoff into the ground and control temperatures are also being conducted to help augment groundwater supplies and maintain stream habitat.

Sugar River at CTH S, Near the Headwater

Photo: Steve Fix

Stream morphology in the Sugar River changes upstream to downstream. Stream width in the headwaters area is 6 to 10 feet and widens to 35 to 65 feet near Lake Belle View. The upper river reach has a softer sand/silt bottom with long runs, while the lower reaches below Valley Road contains runs, riffles, pools and a stream bottom that varies from silt to gravel and cobble.[178] The reach of the Sugar River upstream of Riverside Road is buffered by riparian wetlands and grasses and shrubs along its banks. The riparian corridor downstream of Riverside Road is a mix of agriculture, woodlands, grasslands and some wetlands. The river picks up significant flow between Riley and Paoli due to the number of springs and groundwater seeps in this reach. There are several small unnamed streams tributary to the Sugar, most of them have been channelized to facilitate agricultural drainage. Some of these unnamed tributaries may be spring-fed. A dam at Paoli impedes fish migration.

178 Amrhein, 2004.

Much of the valley bottom adjacent to the river was covered with wetlands prior to European settlement. Wetlands in the Upper Sugar River Watershed typically only occur along stream and river margins. With the exception of some failed attempts at agricultural crop production, the valley bottom has not been historically used and will probably never be used due to its wetness and location in the floodplain. While the meanders of the Sugar River have been artificially straightened and the river itself has been significantly channelized, there is a high potential for the bottomland to be restored as a significant natural area.

Perhaps the most ecologically significant area is the large wetlands complex extending from Valley Road near Verona northward past the community of Riley. The Sugar River wetlands south of USH 18/151 were designated a State Natural Area by the WDNR in 1996. There are springs and groundwater seeps in or adjacent to this important wetlands complex. This is an area of significant wetlands diversity including a calcareous fen community, a rare wetland type. This extensive wetland also harbors numerous rare plant and animal species. The area is part of a larger priority grassland habitat restoration complex along the Sugar River, identified in the Dane County Parks and Open Space Plan. The designation seeks to establish landscape management areas for the benefit of declining grassland birds and animals, vegetation communities, and invertebrates that depend upon native vegetation. There are also existing and proposed land and water trails through the area including the Military Ridge State Trail, which accents the river/wetland complex between Verona and Mt. Horeb.

Water quality in the Sugar River is generally considered good and has gradually improved over the last few decades. It supports a diverse cool and coldwater fishery above Lake Belle View and a cool to warmwater sport fishery below the Belleville dam. It is designated an Exceptional Resource Water (ERW) from it headwaters downstream to the Green-Rock county line due to its diverse fishery and water quality. Progressive surveys have noted a trend toward more coldwater species. While mottled sculpin (an intolerant coolwater indicator species) has been noted in the Sugar River as a primary species in the headwaters since the 1960s, it has only been within the last 10 years that brown trout have shown up in increasing abundance throughout this stretch of river.

Historically, the headwaters of the Upper Sugar River was home to a variety of forage species. Further downstream, species numbers increased to include larger fish and game species reflecting the increased size of the river. Brown trout were occasionally found, believed to be migrating to the river from other coldwater tributaries in the area.

Since the mid-1980's agricultural land use in the watershed improved due largely to a Natural Resources Conservation Service PL-566 project conducted in the watershed; enrollment of farmlands in the Conservation Reserve Program; several streambank improvement projects; and elimination of direct industrial discharges. The section of river upstream from Frenchtown Road has evolved to the point where it can sustain a coldwater fishery.

Sugar River at Frenchtown Road

Photo: Steve Fix

In 1992, an extensive survey of the river was conducted. Forty-three brown trout were captured during this survey along with 27 other species. In a 1997 survey a total of 104 brown trout were collected. After the 1997 survey, a coldwater IBI was determined for each of the sections. Coldwater IBI scores ranged from "Poor" (score = 10) to "Fair" (score = 40. In a 2002 survey a total of 625 trout were collected. Catch per unit effort estimates increased steadily from upstream to downstream and peaked at an estimated 663 trout per mile. Coldwater IBI scores ranged from "poor" (score = 10) to "Fair (score = 40). While there was no trend in scores from upstream to downstream, the fishery seems to have improved overall.[179] It was noted that populations of pollution intolerant mottled sculpin generally declined upstream to downstream along with disproportionally high numbers of white suckers (Castostomus commersoni), a common warmwater fish. Monitoring conducted at Remy Road downstream of the Lake Belle View dam indicated "Excellent" biotic integrity (warmwater IBI = 85) with a good population of smallmouth bass and good stream habitat.

The 2002 survey work documented natural reproduction within the Sugar River and indicates a potential for the available habitat to support even *more* fish. Catch-per-unit effort values are comparable with other listed trout waters in Dane County. The size distribution shows that this section of the Sugar River contains at least 4 year classes of trout. Supplemental stocking of brown trout can be used to help attain the potential carrying capacity. Invertebrate HBI scores are also consistent with those commonly generated from trout waters. Water temperature, substrate, and habitat parameters are all consistent with values regularly found in other trout waters. Dissolved oxygen monitoring by USGS measured at STH 69 from April 2009 to July 2012 ranges between 16.6 ppm and 3.5 ppm, with the lowest daily mean of 4.2 ppm on July 25, 2010 (**Figure 35**). Except for occasional periods between June and August, DO levels are typically above 6.0 ppm. Water temperatures are generally below the WDNR's criteria for coldwater streams,[180] although temperature exceeded the criteria 15 days in July 2012 (**Figure 36**), a period of record-breaking heat in southern Wisconsin. The upward trend is cause for concern.

179 Amrhein, 2004.
180 Maximum daily mean of 220C and instantaneous maximum temperature of 250C.

Figure 35. Dissolved Oxygen in the Sugar River near Verona

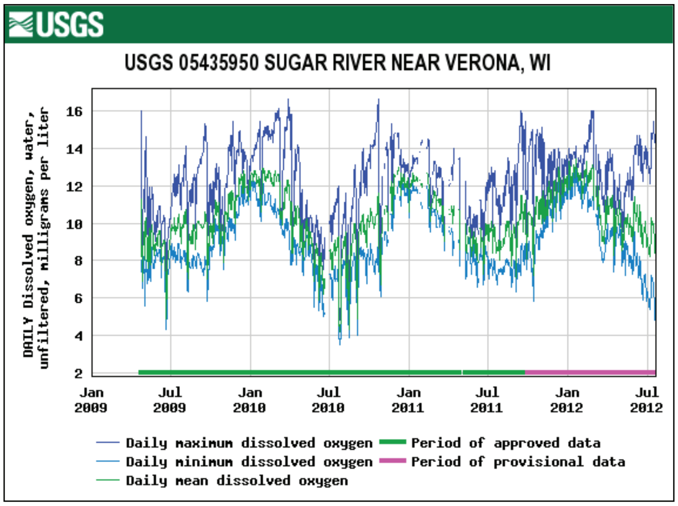
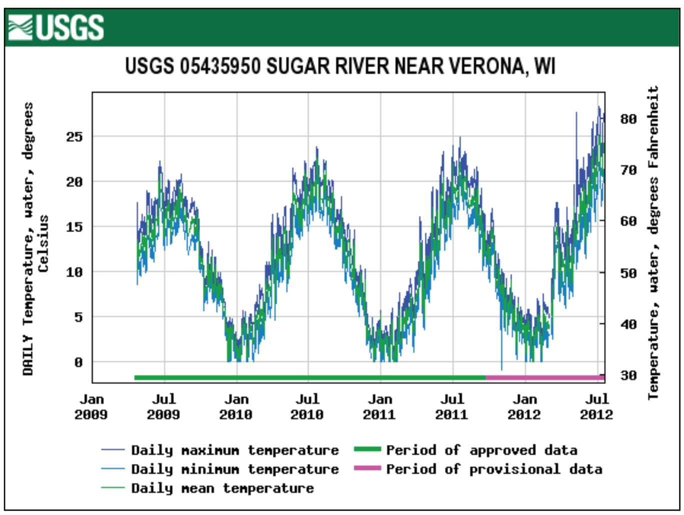


Figure 36. Daily Temperature Values in the Sugar River near Verona



In 2008 the Sugar River between Frenchtown Road and its headwaters at CTH P was classified as a Class II trout stream, representing an abundant trout resource comprised of multiple year classes. Class II trout waters may have some natural reproduction but not enough to utilize available food and space. These streams show good survival and carryover of adult trout and often producing some fish of better than average size. MMSD found the third highest number of brown trout (119) in 2009 since monitoring began in 1994. Land use and watershed characteristics that influence baseflow, ambient water quality, and the fisheries resource have resulted in a systematic shift toward a more wide-spread and consistently cold water condition within the Sugar River. Overall, a substantial trout fishery has been restored on the Upper Sugar River. Significant angler effort is currently directed here because of its proximity to a large metropolitan area, the presence of large wild fish, and the ability for anglers to fish a large meadow-type stream. It is particularly popular with fly fishing anglers. While much has been accomplished, more work is needed. A major fishkill occurred in the Sugar River in September of 2010. Over four miles of the river upstream of CTH PD was affected. The source of the kill was not determined, but is thought to be agricultural related.

While this system lacks the characteristic spring flow inputs of streams of similar scale (e.g., Mt. Vernon, Black Earth Creek), the Sugar River should continue to support a quality brown trout fishery of moderate density. Many of the underlying habitat principles referenced in DNR Technical Bulletin 39 exist within this stream, especially in terms of streambank vegetation and watershed land practices. Traditional in-stream and bank habitat features and practices should be applied where applicable to increase in-stream cover and under-bank area. Project elements that encourage stream sediment transport, maintain current velocity, and encourage both substrate and morphological diversity (pool-riffle-run) are recommended. These efforts are meaningless, however, without first protecting the resource from the impacts of agricultural and urban development activities in the watershed. Periodic coldwater IBI fishery surveys should also be continued to monitor the fisheries community including periodic temperature, invertebrate, and habitat monitoring.

Overall, water quality in the Sugar River is generally good and has improved due to the significant efforts by many concerned public and private groups, citizens, and landowners. While much has been accomplished, more work needs to be done for the river to meet its full potential. The primary water quality impacts continue to be from agricultural and urban nonpoint sources of pollution. There are also concerns about the long-term, cumulative effects of urbanization on water quality and instream habitat in the upper reaches of the Sugar River. Municipal groundwater pumping for public water supply purposes has lowered the groundwater levels in the eastern part of the Sugar River watershed. This could lower stream baseflow in part of the headwaters area affecting the river's ecosystem and wetlands in the area.[181] Programs that would protect and possibly improve water quality and habitat include the continuation and expansion of various land conservation and wetland restoration programs run by the Dane County LWRD (in cooperation with state and federal partners), as well as more aggressive stormwater management programs in urban areas that maximize infiltration opportunities, water conservation, and promote more innovative "green infrastructure"[182] designs and retrofits. More intensive, ongoing monitoring of the aquatic and physical condition of the river is also needed to determine if the effects of urbanization are adversely affecting current conditions.

Lake Belle View

Lake Belle View is a shallow impoundment on the Sugar River at Belleville approximately 20 miles southwest of Madison. Both the Upper Sugar River and West Branch Sugar River watersheds drain to it, an approximately 172 square mile drainage area. Land use in its watershed is primarily agricultural and rural residential, but does include the rapidly growing area of Verona, the southwest side of Madison and part of Mount Horeb. The Mount Horeb wastewater treatment plant and MMSD both have treated effluent discharges in the lake's watershed

Lake Belle View covered 90 acres, plus 18 acres of forested islands before its drawdown in 2009. It is a hypereutrophic lake. The lake suffered from water quality problems usually associated with impoundments including sedimentation, turbidity, and excessive algae growth all inhibiting recreational use and aesthetic enjoyment of the lake. The Sugar River delivers an estimated 59,800 pounds per year of phosphorus to Lake Belle View.[183] Lake Belle View is shallow with a maximum depth of 7 feet and an average depth of 1-2 feet. It has been described as a "carp factory."

The Wisconsin Tropic State Index (TSI) indicates an average value of 68 between 2007 and 2008 indicating generally fair to poor water quality conditions. The public beach on Lake Belle View was closed after WDNR monitoring detected high fecal coliform bacteria levels throughout the 1970s. The quality of the river system is further reduced by the extensive warming of the water by the shallow turbid lake resulting in a warming of the Sugar River and thermal pollution downstream of the dam.

After many years working with various federal, state, and local groups, the Village of Belleville initiated a project to restore Lake Belle View in 2010 to help reverse the many years of neglect and abuse.

Objectives of the restoration project include:

- Improving water quality of the lake and the river;
- Creating diverse aquatic lake habitat and vegetation;
- Restoring a sport fishery in the lake; and
- Enhancing and restoring floodplain forest and wetland habitat for wildlife.

The lake has since been dredged to a depth of 8-10 feet with the deepest part located near the community park. Some of the dredge material was used to enlarge existing islands for floodplain forest habitat enhancement and restoration. There is approximately 30 acres on the river side of the berm that will be restored to wetlands and upland habitat through native plantings and seeding. Vegetative response will be monitored closely during and after the project to make sure the right plants get established and invasive, aquatic nuisance plants are prevented from being established.

The Lake Belle View restoration project has been designed to mimic a natural river floodplain lake that harbors many native fish, including largemouth bass and bluegill. Separation of the Sugar River and Lake Belle View will significantly reduce the amount of sediment and nutrients transported by the Sugar River to the lake, which will improve the overall water quality and increase the lifespan of any lake enhancement projects. In addition, the separation allows for more targeted fish management options, such as carp control, and the establishment of a desirable warmwater fishery. Control of lake water levels at the former millrace structure allow for manipulation of water levels in the future as part of fish or habitat management, independent of flood or low flow conditions in the Sugar River. The benefits also include an increase in the available habitats for various wetland, upland, and migratory animals, and a powerful education-

181 DCRPC, 2004b.
182 See U.S. EPA: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm
183 Montgomery and Associates, 2009.

al opportunity for the village and other interested parties in millpond management options. This project is unique in its approach to the lake and river separation by maintaining both bodies of water while allowing the river to run continuously past the lake. This comprehensive project serves as a national model for other millponds and rivers in Wisconsin and the United States. The project provides an alternative to an "all or nothing" scenario typical of the past management considerations. Additional future project activities may include further deepening of a portion of the lake and construction of fish passage features to meet longer-term objectives.

Lake Belle View Prior to Construction (2010 drawdown)

Source: Montgomery and Associates

Lake Belle View After Construction of Separation Berm, Lake Deepening, and Habitat Earthwork (June 2011)

Source: Mike Kakuska

Goose Lake

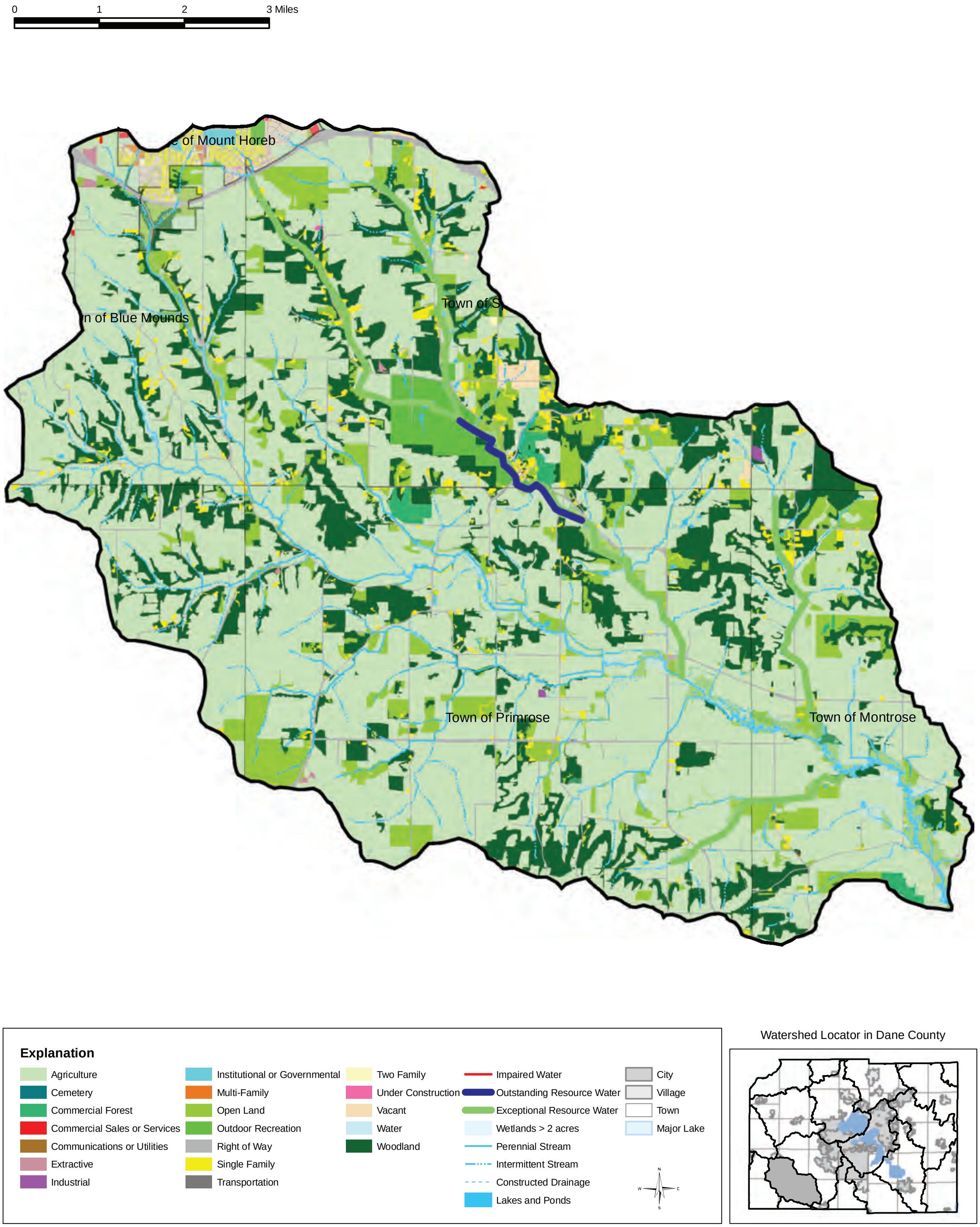
Goose Lake is a small pothole seepage pond east of Verona just off USH 18-151. Residential subdivisions comprise most of the surrounding watershed. Being a pothole and seepage pond, water levels tend to fluctuate. It has a maximum depth of 10 feet. Algae growth and blooms, a sign of excessive nutrient loading, has been a problem inhibiting enjoyment of the lake.[184] Increased stormwater flows in a drainage ditch also threaten water quality of the lake. Reports from 2005 through 2009 show fluctuating secchi disk (a measure of water clarity) readings of between 0.25 to 3 feet. From 1994 to present TSI values typically exceed 70, indicating "Poor" conditions.

Morse Pond

Morse Pond is a small, shallow, land-locked pothole pond on the edge of the driftless region west of Madison. Maximum depth is 4 feet. There are a few acres of shallow marsh on the north and south ends, while the remaining shoreline is wet meadow. It lies adjacent to the University of Wisconsin golf course. The pond is unique in that it has a large bed of American lotus (*Nelumbo lutea*) not found on many other waterbodies in the Sugar-Pecatonica basin. American lotus beds are uncommon in Dane County and may be declining.[185] This bed of lotus was threatened by the construction of the University of Wisconsin golf course, which resulted in significant sediment loading to the pond in the 1990s. Although the completion of the golf course reduced the sedimentation problem, the lotus beds are still threatened by the nutrients and herbicides that run off the golf course and into the pond. The University of Wisconsin Foundation had agreed to initiate a study of long-term impacts of gold course operations on water quality and aquatic life in Morse Pond, but nothing has yet been done. The water level is highly variable. Historically, Morse Pond has had very little recreational activity as the water is turbid and the bottom is very soft. Severe winterkill conditions prohibit the establishment of a fishery. Various species of amphibians and reptiles, as well as raccoons, deer, and waterfowl frequent the area. Increasing development of the surrounding area and subsequent stormwater runoff threatens the health of the pond. Appropriate stormwater mitigation measures should be installed to limit additional stormwater runoff from reaching the pond, and to maximize local infiltration.

184 Information from WDNR Citizen's Lake Monitoring website http://dnr.wi.gov/lakes/clmn/Stations.aspx?location=13
185 Marshall, 2007c.

West Branch Sugar River Mt Vernon Creek Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

West Branch Sugar River Watershed (SP16)	
Land Cover	**Acres**
Residential	1,016
Transportation	1,611
Industrial	56
Commercial	24
Institutional/Governmental	83
Communication/Utilities	4
Other Lands*	4,583
Agricultural	26,190
Outdoor Recreation	583
Woodland	7,190
Open Water	16
Wetlands	1,124
Hydric Soils**	3,474
Size of Watershed in Dane County	42,480

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The West Branch Sugar River Watershed lies in the Driftless Area of southwest Dane County. Its drainage area is about 66 square miles and includes part of the Village of Mount Horeb, the community of Mt. Vernon and parts of the towns Blue Mounds, Springdale, Primrose, Montrose, Perry and Verona. Agriculture is the primary land use in the watershed occupying about 62 percent of the watershed's land cover. Mount Horeb is a rapidly growing village on the north edge of the watershed and has the only municipal wastewater discharge in the watershed.

The watershed is characterized by steep, narrow valleys set between the ridgetops of the driftless area. The ridgetops and valleys are usually grazed or cultivated while the steep hillsides are wooded. Soils on the ridgetops are generally thin over bedrock while valley soils are alluvial. There are few wetlands and no natural lakes. Principle streams in the watershed include the West Branch Sugar River, Mt. Vernon Creek, Deer Creek, Fryes Feeder, Primrose Branch, Flynn Creek, and Milum Creek. Except for Milum Creek, all the named streams in the watershed are coldwater trout streams.

West Branch Sugar River

The West Branch Sugar River begins in the Village of Mount Horeb and flows 18 miles southeast to join the Sugar River north of Lake Belle View in Dane County. It drains 66.4 square miles, which is mostly pasture land with the remainder being in upland hardwoods, marsh, and cropland. The Mount Horeb wastewater treatment plant is the only permitted facility discharging treated effluent to the headwaters of the river. The Village of Mount Horeb sits on top of Military Ridge in the headwaters of seven coldwater streams in three watersheds and two river basins. A portion of the developing southwest side of Mount Horeb drains to the headwaters of the West Branch. Above Mount Vernon Creek, the West Branch has a moderate gradient (13.6 ft./mi) and low baseflow. Below this point, the creek has a mostly very low gradient (1.5 ft./mi.) and meanders through a wide floodplain. Flow is augmented by the input from several spring-fed tributaries that support trout. The 1923 USGS topographic map shows the West Branch had a significant adjacent floodplain wetland from approximately CTH U downstream to its confluence with the Sugar River. Parts of that historic wetlands complex was drained for agricultural purposes, but some of the drained land (or attempted drainage) has reverted back to wetlands. The West Branch is considered a Class II trout stream by the DNR. Biological indices range from fair to good conditions. Threats include increased urban stormwater and meltwater runoff from the Village of Mount Horeb, agricultural nonpoint sources of pollution, and a potential expansion of the Mount Horeb wastewater treatment facility.

Historically, the stream water quality and habitat of the West Branch Sugar River have been adversely affected by streambank, upland, and cropping erosion, overgrazed riparian areas, cattle access to the stream, barnyard runoff, sediment and nutrient delivery, and discharge from the Mount Horeb wastewater treatment plant. For these reasons the West Branch was put on the Wisconsin 303(d) Impaired Waters list in 2002. In 2004 the river was removed from the list as a result of conservation practices and volunteer efforts taken in the watershed. It holds the distinction of being the first stream removed from the list in Wisconsin. In 2008 the stream was reclassified as a Class II trout stream from its perennial source downstream to USH 92. In 2012 total phosphorus sampling exceeded state phosphorus criteria, however available biological data did not indicate impairment.

Instream habitat surveys from the late 1990s indicated that the habitat and more intolerant fish species had suffered from environmental degradation. Between 2000 and 2002 stream and habitat restoration projects funded by the state's Targeted Runoff Management program and Trout Unlimited were implemented to improve habitat along the river. Monitoring in sections of the stream completed in 2000 and 2001 have shown an increase in the number of brown trout. Dane County has acquired significant permanent and temporary (20-year term) easements on the West Branch upstream of STH 92 to both provide stable riparian areas and for public fishing access. The DNR also has easement and land holdings on the lower reaches of the river. While the upper two miles of the West Branch are designated as a limited forage fishery, monitoring of the stream at Barton Road showed the presence of intolerant coldwater species such as mottled sculpin and brook trout.

Overall, significant water quality and aquatic habitat improvements have occurred in the West Branch Sugar River since 2000. The river is no longer on the state's 303(d) Impaired Waters list and is considered a coldwater fishery for most of its length. Fish surveys done in 1997 showed no young-of-year (YOY) trout at any sampling sites on the West Branch. After the beginning of significant stream and riparian restoration activities, surveys in 2003 showed the presence of YOY trout at 10 of 13 stations indicating that natural reproduction was occurring in the West Branch.[186] WDNR's 2008 *Trout Management in Dane County* publication[187] states the West Branch has "excellent habitat for all life stages of trout." The DNR continues to stock brown and rainbow trout in the West Branch.

Coldwater IBI monitoring conducted at the STH 92 crossing in 2005 and 2008 showed "Fair" biotic integrity indicating the stream has experienced moderate environmental degradation. Coldwater IBI monitoring conducted in 2005 at the Primrose Center Road and the CTH U crossings also showed "Fair" biotic integrity. Coldwater IBIs conducted in 2000 at STH 92 and CTH JG, prior to the beginning of the intense stream and riparian corridor improvement project, had "Poor" biotic integrity indicating major environmental degradation had occurred. By 2002 at CTH JG, the coldwater fish IBI had risen to "Fair," the macroinvertebrate IBI score indicated "Good" water quality, and a DNR habitat evaluation showed "Good" aquatic habitat.[188] The comparison of the 2000 monitoring values with the 2002 and subsequent monitoring values are an indication of the success of the land conservation practices and stream restoration projects implemented on the West Branch Sugar River. Research and monitoring have shown a link between the amount of land in the USDA's CRP program and improvements in small coldwater streams in southwest Wisconsin.[189] A significant improvement in coldwater IBI scores for the West Branch Sugar River was noted in pre- versus post- CRP implementation (**see Figures 13 and 14**).

West Branch Sugar River at Docken Road

Photo: Steve Fix

While much has been accomplished more work is needed. The West Branch Sugar River suffered a major fish kill in February of 2005. Liquid manure spread on a nearby farm field was washed into the river as a result of an early rapid thaw. The fish kill affected approximately six miles of the river down to near the Primrose Branch. A steep-slope farm field where manure had been applied

186 USEPA, 2010.
187 WDNR, 2008b.
188 WDNR fisheries data base, 2010.
189 Marshall, 2008a.

was identified as the source of the fish kill.[190] This fish kill, along with other similar events on other streams in the county, led to the formation of the Dane County Manure Spreading Task Force. Several of the recommendations in the Task Force's final report led to the County amending its existing manure storage ordinance to address winter manure spreading.[191]

In 2008 the DNR noted that river was recovering from the fish kill and that trout populations were fair to good.[192] This indicates the resilience of trout streams in the driftless area, as was noted with a similar situation on Black Earth Creek. However, the winter spreading restrictions in Dane County's ordinance may not be sufficient to protect streams in the Driftless Area where field slopes at specific sites may exceed average field slopes of 12 percent. The slope restrictions in the ordinance may need to be reviewed to assure high quality streams are adequately protected.

Thermal spikes from urban runoff are another concern. Mount Horeb has taken positive steps regarding stormwater management at the policy level. However, implementation of the village's stormwater management plan has not kept pace with development.[193] Additional regional and smaller distributed detention facilities, as well as distributed infiltration measures where possible, are needed to reduce the thermal spikes and provide additional local groundwater recharge.

In addition, Mount Horeb is a growing community that at some point will also need to enlarge and upgrade its wastewater treatment facility. Currently all wastewater generated in the village is discharged to the West Branch Sugar River. Any significant increase in that discharge could adversely affect stream hydrology, morphology, instream habitat, and alter the coldwater fish assemblages.

Mt. Vernon Creek

Mt. Vernon Creek is formed by the confluence of Deer Creek and Fryes Feeder in the Driftless Area southeast of the Village of Mount Horeb. It flows seven miles to join the West Branch Sugar River. It has an average stream gradient of 18.5 ft/mi. The stream gradient decreases downstream of STH 92 as the creek approaches the West Branch Sugar River. Mt. Vernon Creek is a high quality, spring-fed creek supporting a coldwater fish community along its entire length. It is one of the best trout streams in southwest Wisconsin. It has excellent aquatic habitat to support the coldwater fishery there. About four miles of its length is a Class I trout stream while the remainder of the stream is a Class II trout stream. The Class I portion is also designated an Outstanding Resource Water (ORW), while the Class II portion is designated an Exceptional Resource Water (ERW). Its deep pools and long run-riffle habitats hold multiple year classes and sizes of trout. There are also public easements or ownership along most of its length.

Mt. Vernon Creek and its tributaries drain approximately 16.7 sq. mi. of land. The dominant land use in its drainage area is agricultural. Agricultural nonpoint sources of pollution are a water quality and aquatic habitat threat. Parts of the creek have been physically altered. Near the mouth of the stream dredging was conducted in the 1940s, and a dam in Mt. Vernon was removed in 1951. With the assistance of a habitat improvement program and the passage of time, the part of the stream affected by dredging has largely recovered. Increased nitrate levels have been documented. The unincorporated community of Mt. Vernon is located on the Class I portion of the stream. The community uses on-site septic systems to handle wastewater. Many of these systems are suspected of failing and may be degrading water quality of the creek.

Mt. Vernon Creek is a high quality coldwater trout stream with excellent aquatic habitat. It is well buffered over most of its length. The trout fishery in Mt. Vernon Creek has been extensively researched, developed, and managed for over the last five decades. An intensive habitat improvement program initiated in 1964 included placement of in-stream cover, extensive fencing, and installation of spawning beds. Intensive efforts at soil conservation and streambank protection programs in the Mt. Vernon Creek watershed have demonstrated that substantial reductions in erosion and associated impacts on stream habitat can be achieved through aggressive nonpoint source control programs. A 2008 coldwater IBI done at CTH U resulted in a "Good" biotic integrity

190 Fetter, 2005b.
191 Go to http://www.countyofdane.com/lwrd/landconservation/manure.aspx for more information regarding the Task Force Final Report and Dane County's manure management program.
192 WDNR, 2008b.
193 Fetter, 2005b.

rating. Coldwater IBIs done in 2002 at CTH G and STH 92 showed biotic integrity ratings of “Good” and “Fair,” respectively. This is not unexpected as the CTH U and CTH G sites are in the Class I reach while the STH 92 site is in the Class II reach of Mt. Vernon. M-IBI results were “Good” for both sites.

Overall, Mt. Vernon Creek is a high quality coldwater fishery stream. Habitat and water quality conditions are generally good indicating little to moderate environmental degradation. Threats to the creek are primarily from agricultural nonpoint sources of pollution such as farm field erosion and barnyard runoff that carry sediment and nutrients to the creek adversely affecting aquatic habitat and the creek’s fishery. Failing septic systems at the community of Mt. Vernon may also be affecting water quality, but more intensive water resources monitoring and septic system assessment is needed to determine if there is in fact a problem. Increased urbanization in Mt. Vernon’s two principle tributaries (Fryes Feeder and Deer Creek) could also affect Mt. Vernon at some point in the future.

Mt. Vernon Creek at CTH U

Photo: Steve Fix

Deer Creek

Deer Creek is a small headwaters stream that originates in the Village of Mount Horeb on the south flank of Military Ridge. It flows almost six miles southeast to join Fryes Feeder in forming Mt. Vernon Creek. Deer Creek drains about five square miles and has a steep stream gradient of 42 ft/mi. Springs in its middle reach augment flow. It flows through a narrow valley with steep forested slopes. The steep stream gradient, coupled with steep hillside slopes, causes the creek to be very flashy during major runoff events. While its drainage area’s dominant land use is agriculture, its headwaters area is in urbanizing Mount Horeb. Deer Creek is designated an Exceptional Resource Water and currently supports a Class II trout fishery. Brook trout are readily abundant and redside dace (*Clinostomus elongates*), a rare aquatic species, has also been found in the creek.

Deer Creek at Sutter Lane

Photo: Steve Fix

Historically, water quality problems in the creek have stemmed from runoff from barnyards and cultivated fields, excessive grazing, and increased residential development. Stream stabilization (fencing) projects have helped the stream’s trout fishery. In addition, Mt. Horeb, with assistance from the Dane County Land Conservation Department, developed a comprehensive stormwater management plan. Stream and habitat restoration projects have also been completed on the creek with funding from the state’s Targeted Runoff Management (TRM) program. Dane County received a TRM grant from the DNR to improve instream habitat and stabilize stream banks.

This project led to an improvement of the creek's coldwater fishery. Deer Creek flows through Donald County Park which provides it with additional buffer protection. Dane County also has some temporary streambank easements on portions of Deer Creek.

Prior to beginning the TRM project in 1999, sedimentation and stream bank erosion had degraded fish and other aquatic habitat. Stream bank brushing and stabilization, coupled with instream habitat restoration, resulted in narrowing and deepening the creek, improving aquatic habitat. These improvements allowed Deer Creek to be reclassified as a Class II trout stream supporting both brook and brown trout and a designated Exceptional Resource Water (ERW). Forty-three coldwater IBIs done at ten locations on Deer Creek between 1999 and 2007 resulted in biotic integrity ratings ranging from eleven "Excellent" ratings to one "Fair" rating, with the remaining biotic integrity ratings being "Good." Two M-IBIs measured in 2010 indicated "Good" biotic integrity. Eight samples taken between 1999 and 2000 ranged between "Good" and "Excellent." Research and monitoring have shown a link between amount of land in the USDA's Conservation Reserve Program (CRP) and improvements in small coldwater streams in southwest Wisconsin.[194] A significant improvement in coldwater IBI scores was noted for Deer Creek in pre- versus post-CRP implementation (see **Figures 13 and 14**).

While much has been accomplished, more work is needed. Sediment deposition is still a problem in Deer Creek.[195] Mount Horeb urbanization is a threat to the quality of the resource. Potential threats included reduced infiltration, increased runoff from impervious surfaces, and thermal impacts. Mount Horeb has installed regional stormwater detention facilities that appear to be mitigating thermal pollution to Deer Creek. However, increased impervious surfaces due to urbanization will increase Deer Creek's flashiness. The increased flashiness of the stream will result in increased stream bank erosion and downstream sediment deposition without adequate measures being implemented. Working with regional partners, the Village of Mt. Horeb should promote the installation of rain gardens and biofilters as well as other stormwater management practices in both future and existing development areas in order to protect Deer Creek.

194 Marshall, 2008a.
195 Fetter, 2005b.

Fryes Feeder

Fryes Feeder is a small headwaters stream that originates on the southeast fringe of Mount Horeb. It has a steep stream gradient of 38 ft/mi. The steep stream gradient, coupled with steep hillside slopes, causes the creek to be very flashy during major runoff events. It is 5.3 miles long joining with Deer Creek to form Mt. Vernon Creek. Fryes Feeder is a Class II trout for about 1.5 miles upstream from its confluence with Deer Creek. The entire stream is designated an Exceptional Resource Water (ERW). A DNR fisheries Management publication describes the stream as

> "A classic spring tributary, characterized by a narrow channel with overhanging vegetation, cold water, rocky substrates and higher gradient."[196]

Fryes Feeder at Town Hall Road

Photo: Steve Fix

Fryes Feeder has good populations of both brook and brown trout and serves as a nursery feeder to Mt. Vernon Creek. Water quality has been affected by runoff from farm fields carrying sediment and nutrients to Fryes Feeder. This resulted in sediment deposition affecting aquatic habitat and fish populations. The Dane County Land Conservation Department received a TRM grant from the DNR to do stream bank and habitat improvement work immediately above and below STH 92 in 1999. The TRM

196 WDNR, 2008b.

project work and implementation of agricultural conservation measures reduced runoff resulting in improved habitat and water quality conditions. DNR post-TRM project fish surveys showed brook trout and mottled sculpin populations increased, while brown trout numbers were erratic.[197] Forty-six coldwater IBIs done at several locations on Fryes Feeder between 1999 and 2008 resulted in three biotic index ratings of "Excellent" (score = 90), three biotic index ratings of "Fair" (score =50), and the remaining biotic index ratings being "Good" (score =50). Eleven M-IBI samples collected from several locations on Fryes Feeder between 1997 and 2000 resulted in three biotic ratings of "Excellent," six ratings of "Good," and two ratings of "Fair," with an average rating of "Good" (score = 6.72). HBI monitoring done at several sites on Fryes between 1997 and 2000 indicated "Excellent" water quality (range = 2.89-3.95, average = 3.39, n=11). Research and monitoring have shown a link between amount of land in the USDA's CRP program and improvements in small coldwater streams in southwest Wisconsin.[198] An improvement in coldwater IBI scores for Fryes Feeder was noted in pre- versus post-CRP implementation (see **Figures 13 and 14**).

Water resources quality and conditions in Fryes Feeder are very good to excellent. The primary threats are from increased cropland erosion, particularly from fields moving out of the CRP conservation program into crop production. Another threat is from increased runoff from impervious surfaces as more open and agricultural land is developed in Mount Horeb. The increased stormwater flows and decreased infiltration could threaten baseflow, stream hydrology, water quality, habitat, and the coldwater fish community of Fryes Feeder if adequate stormwater measures are not taken.

Fryes Feeder would benefit in the long run from the Village of Mount Horeb promoting the installation of rain gardens in developed and developing areas and requiring biofilters as well as other stormwater management practices in future residential and commercial developments. Agricultural conservations practices, particularly CRP, need to be maintained or expanded to better protect the creek.

Flynn Creek

Flynn Creek is a 4.6-mile long tributary to the West Branch Sugar River south of CTH A in the Town of Montrose. It drains about five square miles of mostly agricultural land. Flynn has a moderate stream gradient of 21.8 ft/mi. There are springs along the creek that allow it to maintain water temperatures cold enough to support a Class II trout fishery (2.5 miles). Flynn is also designate an Exceptional Resource Water (ERW) by the DNR. Flynn supports both a brown and brook trout population.

Flynn Creek at Fritz Road

Photo: Steve Fix

Cropland erosion and livestock pasturing adjacent the creek have affected aquatic habitat in the past. Significant cropland acreage had been put into the USDA's CRP program or had other soil and water conservation Best Management Practices in place. CRP contract expiration led to significant sediment deposition noted by DNR staff in 2005. Conservation practices and re-enrolling lands into CRP significantly reduced sedimentation.[199] Marshall and others point out the value CRP land coupled with other conservation practices in improving and maintaining the quality of aquatic ecosystems in small cool-coldwater streams in southwest Wisconsin.[200]

197 WDNR South Central Region Water Resources Files, 2010.
198 Marshall, 2008a.
199 Fetter, 2005b
200 Marshall, 2008a.

A coldwater IBI done in 1997 on Flynn Creek at Fritz Road resulted in a biotic index rating of "Excellent" (score = 90) indicating very little human disturbance. Coldwater IBI monitoring was done at two locations on Flynn between 2000 and 2004. The biotic integrity rating of the eight samples ranged from "Good" (scores = 60-70) to "Excellent" (score = 90) indicating very little or slight environmental degradation. While these coldwater IBI scores and biotic indices indicate good coldwater aquatic conditions (average = 75), the scores show a slight decline over the period. For example, the coldwater IBI score at CTH A was "Excellent" (score = 90) in 2000 but had declined to "Good" (score = 70) in 2004.[201] M-IBIs sampled between 1997-2000 indicated "Good" biotic integrity (range = 4.92-10.47, average =6.93, n=7). Additional stream monitoring and sub-watershed land use and land practices assessment need to be done to determine if this slight decline is an anomaly, result of changing land use, or other factors. Better or more agricultural conservation practices are needed to protect Flynn Creek.

Primrose Branch

The Primrose Branch begins in the unglaciated Town of Primrose and flows east 6.3 miles to the West Branch Sugar River in the Town of Primrose west of STH 92. It has a moderate gradient of 19.4 ft/mi. and drains an area of about nine square miles. There are abundant springs that maintain coldwater conditions to support a coldwater fishery. About 3 miles of its 6-mile length is considered Class II trout waters. Primrose supports both a brown and brook trout sport fishery.

Agriculture is the dominant land use in its sub-watershed. Portions of Primrose have been ditched and several of the adjacent farm fields have drainage ditches or drain tiles to the stream. The DNR and the Dane County Land Conservation Department have done streambank restoration projects on Primrose. Dane County has also acquired permanent and temporary fishing easements downstream of Primrose Center Road.

Research and monitoring have shown a link between amount of land in the USDA's CRP program and improvements in small coldwater streams in southwest Wisconsin.[202] A significant improvement in coldwater IBI scores was noted for Primrose in pre- versus post- CRP implementation (**see Figures 13 and 14**).

The WDNR has conducted coldwater IBI monitoring at four sites on Primrose between 2002 and 2008. All nine monitoring episodes resulted coldwater biotic integrity ratings of "Good" (scores = 70-80)[203] indicating slight environmental degradation. HBI sampling done in 1997 indicated water quality conditions ranging from "Good" to "Very Good."[204]

The primary threat to Primrose Branch is runoff from farm fields carrying sediment and nutrients to the stream affecting instream habitat. Better farm conservation practices and wider riparian buffers in some locations would help protect Primrose Branch.

Milum Creek

Milum Creek is a two mile long tributary to the West Branch Sugar River. It drains an area of approximately 3.3 square miles and has a moderate stream gradient of 15 ft/mi.[205] Milum currently supports a warmwater forage fishery according to the DNR. It is designated an Exceptional Resource Water (ERW). Redside dace (*Clinostomus elongates*), a rare aquatic species, had been found in Milum in the 1980s. However, fish surveys in 2000 and 2002 did not find any redside dace. It is likely the redside dace has been extirpated from the creek. Milum Creek has experienced an almost 80 percent decline in the number of nongame fish species since 1974. This decline is in line with a general decline of nongame fish in the Greater Rock River Basin.[206] It is thought that sedimentation from croplands is the primary problem limiting water quality. A 2002 assessment showed the stream suffering from nonpoint source pollution, lack of habitat, and low flow.

201 Data from DNR Fisheries Data Base accessed in 2010.
202 Marshall, 2008a.
203 Data from DNR Fisheries Data Base accessed in 2010.
204 WDNR SWIMS database accessed 2010.
205 DCRPC, 1992.
206 Marshall, 2004a.

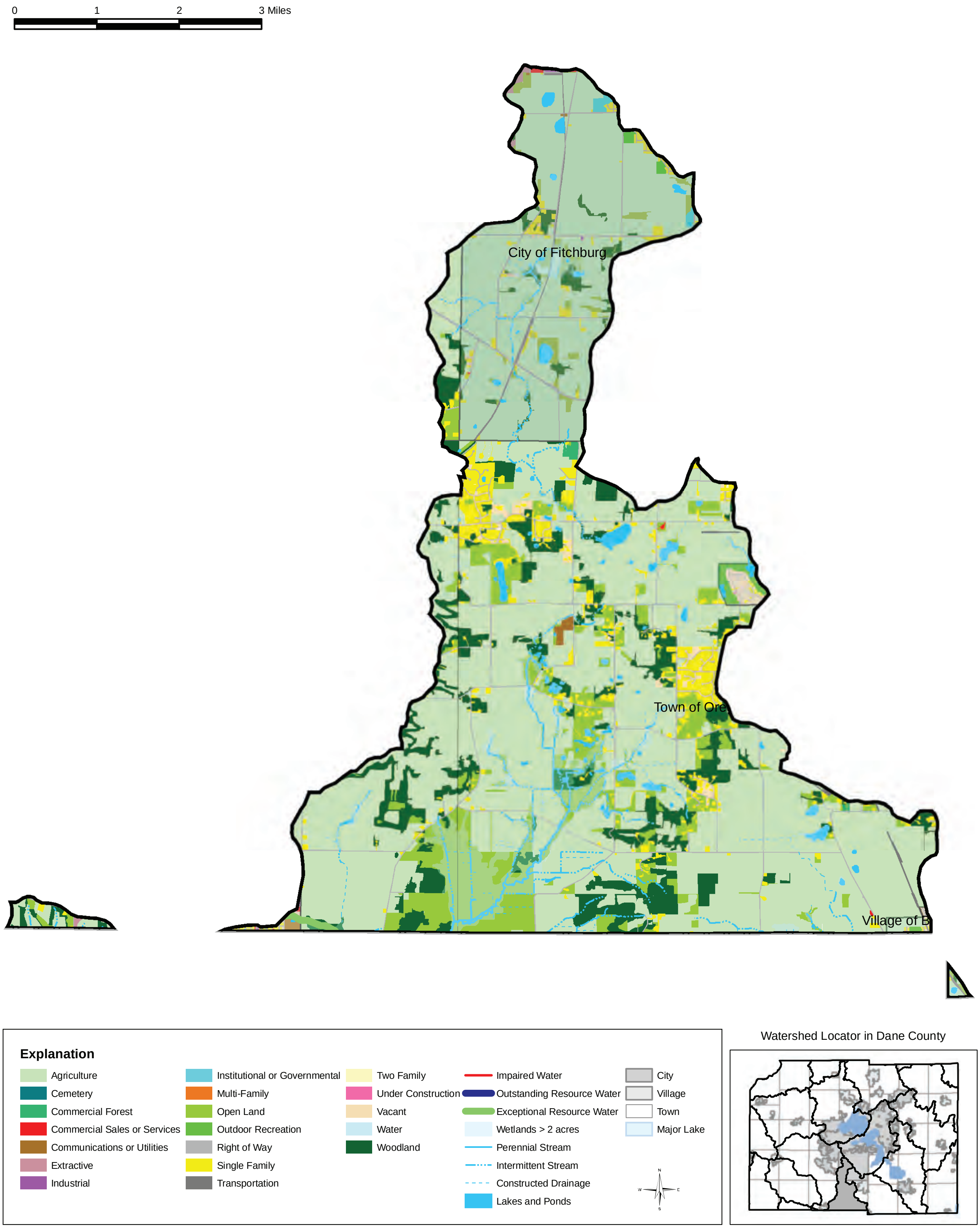
Milum Creek at Fritz Road

Photo: Steve Fix

Monitoring over the last two decades has indicated moderate level of environmental degradation and a reduction in biotic integrity. A 2002 HBI sample indicated “Good” water quality (score = 4.11).[207] A 2002 fish and habitat survey indicated the creek suffers the effects of agricultural nonpoint sources of pollution, particularly runoff from farm fields carrying sediment and nutrients to the creek and downstream waters. The agricultural pollutant loading has resulted in a lack of good fish habitat and low flow.[208] Water quality and instream habitat could be improved with better riparian buffers and additional agricultural conservation measures in place.

207 WDNR SWIMS database accessed 2011.
208 WDNR, 2010b.

Allen Creek and Middle Sugar River Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Allen Creek and Middle Sugar River Watershed (SP13)	
Land Cover	Acres
Residential	1,281
Transportation	802
Industrial	56
Commercial	21
Institutional/Governmental	43
Communication/Utilities	52
Other Lands*	2,272
Agricultural	16,402
Outdoor Recreation	108
Woodland	2,252
Open Water	84
Wetlands	11,31
Hydric Soils**	2,661
Size of Watershed in Dane County	24,503

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Allen Creek and Middle Sugar River watershed is located in south central Dane County, northeastern Green County and northwestern Rock County. About 28 percent of the watershed's area is in Dane County. The Dane County part of the watershed is primarily agricultural, but includes most of the western half of the City of Fitchburg, parts of the Villages of Oregon and Belleville, and parts of the Towns of Verona, Montrose and Oregon. Approximately two-thirds of the Dane County portion of the watershed was covered by the continental glacier during the last Ice Age 10,000 to 25,000 years ago. While not covered by the glacier during the last Ice Age, the remaining part of the watershed southwest of the Johnstown Moraine was covered by an earlier ice sheet. The water resources of the Allen Creek and Middle Sugar River Watershed in Dane County include Story (Tipperary) Creek, Lake Harriet, and the wetlands of the Brooklyn Wildlife Area.

Story (Tipperary) Creek

Story Creek rises on the southwest flank of the Johnstown Moraine and flows 12.5 miles through a wide flat valley to join the Sugar River in Green County. About 6.8 miles of its length is in Dane County. The creek has relatively low stream gradient of 8.7 ft/mi. Story Creek is a small coldwater stream. Several springs have been identified in Dane County and are the sources of the cold water that sustains a Class II trout fishery. It is also designated an Exceptional Resource Water (ERW). Much of its length in Dane County is in the Brooklyn Wildlife Area affording the creek additional protection from agricultural or other human disturbance.
Portions of Story Creek have been channelized in the past and streambank erosion, agricultural erosion and beaver dams in the creek's upper reaches have affected trout habitat. Major streambank and habitat projects funded by trout stamp money have been done improving sections of the stream and providing additional stream buffer and hunting and fishing easements.

Fish and habitat surveys done over the past several years show the stream supports reproducing populations of brook and brown trout as well as coldwater forage fish.[209] Twenty-five coldwater IBIs done between 1993 and 2009 ranged from "Fair" biotic integrity (score = 40) to "Excellent" biotic integrity (score=90).[210] These IBI scores indicate very little environmental degradation and that the creek is one of the better small coldwater streams in Dane County. HBI monitoring done near Bell Brook Road between 1995 and 2002 ranged from 3.62 to 4.32[211] indicating "Very Good" water quality with slight organic pollution.

The primary water quality and aquatic ecosystem threat to Story Creek in Dane County is from runoff from agricultural fields in its headwaters area delivering sediment and nutrients to the creek.

Story Creek at Bell Brook Road

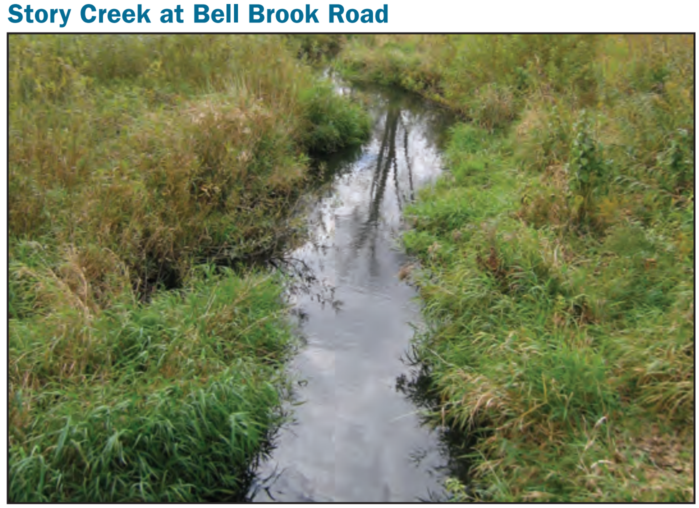
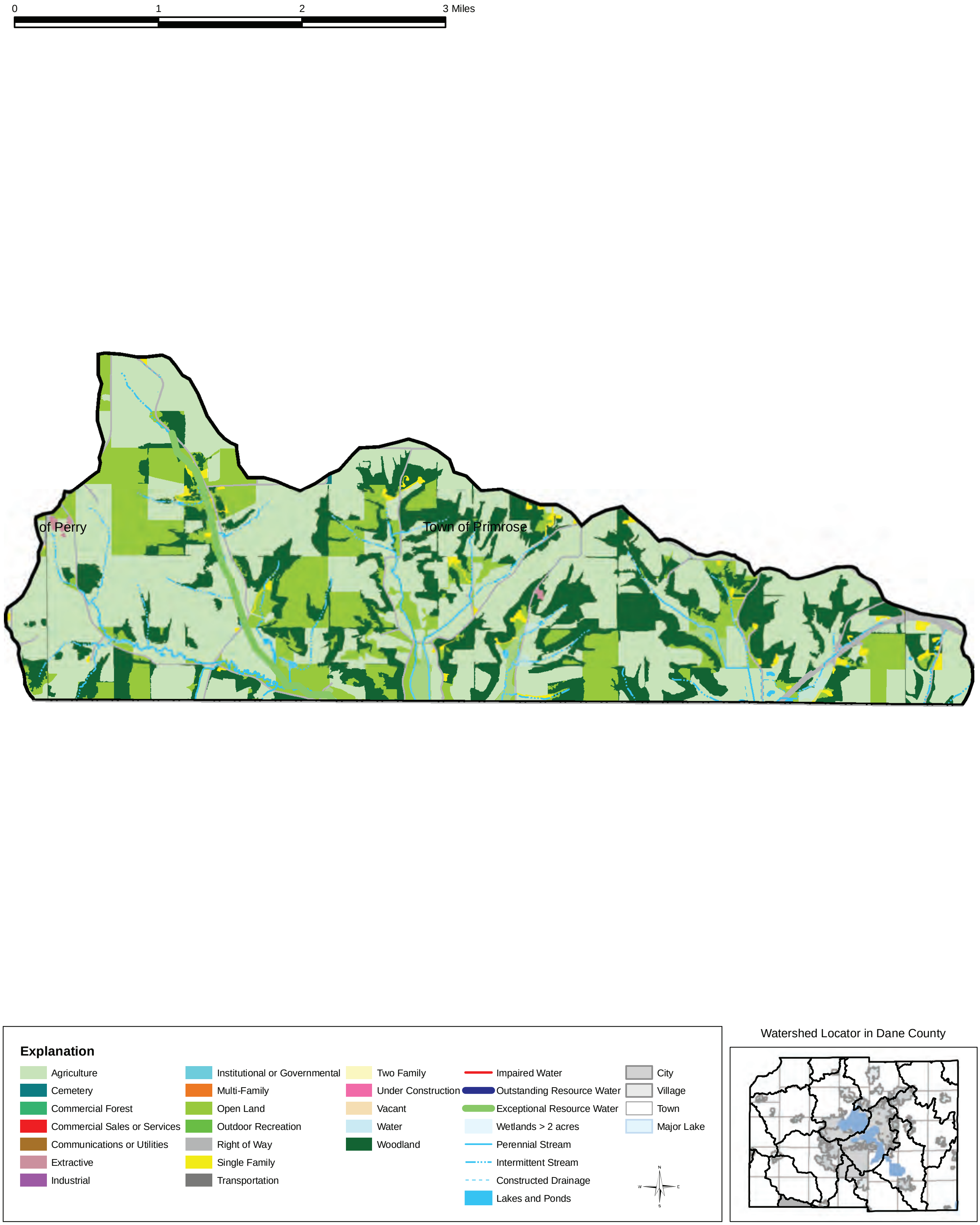


Photo: Steve Fix

209 WDNR, 2011.
210 Data from DNR Fisheries Data Base accessed in 2010.
211 WDNR SWIMS database accessed 2011.

Little Sugar River Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Little Sugar River Watershed (SP14)	
Land Cover	**Acres**
Residential	71
Transportation	211
Industrial	8
Commercial	0
Institutional/Governmental	2
Communication/Utilities	0
Other Lands*	1,109
Agricultural	3,174
Outdoor Recreation	0
Woodland	1,321
Open Water	0
Wetlands	86
Hydric Soils**	594
Size of Watershed in Dane County	5,982

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.

Source: Capital Area Regional Planning Commission 2005 Land Use Data

Most of the Little Sugar River Watershed is in Green County. Approximately 7 percent is in southern Dane County west of Belleville. Portions of the Towns of Primrose, Perry and Montrose are in the Dane County part of the watershed. Short segments of three streams in Dane County (Hustad Valley, Spring Valley, and Ward Creeks) are tributary to the Little Sugar River in neighboring Green County. Agricultural land uses dominate with dairying, corn and soybeans, and animal feeder operations.

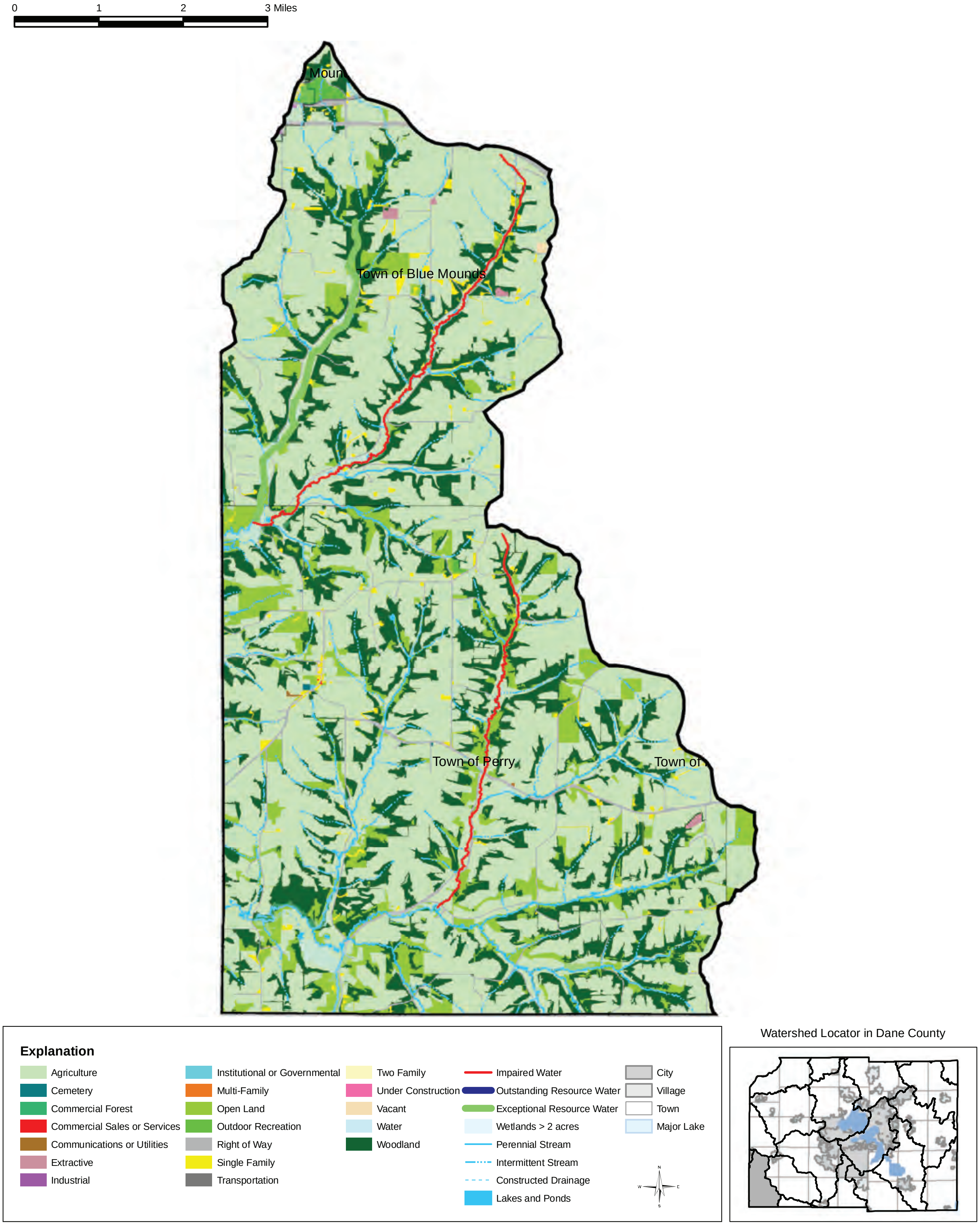
Little Sugar River

The Little Sugar River begins in the Driftless Area ridges and valleys of the Town of Primrose in southwest Dane County. It flows southeast through New Glarus joining the Sugar River near Albany in Green County. About two miles are in Dane County. Agriculture is the dominant land use and runoff from farm fields, pastures, and barnyards are the greatest threat to the river.

The Little Sugar is a Class II trout stream upstream from New Glarus to Dane County. It is designated an Exceptional Resource Water (ERW) from its headwaters to New Glarus. A 2002 fish and habitat survey conducted on the Class II reach found brown trout and cold water forage species but noted the stream lacks good habitat. Two coldwater IBIs done in 2000 near CTH G had "Poor" biotic integrity indicating major environmental damage has occurred.[212] M-IBI results in 2002 and 2011 indicated "Good" biotic integrity (range = 4.59-5.68, average = 5.13, n=2) indicating its condition may be improving.

212 Data from DNR Fisheries Data Base accessed in 2010.

Gordon Creek Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Gordon Creek Watershed (SP05)	
Land Cover	**Acres**
Residential	376
Transportation	915
Industrial	42
Commercial	1
Institutional/Governmental	10
Communication/Utilities	4
Other Lands*	3,171
Agricultural	19,789
Outdoor Recreation	81
Woodland	6,000
Open Water	4
Wetlands	394
Hydric Soils**	1,316
Size of Watershed in Dane County	30,788

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

Seven named streams bisect the broad ridge tops within the Gordon Creek Watershed. The streams are currently managed for trout. Until recently, the streams were degraded from decades of cropland erosion, over-pasturing, and feedlot runoff. The Dane County Animal Waste Management Plan (1985) identified livestock operations as serious threats and impacts to the streams. Significant pollution problems and limited potential for successful water quality improvements were important reasons why the watershed did not rank high for Priority Watershed designation under Wisconsin's former Non-point Source Water Pollution Abatement Program. Three of the streams, German Valley Creek, Syftestad Creek and Pleasant Valley Creek, were listed as 303(d) Impaired Waters.

Recent monitoring data and research demonstrated significant improvements in Gordon Creek Watershed streams.[213] Syftestad Creek is now considered a coldwater community and has been removed from the 303(d) list. German Valley Creek was re-classified as a trout stream and is expected to be removed from the 303(d) list soon. The primary reasons for these and other water quality improvements are linked to positive trends in agriculture and conservation efforts (see **Figures 13 and 14**).[214]

State Special Concern redside dace had been collected in Gordon Creek and Syftestad Creek when eurythermal populations were dominant. The species is now considered extinct in the streams. While the loss of redside dace from the streams is unclear, a number of contributed factors may have influenced its distribution. It prefers cool water habitats while the streams now display cold water conditions. Redside dace is also vulnerable to the dominant species and top predator in the streams, brown trout. Finally, the occurrence of redside dace during the 1970s may have been a temporary artifact of more widespread habitat disturbances.

The combined long term hydrology/water quality improvements and management of trout streams in the Gordon Creek Watershed is a model of restoration. Improvements began at the watershed/landscape scale. Now, DNR, Dane County LWRD, and Trout Unlimited have fine-tuned the restoration at the stream corridor level. As the overall environmental conditions improved in the streams, numerous stream habitat improvement projects are now in various stages of planning and completion. These efforts have been reversing the long term habitat loss associated with box elder growth over incised channels with eroding stream banks.

Water quality and biological monitoring will continue in the watershed as DNR and local partners assess stream responses to local habitat restoration projects. Additional monitoring will involve watershed-scale biological, chemical, and physical data collections as part of a new pilot project involving U.S. EPA, WDNR, and Midwest Biodiversity Institute that will develop sampling designs to improve monitoring strategies.

213 Marshall, 2003.

214 Marshall, 2008a.

Gordon Creek

Gordon Creek, also known as Blue Mounds Branch or Big Spring Creek, rises in Section 8 of Blue Mounds Township and flows south for about eight miles to the confluence with German Valley Creek before entering Iowa County. It is considered one of the premier trout streams in Dane and Iowa counties and has been the focus of extensive habitat restoration in recent years. In Dane County Gordon Creek is designated an Exceptional Resource Water (ERW) and has been managed as a Class II trout stream for decades. The recent interest in the creek coincided with findings that it had significantly improved. **Figure 37** demonstrates how the fish community changed over the years, from eurythermal (tolerant) populations to stenothermal (environmentally intolerant) fish populations more typical of healthy trout streams. Surveys completed from 2007 to 2009 demonstrated that good to excellent trout habitat in the stream continues. Gordon Creek previously supported State Special Concern redside dace but the current cold water temperatures and brown trout predation present survival obstacles for the rare fish.

Figure 38 reveals improved cold water IBI scores over time with the best scores beginning in 2001. In 1994, the IBI score reflected poor coldwater habitat eight years after CRP signups began. The poor coldwater conditions may have indicated a lag time for ecosystem response to improved conditions and/or lower numbers of CRP participants at that time. M-IBI monitoring between 2002-2010 indicated "Good" biotic integrity (range = 5.54-6.55, average = 5.94, n=5).

Figure 39 displays daily maximum mean temperatures and sustained cold water habitat based on Onset Hobo data loggers. HBI scores from samples collected in 1994 through 2002 indicated "Very Good" water quality (range = 2.39-4.96, mean = 3.62). The highest HBI score (lowest water quality) coincided with a manure spill that caused a major fish kill. The favorable HBI score during that pollution event likely reflected macroinvertebrate escape into the groundwater-fed hyporheic zone. The macroinvertebrate community in Big Spring-Gordon Creek typically supports abundant stonefly populations, primarily *Isoperla signata*.

German Valley Branch

German Valley Creek arises in Section 10 of Blue Mounds Township and flows about 7.6 miles to the confluence with Gordon Creek. Until recently, German Valley had never been managed for trout due to chronic low stream flows, poor habitat, and poor water quality. However, while it has been more degraded than Gordon Creek, German Valley Creek followed a similar path toward restoration (**Figure 38**). German Valley Creek now supports primarily stenothermal cold water fish species and the trout stream classification reflects these fish community changes and angler opportunities. Surveys completed from 2007 through 2009 demonstrate continued favorable trout habitat. Several miles of the stream habitat was restored and include easements for public fishing. German Valley Creek is still listed as a 303(d) Impaired stream but it is expected to be removed from the list soon to reflect the significantly improved water quality, habitat, and sustained brown trout population. The Dane County LWRD continues to work with area farmers to improve manure management and other conservation practices. The best trout habitat is located in the lower reaches where enough spring flow sustains habitat and cold water temperatures. HBI monitoring conducted between 1994-2002 indicated "Very Good" water quality (range = 2.91-5.09, average = 4.09, n=7). M-IBI sampling between 2002-2010 indicated generally "Fair" biotic integrity (range = 2.50-7.99, average = 4.79, n=5), improving to "Excellent" downstream to upstream.

Figure 37: Fish Community Changes in Gordon Creek

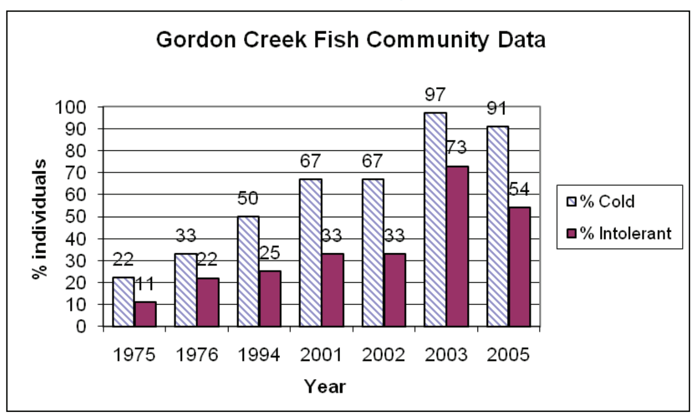


Figure 38. Changes in Coldwater Index of Biotic Integrity scores Over Time in Gordon, German Valley, and Syftestad Creeks

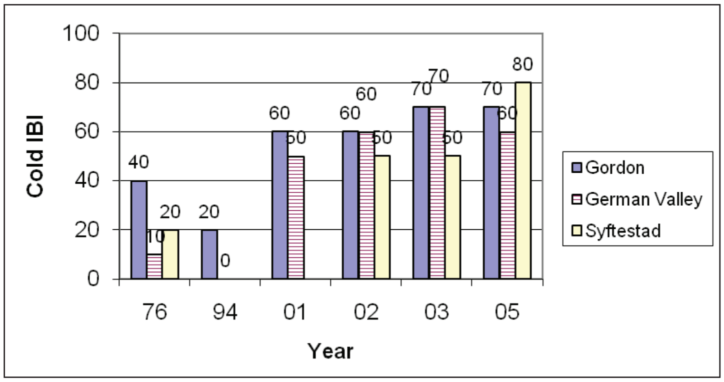
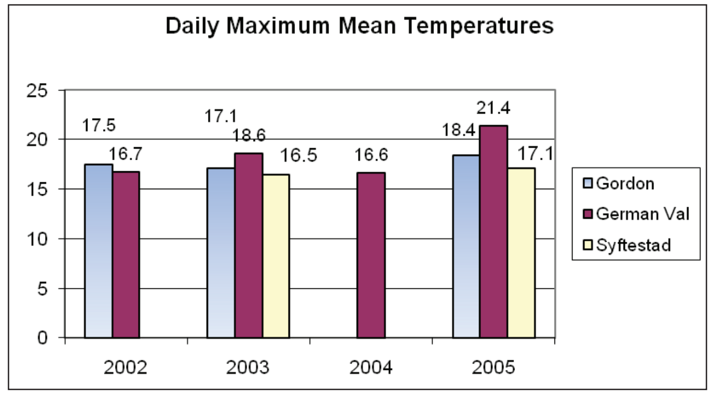


Figure 39. Summary of Continuous Water Temperature Data for Gordon, German Valley, and Syftestad Creeks



Syftestad Creek

Syftestad Creek, also known as Daleyville Branch, is a small stream that rises in section 25, Perry Township and flows south for about 5.2 miles to its confluence with Kittleson Valley Creek. Until recently, Syftestad Creek was considered a degraded forage fish stream due to habitat problems and polluted runoff in the watershed. It was removed from the 303(d) list in 2006 to reflect recent data that revealed conditions favorable for trout and coldwater communities. Syftestad Creek supported 13 species of fish in the 1970s, including the State Special Concern redside dace. The rare fish disappeared from the stream along with most of the other species that do not thrive in sustained cold water habitats. **Figures 38 and 39** display cold water IBI changes over time and continuous data logger water temperature summaries. Fish species richness ultimately declined while cold water IBI scores improved; a consistent pattern among Military Ridge Prairie Heritage Area[215] (MRPHA) streams. Also consistent with the other trout streams in the area, HBI values reflected very good water quality in Syftestad Creek. M-IBI monitoring between 2002-2010 indicated "Good" biotic integrity (range = 3.56-7.51, average = 5.53, n=4). On October 2, 2010, Underwater Habitat Investigations LLC performed a stream shocking demonstration for the Southern Wisconsin Chapter of Trout Unlimited. The survey revealed healthy brook trout and brown trout populations and an "Excellent" biotic integrity rating (score = 90).

Kittleson Valley Creek

Kittleson Valley Creek rises in Section 25 of Perry Township and flows west to the confluence with Gordon Creek in Iowa County. Approximately 10 miles of its 12.7 miles length is in Dane County. The stream has been a classified trout stream for decades but had been plagued with severe bank erosion and livestock grazing. Kittleson Valley Creek improved along with other MRPHA streams more recently. In 2009, WDNR baseline fish shocking surveys revealed that parts of Kittleson Valley Creek supported typical trout stream fish species; primarily brown trout and mottled sculpin. IBI scores from 2006-08 indicated "Fair" to "Good" biotic integrity (range = 30-70, average = 57, n=6). M-IBI monitoring indicated generally "Fair" biotic integrity (range = 1.46-8.62, average = 4.97, n=11). A 2008 HBI sample indicated "Excellent" water quality with a score of 3.19. Kittleson Valley Creek and tributaries Pleasant Valley Creek and Lee Creek, are part of a pilot study known as the Wisconsin Buffer Initiative.[216] The concept is based on targeted croplands and pastures that likely contribute the largest amounts of nutrients and sediment to the streams. The USGS operates a gaging station at CTH H as part of the Wisconsin Buffer Initiative. In 2007 the monitoring data demonstrated how a single storm event can affect water quality. Approximately six inches of rain fell on August 5th and contributed approximately 10 percent of the annual phosphorus load (1,170 lbs.) and approximately 14 percent of the annual sediment load (291 tons) in Kittleson Valley Creek. Flow rates typically average around 16 cfs at that location but peaked at 164 cfs during the late summer storm.[217]

215 Go to http://www.militaryridgeprairie.org/ for more information on the Military Ridge Prairie Heritage Area.

216 Go to http://www.nelson.wisc.edu/people/nowak/wbi/ for more information on the Wisconsin Buffers Initiative.

217 USGS, 2008.

Pleasant Valley Branch

Pleasant Valley Creek is a small stream that rises in section 3 in the Town of Perry and flows south for about 5.9 miles to its confluence with Kittleson Valley Creek. Pleasant Valley Branch is listed as a 303(d) Impaired Water and is a key focus of the Wisconsin Buffer Initiative. HBI samples collected in 2003-04 indicated "Fair" to "Fairly Poor" water quality and ranged from 5.97 to 7.46. More recent biological indicators suggested that the stream likely improved with coldwater IBI scores ranging from "Fair" (score = 30) to "Good" (score = 70). The dominant species were brown trout and mottled sculpin. M-IBI sampling between 2003-2010 indicated "Good" biotic integrity (range = 2.94-6.28, average = 5.59, n=9). Six flow rates measured in 2008 averaged less than 0.5 cubic feet per section approximately one mile above the confluence with Kittleson Valley Creek.

Lee Creek (York Valley)

Lee Creek originates in Green County and flows northward to join Kittleson Valley Creek. The small trout stream displays "Fair" coldwater conditions (IBI=30) near Tyrand Road and improves to "Good" (IBI=60,70) conditions from Lee Valley Road to the confluence with Kittleson Valley. M-IBI monitoring indicates "Good" biotic integrity near Tyrand Road, improving to "Excellent" downstream near Lee Valley Road. An HBI sample collected in 2008 indicated "Excellent" water quality (score = 1.46).

Jeglum Valley

Jeglum Valley Creek originates in Green County and flows 1.5 miles north to join Kittleson Valley Creek. It is classified as a Class III trout stream with a history of brown trout being stocked and having a good diversity of forage fish present.[218] More current fishery information is needed. An M-IBI sample taken in 2010 indicated "Good" biotic integrity (score = 6.71)

C. UPPER ROCK RIVER BASIN

The Upper Rock River Basin includes the Upper and Lower Crawfish River, and Maunesha River watersheds located in the northeastern corner of Dane County. It is in the Drumlin and Marsh physiographic region of the glaciated part of south-central Wisconsin. This physiographic region can be described as having interconnected wetlands drained by sluggish streams and bounded by drumlins. This area was covered by the Green Bay ice lobe during the last glacial age. Depth of the glacial till is generally less than 100 feet.[219] Drumlins, low elongated glacial till hills formed during the last great ice age 10,000 to 12,000 years ago, generally run northeast to southwest in the two watersheds. This area is in the DNR designated Southeast Glacial Plains Ecological Landscape.[220] Historically, vegetation of the Southeast Glacial Plains consisted of a mix of prairie, oak savanna and maple-basswood forests. Wet-mesic prairies, southern sedge meadows, emergent shallow water marshes, and occasional calcareous fens were found in low areas. Baseflow in streams in the watersheds is generally low and water temperatures are warm because groundwater recruitment is minimal.[221] Many of the named and tributary streams have been ditched and straightened and wetlands drained to facilitate draining for agriculture.

Land use in the two watersheds is predominantly agricultural with dairying the major agricultural activity. The soils of northeastern Dane County are highly productive. The drumlin slopes and tops have well-drained to very well-drained mineral soils. Soils of the low areas between drumlins range from somewhat poorly-drained and poorly drained wet mineral soils to very poorly drained organic soils such as Houghton muck. Principle crops include corn, soybeans, and alfalfa. Research in Wisconsin has shown that concentrations of phosphorus (P) and nitrogen (N) in streams increase as the percentage of agricultural land increases in the watershed.[222] This affects the quality of the biotic communities of the streams and of downstream receiving waters such as the Marshall Millpond and the Crawfish River.

218 WDNR, 1985.

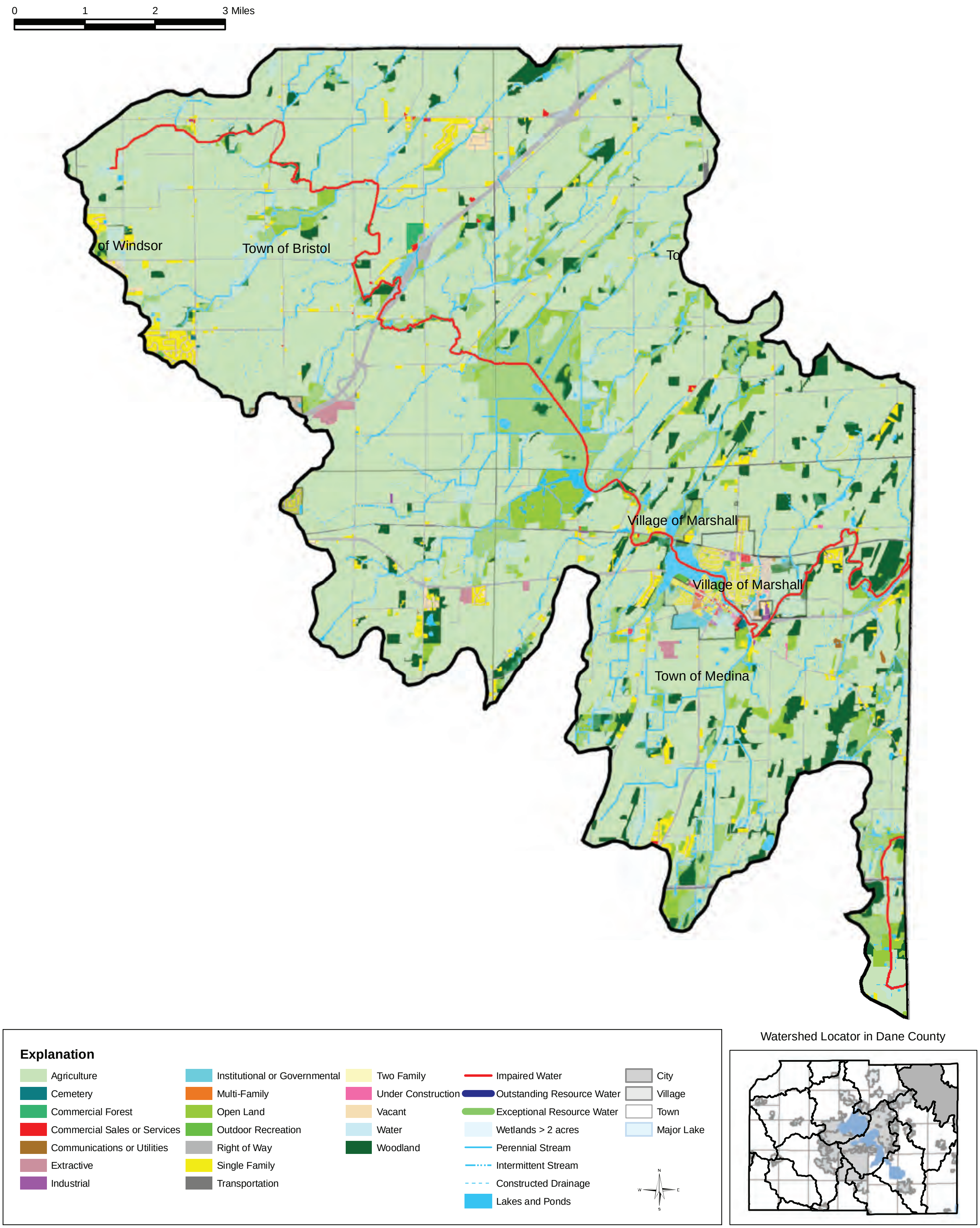
219 Schultz, 1986.

220 WDNR, 2006. http://dnr.wi.gov/topic/landscapes/

221 DCRPC, 1992.

222 Robertson, 2006.

Maunesha River Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Maunesha River Watershed (UR05)	
Land Cover	Acres
Residential	1,608
Transportation	2,158
Industrial	160
Commercial	69
Institutional/Governmental	137
Communication/Utilities	23
Other Lands*	2,856
Agricultural	40,270
Outdoor Recreation	54
Woodland	2,833
Open Water	84
Wetlands	5,779
Hydric Soils**	15,778
Size of Watershed in Dane County	56,030

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.

Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Maunesha River rises along the Dane-Columbia county line in northeastern Dane County. It flows southeasterly through the Towns of Bristol, York and Medina into Jefferson County, eventually emptying into the Crawfish River. The Maunesha River watershed drains about 88 square miles of primarily agricultural land in Dane County. Other streams in the watershed are Schumacher Creek, Spring Creek, and Stransky Creek. There are also several unnamed tributaries, most of which have been ditched and straightened for agricultural purposes. The only incorporated community in the watershed is the Village of Marshall, whose wastewater treatment plant has a surface discharge to the river.

Land use in the Maunesha River watershed is predominately agricultural with 70 percent of its land in agriculture.[223] Corn and soybeans are the primary crops. Each of the three towns through which the Maunesha flows have shown reductions in erosion and soil loss since 1988.[224] However, cropland soil erosion resulting in nutrient loading to the river and downstream waters is still a significant problem. The ditching and straightening of the streams in the watershed has resulted in the loss or conversion of wetlands to agricultural land.

The Maunesha is a shallow meandering gradient river. Much of its length above Elder Lane and west of USH 151 has been ditched and straightened to facilitate and improve agricultural drainage. It has several unnamed channelized tributaries to it, particularly above the Marshall Millpond. The stream channel is natural and the gradient increases with occasional riffles between Elder Lane and the Deansville Marsh State Wildlife Area. The Maunesha has been ditched and straightened through the Deansville Marsh. There is a calcareous fen in the Deansville Fen State Natural Area that is assumed to provide some additional baseflow to the river. There are other small springs in the watershed that provide additional limited baseflow.[225] The river meanders from Deansville Marsh to the Dane-Jefferson county line, passing through the Marshall Millpond. A portion of the watershed from Deansville Marsh downstream is in the DNR proposed Glacial Heritage Area.[226] The Maunesha is also listed as a water, or "paddling," trail by Dane County.[227]

Maunesha River at Twin Lane Road

Photo: Steve Fix

223 Dane County OLW, 2008.

224 Dane County LWRD, 2008
225 DCRPC, 1988.
226 WDNR, 2009d.
227 For more information about Dane County water trails, go to the Capitol Water Trails webpage http://www.capitolwatertrails.org/index.php

The WDNR considers the Maunesha River as a warm-water sport fishery stream that was not supporting its existing or potential use.[228] The DNR placed the Maunesha River on the state's list of impaired waters in 1998.[229] Phosphorus and sediment pollutants were thought to be causing dissolved oxygen (DO) and degraded habitat impairments in the river. The DNR is developing a Total Maximum Daily Load (TMDL)[230] to address the water quality impairments of the Maunesha and other streams in the Rock River Basin. A target instream phosphorus level of 0.075 mg/L has been established for the Maunesha River and for other larger, low gradient streams in the Rock River basin.[231] This level is significantly above the reference background value for streams recommended by Robertson et.al. of 0.03-0.04 mg/L for wadeable streams,[232] but reflects the realities of such low gradient streams in agricultural areas. The Rock River TMDL recommends an average percent reduction of total P loading to the Maunesha of between 31-37 percent in Dane County.[233]

In 1992 water quality of the Maunesha River was considered to be generally good, although concern was expressed regarding the possibility of nighttime DO sags and low-flow conditions that could affect instream habitat and water quality.[234] This is reflected in declining DO levels based on USGS data (**Attachment C-6**). Whereas ammonia nitrogen, nitrates, and suspended sediment have generally improved, total phosphorus levels have increased somewhat.

The DNR has conducted fish and habitat monitoring on the Maunesha and some of its unnamed tributaries. Biotic index monitoring was done in 1998 at two locations, in the vicinity of Greenway Road, upstream from the Deansville Marsh, and at CTH TT downstream from the marsh. HBI scores in 1998 indicated "Good" water quality (score = 4.69) and "Fairly Poor" water quality (score = 6.83), respectively.[235] These scores indicate better water quality above the Deansville Marsh than below the marsh. This can be explained by noting higher stream gradient and riffles between Elder Lane and Greenway Road upstream of the marsh. A 2005 intermittent-IBI done at Muller Road in the headwaters area indicated "Fair" water quality conditions. M-IBI sampling conducted between 1998 and 2003 indicated "Fair" biotic integrity (range = 3.17-4.16, average = 3.84, n=4).[236] M-IBI sampling below the Village of Marshall between 2001-03 also indicated "Fair" biotic integrity.

228 Johnson, 2002a.
229 Section303(d) of the Clean Water Act.
230 For an explanation of Wisconsin's TMDL program, go to http://dnr.wi.gov/topic/tmdls/documents/TMDLFactSheet2012.pdf
231 Cadmus Group, 2012.
232 Robertson, 2006. A stream or other water body reflecting natural conditions with few impacts from human activities and which is representative of the highest level of support attainable in the basin or ecoregion.
233 Cadmus, 2010.
234 DCRPC, 1992.
235 Data from WDNR SWIMS Data Base, 2010.

Schumaker Creek

Schumaker Creek is a small stream that rises in the Town of Medina and flows about three miles northeast to the Maunesha River joining it at the Marshall Millpond. It drains about 11 square miles of mostly agricultural land. Much of its length is channelized to facilitate agricultural drainage. The creek flows through a wetlands complex downstream of CTH TT before entering the millpond. Little is known of conditions in the creek. The DNR considers it as supporting a limited forage fishery but no recent surveys have been done. It is suspected of having poor instream habitat conditions due to the agricultural nature of its small sub-watershed.

Spring Creek

Spring Creek rises in the Town of Deerfield and flows approximately four miles north to join the Maunesha River below the Marshall Millpond. It has been channelized for most of its length to facilitate agricultural drainage. HBI monitoring done in 1988 indicated "Fair" water quality. No recent monitoring or assessment has been done. It is categorized as supporting a fish and aquatic life (FAL) community. Habitat has been affected by cropland erosion depositing sediment in the creek.[237]

Stransky Creek

Stransky Creek is a small ditched creek that flows two miles south to join the Maunesha just upstream of the Marshall Millpond. Much of its length has been channelized to facilitate agricultural drainage. It is categorized as supporting a fish and aquatic life (FAL) community. The stream has a low baseflow. IBI Monitoring was done in 2007 at two locations on Stransky Creek. Conditions at the Stransky Creek sites ranged from fair to very poor based on IBI and HBI scores.

236 WDNR South Central Region Water Resources files, 2010.
237 Johnson, 2002a.

Stony Brook

Stony Brook is a small stream that rises on the Dane-Jefferson line flowing south then east into Jefferson County where it empties into the Maunesha River in the Waterloo State Wildlife Area in Dodge County. The DNR considers Stony Brook of having the potential to be a warmwater sport fishery. About three miles of its 15-mile length is in Dane County. It has been channelized for most of its length in Dane County. It has very low baseflow in Dane County. Water quality and instream habitat suffer due to agricultural runoff carrying sediment and nutrients to the stream. It has been placed on the state's 303(d) Impaired Waters list due sedimentation adversely affecting habitat. It is included in the Rock River TMDL plan. Further downstream in Jefferson County, M-IBI results in 2004 and 2009 indicated "Good" biotic integrity (average = 5.91, n =2).

Marshall Millpond

The Marshal Millpond is a 185-acre impoundment of the Maunesha River in the Village of Marshall. It has a maximum depth of 5 feet. Water Quality is considered poor and it suffers many of the same water quality problems as other shallow impoundments in southern Wisconsin. Those include sedimentation from upstream agricultural practices, turbidity, high bacteria growth, and excessive macrophyte growth.[238] A WDNR fish survey done in 2005 found the lake's fishery was dominated by common carp.[239] Some panfish and largemouth bass have also been noted. The Village of Marshall has commissioned a study to investigate measures to improve the millpond.

Water quality conditions in the Maunesha River watershed appear to be holding steady and perhaps improving slightly. Measured DO values are good. Measured total P, while still above the DNR target, have improved slightly. Runoff from farm fields carrying sediment and nutrients is still the major source of pollution. Increasing buffer widths, particularly along ditched sections and tributaries, may help reduce sediment and nutrient loading, although significant additional water quality and instream habitat improvements may be difficult to achieve. Maintaining a 120-foot continuous stream buffer, natural vegetation, or a combination of natural vegetation and forage or biomass crops can improve water quality and instream aquatic communities. [240, 241] Buffers may also increase stormwater infiltration, especially if planted with deep-rooting native prairie vegetation. Planting native trees on drumlin slopes may also encourage more infiltration needed to maintain stream baseflow.

238 WDNR. 2010. Upper Rock River Basin webpage, http://dnr.wi.gov/water/basin/uprock/
239 WDNR, Fishery Management Data Base, accessed in 2010.

240 Weigel, 2005.
241 Weigel, 2003.

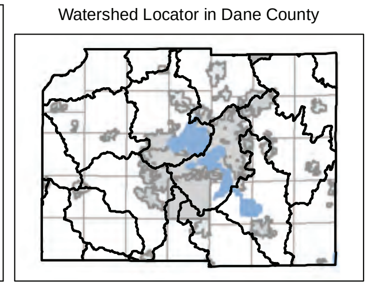
Upper Crawfish River Watershed

0 1 2 3 Miles

Explanation

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland
- Impaired Water
- Outstanding Resource Water
- Exceptional Resource Water
- Wetlands > 2 acres
- Perennial Stream
- Intermittent Stream
- Constructed Drainage
- Lakes and Ponds
- City
- Village
- Town
- Major Lake

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Upper Crawfish River Watershed (UR02)	
Land Cover	**Acres**
Residential	25
Transportation	37
Industrial	16
Commercial	0
Institutional/Governmental	2
Communication/Utilities	7
Other Lands*	41
Agricultural	1,338
Outdoor Recreation	0
Woodland	25
Open Water	0
Wetlands	189
Hydric Soils**	335
Size of Watershed in Dane County	1,680

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

Small portions of two Crawfish River watersheds are in the Upper Rock River Basin in Dane County: the Upper Crawfish River Watershed and the Lower Crawfish River Watershed. These two partial watersheds are combined for this report. The Upper Crawfish Watershed in Dane is a small wedge-shaped area on the Dane-Columbia county line, while the Lower Crawfish River Watershed is in the northeast corner of the Town of York in Dane County. Agriculture is the dominant land use in the watershed.

Mud Creek

Mud Creek originates in Section 26 of the Town of York and flows 11 miles northeast into Dodge County, where it enters the Crawfish River. The first three miles are in Dane County. The stream is classified as a warmwater forage fishery, but agricultural nonpoint pollution and associated habitat and sedimentation impairments keep it from being classified as a warmwater sport fishery. The DNR considers conditions in the creek to be poor and has placed it on the state's 303(d) Impaired Waters list due to sedimentation impairing instream habitat.

Nolan Creek

Nolan Creek is a 10-mile long stream originating in Section 10 of the Town of York. It supports a limited forage fish population. It flows northeast into Dodge County joining the Crawfish River near Danville. Much of its length has been channelized to facilitate agricultural production. While its current biological use is a limited forage fishery, the WDNR believes it has the potential to support a warmwater sport fishery.

D. Lower Rock River Basin

The Lower Rock River basin occupies the central one-third of Dane County. It includes the Yahara River, Koshkonong Creek, and Badfish Creek watersheds. This area lies in the Southeast Glacial Plains Ecological Landscape.[242] Historically, vegetation consisted of a mix of prairie, oak savanna and maple-basswood forests. Wet-mesic prairies, southern sedge meadows, emergent shallow water marshes, and occasional calcareous fens were found in low areas. The depth of glacial till in this basin is generally less than 100 feet, except in the pre-glacial Yahara River valley where the till reaches depths up to 300 feet. The glaciers and glacier meltwater deposited rubble, gravel, and sand along its edges when it stopped moving for long periods. Over time, this deposition built up a hilly belt of irregular, inter-connected ridges and hills called moraines. The Johnstown terminal moraine is located along the western edge of the basin, separating it from the mostly non-glaciated Sugar River Basin. There were large wetland areas adjacent to streams and lakes in the basin. However, many wetlands have been ditched and drained for agriculture and development.

The northern third of the Yahara River sub-basin is primarily agricultural. Dairying, corn and soybean production are the primary agricultural activities. The agricultural nonpoint sources of pollution include cropland erosion and livestock operations. The primary source of pollution is erosion from agricultural lands, contributing sediment and nutrients to streams and downstream lakes.[243] There are several rapidly growing communities in the northern third of the watershed. These include the northwest third of the City of Sun Prairie, the Villages of DeForest, Waunakee, and Dane, and the unincorporated communities of

242 WDNR, 2006. http://dnr.wi.gov/topic/landscapes/
243 DCRPC, 1992.

Windsor, Westport, and Morrisonville. Most wastewater from this part of the basin is sent to the MMSD Nine Springs treatment plant. Both agricultural and urban runoff in the watershed cause significant water quality problems downstream.

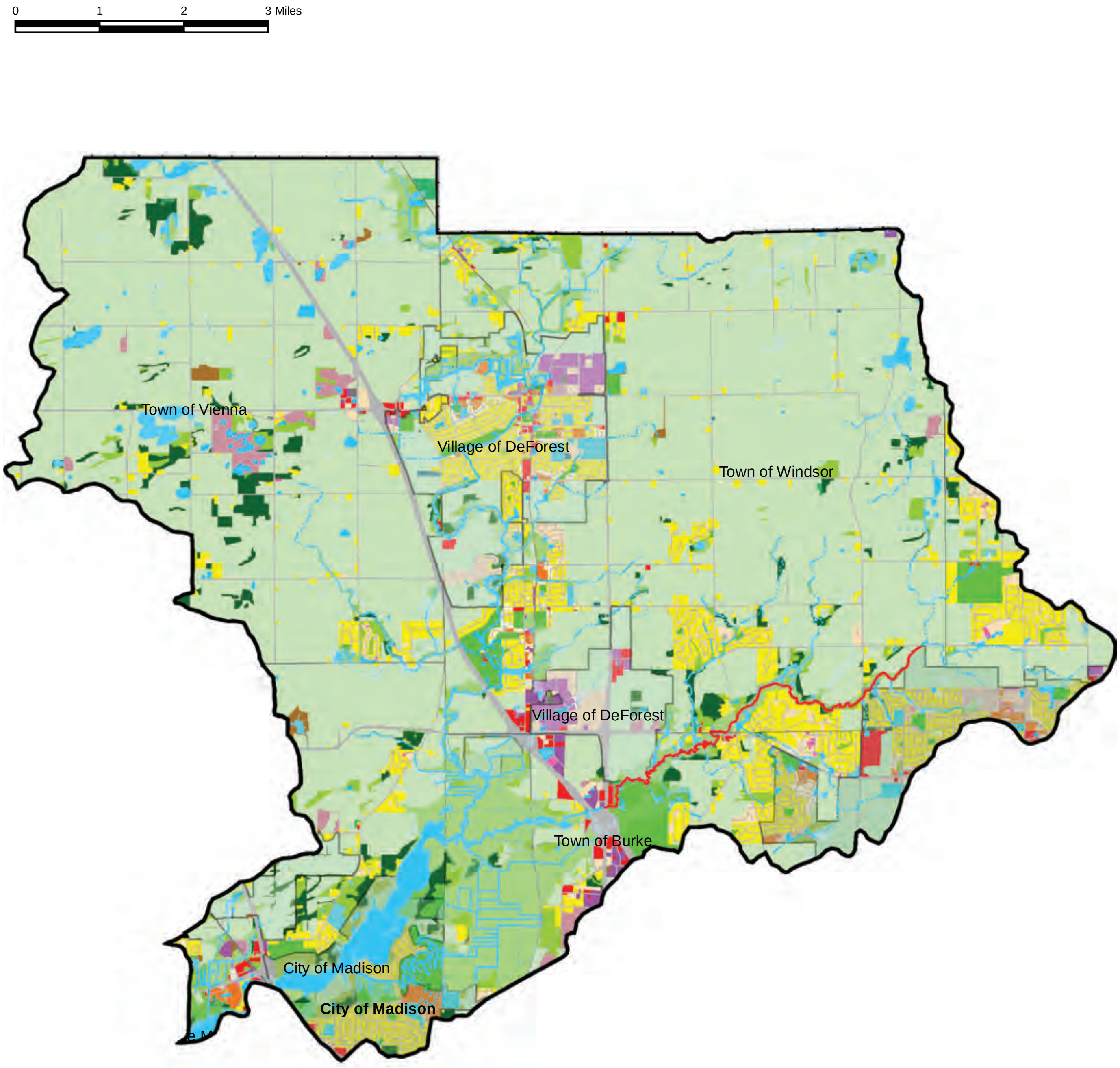
The central part of the sub-basin, the area surrounding Lakes Mendota, Monona, Waubesa, and Wingra, is predominantly urban. It includes much of the Cities of Madison, Middleton, Monona, and the Village of McFarland. Runoff from impervious surfaces and associated pollutants washed from the landscape have degraded water quality and instream habitat characteristic of urban streams. These sources deliver sediment, nutrients, and toxic substances to streams and drainage systems and ultimately to the lakes. There are few industrial discharges to surface water, usually non-contact cooling water. All municipal wastewater is treated at MMSD's Nine Springs facility and subsequently diverted around the Yahara chain of lakes where it is discharged to Badfish Creek east of the Village of Oregon.

This water diversion coupled with groundwater drawdown due to high capacity municipal well water withdrawals has resulted in a reversal of flow to lakes Mendota and Monona -- rather than receiving groundwater discharge prior to municipal well withdrawals, the lakes are now a source for local groundwater recharge. In addition, municipal well withdrawals have reduced baseflow in the Yahara River by nearly half (45 percent) measured at McFarland in 2000 – from 127 cfs to 70 cfs, compared to pre-development conditions (no municipal well withdrawals).[244] Baseflow is expected to be reduced an additional 12 percent, decreasing to 54 cfs in 2030 as a result of future water demand. Baseflow is important to the health and well-being of surface water features since it provides more stable environmental conditions (e.g., temperature and oxygen), especially during critical summer dry-weather periods and droughts.

The southern portion of the Yahara River sub-basin, including the area directly tributary to Lake Kegonsa, is predominantly agricultural. The soils of this part of the basin are generally very productive and the soil associations are similar to those found in the northern third. The main sources of water pollution in this part of the basin are agricultural nonpoint sources, such as cropland erosion and livestock operations. Two incorporated communities, the City of Stoughton and the Village of Oregon, are in this portion. Both Stoughton and Oregon discharge treated municipal effluent to the Yahara River and Oregon Branch of Badfish Creek, respectively. The Badfish Creek and Koshkonong Creek watersheds are described more fully in subsequent sections of this report.

244 DCRPC, 2004b.

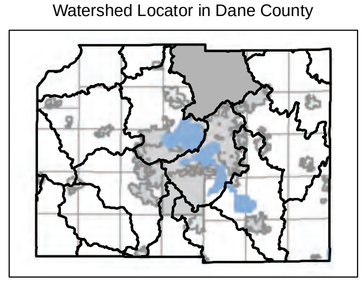
Yahara River and Lake Mendota Watershed



Explanation

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland
- Impaired Water
- Outstanding Resource Water
- Exceptional Resource Water
- Wetlands > 2 acres
- Perennial Stream
- Intermittent Stream
- Constructed Drainage
- Lakes and Ponds
- City
- Village
- Town
- Major Lake

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Yahara River and Lake Mendota Watershed (LR09)	
Land Cover	**Acres**
Residential	5,108
Transportation	3,353
Industrial	958
Commercial	405
Institutional/Governmental	361
Communication/Utilities	119
Other Lands*	3,158
Agricultural	32,725
Outdoor Recreation	1,156
Woodland	1,437
Open Water	585
Wetlands	4,898
Hydric Soils**	7,924
Size of Watershed in Dane County	54,261

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Yahara River and Lake Mendota Watershed (more commonly referred to as the Upper Yahara River watershed), is located in north central Dane County. About 25 percent of the watershed is in Columbia County. It has a mixture of agricultural, suburban and urban land uses. Urban areas include the Village of DeForest, parts of the Town of Windsor, and the rapidly developing northwest side of the City of Sun Prairie. Large portions of the historic wetlands have been drained for agricultural purposes or for development. Cherokee Marsh, at nearly 2500 acres, is the last large wetland complex in the watershed. There are several smaller wetlands complexes also remaining but most, if not all of these wetlands, have been altered or degraded.

Yahara River.

The Yahara River originates in a marshy area of Columbia County near Morrisonville. It meanders about 20 miles through extensively farmed land before reaching Lake Mendota. The DNR has classified the Yahara River as a warmwater sport fishery.[245] The river has a relatively low gradient of about 4.4 ft/mi. between Morrisonville and Lake Mendota. A higher gradient exists near DeForest where the river drops about 55 feet between DeForest and the I-39/90/94 crossing of the river. There is a nice series of runs and riffles between DeForest and the Lake Windsor Country Club that provides good habitat. Groundwater augmentation of flow occurs in this reach. The Lake Mendota Priority Watershed Plan listed this reach of the Yahara River as a priority.[246]

While many wetlands areas formally associated with the river have been drained, particularly in the headwaters area, there are still some wetlands buffering the stream including the large Cherokee Marsh complex. Cherokee Marsh is an extensive peat deposit along the Yahara River and Token Creek, north of Lake Mendota. Covering nearly 2500 acres, Cherokee marsh is the largest wetland in Dane County and the major wetland in Lake Mendota's watershed. Cherokee Marsh contains a large expanse of open wet sedge meadow, varying to fen, prairie, bog, and shallow marsh in places. Islands of upland support oak forest or open fields, while small depressions have high quality ponds or springs. The less accessible central areas probably retain the condition and appearance of many of the Yahara basin marshes a century ago, and therefore considered an important regional reference site.[247]

Attempts to ditch and drain portions of the wetlands in its southern portion has resulted in highly disturbed wetland areas containing invasive species. Much of the marsh is in the public domain with a DNR fishery area and state natural area, Dane County parkland, and Madison Cherokee Conservancy Park. These wetlands are some of the best in the county as well as south central Wisconsin. The Wisconsin Wetlands Association has designated Cherokee Marsh as a state "wetlands gem"[248] and it is used for outdoor environmental education by several schools. The effect of well water withdraw-

245 Johnson, 2002b.
246 Betz, 1997.
247 Bedford, 1974.
248 Wisconsin Wetlands Association. 2009.

als from high capacity municipal wells in the surrounding area, resulting in water table declines and disrupting the hydrologic balance, continues to be a concern. More emphasis is needed on innovative mitigation strategies, such as pumping more water from wells located closer to the Yahara Lakes (a more resilient and sustainable water source), enhanced infiltration and recharge of precipitation and runoff, along with water conservation and reuse.[249]

The Lake Mendota Priority Watershed Plan divided the Yahara River into three distinct reaches. The first reach is from its headwaters near Morrisonville to County Trunk Highway (CTH) V on the north edge of DeForest; the second reach was from CTH V to Windsor Road; the third reach was from Windsor Road downstream to Cherokee Marsh.

Water quality in the Yahara River above Lake Mendota is considered to be fair to good. It supports a warmwater sport fishery. Problems affecting water quality in the first reach, headwaters to DeForest, are related to agriculture followed by development on the north edge of DeForest. The stream's natural channel morphology has been altered by sedimentation from farm fields, channelization, and feeder tributaries. This has led to poor aquatic habitat and facilitating aquatic plant growth. Water quality problems of this reach included low flows, lack of suitable habitat for aquatic organisms, heavy instream sedimentation, and loss of wetlands. While the current biological use of this reach is listed as a warmwater sport fishery, it is more accurately a warmwater forage fishery due to low flows, elevated temperatures, lack of diverse habitat, and low DO levels.[250] The 1997 WDNR priority watershed plan estimated that the Yahara River sub-watershed delivered approximately 12.7 percent of the annual total sediment and phosphorus loading to Lake Mendota.[251] Analysis of USGS data shows a general downward trend in suspended sediment concentrations in the river likely due to improved conservation practices (**Attachment C**). Total phosphorus concentrations over the same period have declined slightly.

The section of the river from South Street in DeForest downstream to Windsor Road is the best stretch of stream in the sub-watershed. It has riffles, pools, diverse substrate, and good velocity. The priority watershed plan considered this reach as having the greatest potential for supporting a valuable sport fishery. In 2010 the DNR identified this segment as a coldwater resource.[252] The area is also identified as a Natural Resource Area in the Dane County Parks and Open Space Plan.

The third reach from Windsor Road to Lake Mendota including Cherokee Marsh supports a diverse warmwater sport fishery. This reach has the same water quality problems as the upstream reaches. It was noted that bank erosion was so significant that it resulted in stream braiding in some locations. There are some better quality wetlands associated with this lower reach. The river and the associated wetlands reach play an important role in providing spawning habitat for a variety of game fish including northern pike, walleye, and white bass that sustain the sport fishery of Lake Mendota. There is a problem with excess carp populations in this reach.

The USGS maintains two stream monitoring stations on the Yahara above Lake Mendota: one at Windsor Road and the other at STH 113. Concentrations of total phosphorus and ammonia nitrogen at the Windsor Road site have remained relatively the same over the past 20 years (1990-2009), about 0.09 mg/L and 0.03 mg/L, respectively, with ammonia showing a slight downward trend (**Attachment C**). Suspended sediment has declined significantly from about 50 mg/L to 15 mg/L over the same period at Windsor Road.[253] Over the 20 year record at this site the month with the highest mean monthly discharge of phosphorus is March at 125 pounds per day (range 5.17-503.0 lbs), followed by February with a mean of 112 pounds per day (range 2.95-429.3 lbs), and June with a mean 94.6 pounds per day (range 5.81-737.1 lbs).[254]

The top three months for suspended sediments are June with a mean discharge of 19 tons per day (range 0.49-103.9 tons), March with a mean discharge of 14 tons per day (range 0.33-77.0 tons), and July a mean discharge of 12 tons per day (range 0.62-163.3 tons). Lathrop concluded that 48 percent of the total phosphorus loading occurs between January and March based on data from this station.[255] Lathrop also suggested that summer algal

249 DCRPC, 1997.
250 Betz, 1997.
251 Betz, 1997.
252 Johnson, 2010.
253 CARPC Files, from USGS data, 2010.
254 USGS data, http://waterdata.usgs.gov/wi/nwis/
255 Lathrop, 2007.

growth in Lake Mendota may be limited by both phosphorus and nitrogen loading to the lake.

Watershed appraisal HBI monitoring for the Yahara River done in 1994-95 indicated a range from “Very Good” water quality conditions at the upper River Road crossing (score = 4.44) to “Fair” conditions at CTH V (score = 5.90).[256] The average HBI score for the five locations monitored was 4.91 indicating overall “Good” water quality.

Yahara River at Windsor Road

Photo: Steve Fix

The WDNR conducted additional monitoring upstream from Windsor Road in 2007. The Wisconsin warmwater IBI fish monitoring indicated “Fair” water quality, while instream habitat was rated as “Good”. The WDNR noted that some intolerant coldwater species were found in this reach. HBI macroinvertebrate monitoring done in 2007 at Windsor Road indicated “Good” water quality. HBI monitoring done at sites upstream of Windsor Road (South Road and CTH V) between 1992 and 2000 indicated water quality ranging from “Good” to “Poor” as one traveled upstream.[257] With one exception, HBI scores at sites between Windsor Road and DeForest have consistently indicated “Good” to “Very Good” water quality conditions for the Yahara River in this reach. M-IBI monitoring between 1998-2007 indicated overall “Fair” biotic integrity (range = 3.03-5.55, average = 4.35, n=10).

256 Sorge, 1996.
257 WDNR, South Central Region Water Resources Files, 2010.

The Yahara River between South Street in DeForest downstream to Windsor Road should be carefully monitored to detect any changes in conditions before they adversely affect water quality, habitat and aquatic communities. Types of monitoring should include F-IBI, M-IBI, HBI, flow, and temperature monitoring.

The USGS monitoring station at STH 113 has a shorter period of record, dating from 2002. Over the 8 year record at this site, the month with the highest mean monthly discharge of phosphorus is March at 147 pounds per day (range 11.27-641.1 lbs), followed by June with a mean of 130 pounds per day (range 28.62-567.4 lbs), and August with a monthly mean of 128 pounds per day (range 30.66-594.4 lbs).[258] This differs slightly from the mean monthly suspended sediment discharge over the same period. Three months (April, May, and June) had the same mean monthly suspended sediments discharge at 15 tons per day. March was close at 14 tons of sediment per day over the 8-year record.

The primary water quality threats to the Yahara River are sediment and nutrient loading to the river from both agricultural and urban sources. The draining of wetlands in the watershed and the straightening of small feeder streams coupled with the intensive agriculture of the watershed has resulted in large sediment and nutrient loading to the river and to Lake Mendota. Farmers, municipalities, Dane County, the WDNR and the NRCS need to continue to install and maintain best-cost practices to minimize runoff, sediment, and nutrient loading to the river. The Village of DeForest and Town of Westport have adopted stringent stormwater management requirements for new development requiring pre-development runoff conditions be maintained. This serves as an important lead or model for other communities wishing to help protect the integrity of their water resources. Common practices include distributed infiltration measures such as rain gardens and bio-filters in both new and previously developed areas. Wetland restoration in the watershed is also needed to help reduce both stormflows and pollutant loads.

258 USGS data, http://waterdata.usgs.gov/wi/nwis/monthly?referred_module=qw&search_criteria=county_cd&submitted_form=introduction

Token Creek

Token Creek is a spring-fed tributary to the Yahara River that originates in north central Dane County near Sun Prairie. It is 10 miles long with a 25.3 square mile drainage area. Token Creek has a moderate gradient of 8.7 feet/mile. The creek provides nearly half of the baseflow for the Yahara River and Lake Mendota.[259]

Token Creek has a diverse fishery containing warmwater, coldwater, forage fish, and rough fish species. The DNR has identified the first three miles upstream from the Yahara River as supporting a warmwater sport fishery, with the potential of becoming a Class III trout stream. The next 3.5-mile segment is identified as supporting a Class III trout fishery with the potential of supporting a Class II trout fishery. The remaining reach of about 3.3 miles upstream is identified as being a warmwater sport fishery with the potential of supporting a coldwater fishery. Token Creek is one of the few trout streams in the glaciated part of Dane County.[260] Token Creek was placed on the state's 303(d) Impaired Waters list in 1998.[261] It was listed because of water quality impairments due to excessive sediment and suspended solids loading, and because of the partially failed Token Creek Millpond dam was an obstruction to fish passage.

The 1997 WDNR priority watershed plan estimated that Token Creek sub-watershed delivered approximately 13.4 percent of the annual total sediment and phosphorus loading to Lake Mendota.[262] Analysis of USGS data shows a general downward trend in suspended sediment concentrations in the creek. Total phosphorus concentrations over the same period also show a downward trend (Attachment C).[263]

Token Creek has substantial groundwater inflow and has been designated a thermally sensitive stream similar to other cold water streams in Dane County.[264] Springs that feed Token Creek are estimated to supply 50 percent of the baseflow to Lake Mendota.[265] The springs flow at a rate of between 3,400 and 4,000 gallons per minute at a temperature of 50^0 F. The largest of these are the Culver Springs on the northeast side of the former millpond which generate approximately half the total spring flow. The main recharge area for the Culver Springs is to the north. Groundwater flowing out of Culver Springs at 50^0 F has a cooling effect on Token Creek, maintaining a stream water temperature within the optimum temperature range for trout.[266]

Former Token Millpond at Dam Site Off Portage Road

Photo: Steve Fix

In 1993 the dam on Token Creek that formed the 44 acre Token Creek Millpond partially failed. The resulting partial drawdown of the millpond exposed several springs and seeps in the wetlands that filled in the former millpond. The dam was finally removed in 2005. Token Creek was placed on the state's 303(d) list in 1998. In 2002 the EPA approved a Total Maximum Daily Load (TMDL)[267] plan for Token Creek. Project goals included:

- restoration of stream morphology and habitat,
- managing and reducing sediment and other pollutant loading from agricultural land through Lake Mendota Priority Watershed Plan, and
- managing stormwater discharges through the Lake Mendota Priority Watershed Plan and DNR's storm water discharge permit program.[268]

259 DCRPC, 1992.
260 WDNR, 2008b.
261 See http://dnr.wi.gov/topic/impairedwaters/ for a discussion of the DNR's impaired waters program.
262 Betz, 1997.
263 Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
264 Dane County LWRD, http://www.countyofdane.com/lwrd/landconservation/cws/index3.html
265 Betz, 1997.
266 Roa-Espinosa, 2003.
267 See http://dnr.wi.gov/topic/impairedwaters/ for a more detailed TMDL discussion.
268 WDNR, 2002e.

The DNR has added the goal of restoring a native brook trout fishery in the reach downstream of the Culver Springs. Brook trout are a very pollution intolerant coldwater sport fish. Restoration work on Token Creek to improve habitat and hydrologic functions include:

- removing the berm around the Culver Springs (completed) allowing them to flow freely,
- bank stabilization, and
- removal of pond sediment above the dam location.[269]

Priority watershed HBI appraisal monitoring of Token Creek done in 1994 and 1995 at four sites indicated a range of water quality conditions from "Very Good" (score = 4.30) to "Fairly Poor" (score = 7.44) depending on location. The monitoring was done prior to complete dam removal.[270] Water quality conditions in Token Creek at CTH C improved significantly between 1994 and 2008 based on HBI scores. The HBI score at CTH C in 1994 indicated "Fairly Poor" water quality conditions (score = 7.49), while the HBI score at the same site in 2008 indicated "Good" water quality conditions (score = 4.92). M-IBI data indicated "Fair" biotic integrity (average = 3.73, n=2). The site immediately below Culver Springs indicated "Good" biotic integrity (score = 5.67).

The WDNR has conducted coldwater IBI monitoring at several sites on Token Creek. Cold-IBI monitoring upstream of the millpond and Culver Springs at CTH C in 1998 and 2000 indicated "Very Poor" biotic integrity conditions (prior to the dam removal). DNR 2006 coldwater IBI monitoring beginning just downstream of the dam site and continuing upstream to the Culver Springs showed a biotic integrity rating of "Good."[271] These data coupled with the ongoing channel and habitat improvement indicates that Token Creek can sustain a viable coldwater fishery. The DNR is attempting to establish a native brook trout fishery in the Culver Springs area.

Results of coldwater IBI monitoring conducted in 2000 and 2001 downstream near Token Creek County Park indicated "Fair" biotic integrity conditions for both years. Coldwater IBIs at STH 19 indicated "Poor" biotic integrity condition in 2000 and "Fair" biotic integrity conditions in 2001.[272] M-IBI scores also indicated "Fair" biotic integrity (range = 2.67-4.85, average = 3.68, n=6) between 1992-2002. A single sample taken below I-39/90/94 in 1998 indicated "Fair" biotic integrity. Overall, more frequent monitoring is needed to track the condition of this important resource.

The primary threat to Token Creek water quality is from urban stormwater and runoff from major roadways. Token Creek is subject to a high level of development pressure from the City of Sun Prairie, the Village of DeForest, and adjacent unincorporated areas of the Towns of Windsor and Burke. Stormwater runoff from these areas, and the three major highways which cross it, is often warmer than ambient water temperature. This runoff can raise instream water temperatures degrading habitat. The City of Sun Prairie has installed several stormwater measures in developing areas near the creek to minimize pollutants reaching the stream and to minimize adverse thermal impacts from urban runoff. The Friends of Token Creek, Dane County, and the WDNR have also acquired land adjacent the creek to further protect it. The area is identified as a Natural Resource Area in the Dane County Parks and Open Space Plan upstream to CTH C.

Continued urban development increasing the amount of impervious cover is a threat to Token Creek and Culver Springs. Extraordinary stormwater management measures will need to be taken to maintain or improve the existing hydroecology of the creek. Maximizing stormwater infiltration opportunities in new development and existing development, where opportunity permits, is needed to maintain existing baseflow and thermal conditions in Token Creek, thereby protecting and possibly even *improving* the coldwater fishery of the creek.

Harbison (Pederson) Tributary

The Harbison Tributary is a cold water tributary to Token Creek arising in Section 33 in the Town of Windsor. A large collection of springs provides its baseflow. The springs and surrounding property is owned by Dane County. The springs provide a stable supply of cold water to Token Creek and also support natural reproduction of brown trout. The 1997 Lake Mendota Priority Watershed Plan reported that this tributary had the highest water quality within the Token Creek Sub-watershed.[273] Four cold water IBIs done in 2000 and 2001 all indicated "Good" biotic integrity. This is consistent with the watershed HBI assessment monitoring done in 1994 and

269 WDNR, 2009a.
270 Sorge, 1996.
271 WDNR, 2008b.
272 Data from DNR Fisheries Management files.
273 Betz, 1997.

1995. M-IBI monitoring indicated "Fair," and improving, biotic integrity between 1994-2000 (range = 1.91-5.07, average = 4.51, n=4). The WDNR has been conducting habitat improvement projects including removal of a rough fish holding pen and streambank work to improve instream and riparian habitat.

The primary threats to the Harbison Tributary are from stormwater runoff from STH 19 that carries pollutants to the stream and thermal loading. A new commercial development proposed at the intersection of USH 51 and STH 19 had the potential to significantly increase stormwater volume altering instream habitat, thermal, and pollutant loading affecting the coldwater fishery of the stream. However, as a condition of its approval the developers agreed to incorporate stringent stormwater controls. Stormwater management measures have been designed and are being installed at this development to maintain the pre-development hydraulic conditions and protect the coldwater designation of this tributary.[274]

Continued urban development in DeForest and the towns of Windsor and Burke that increases the amount of unmitigated impervious cover is a threat to Harbison Tributary and the springs that support the coldwater fishery. Extraordinary stormwater management measures will need to be taken to maintain or improve the existing ecohydrology of the creek. Maximizing stormwater infiltration opportunities in new developments is needed to maintain existing baseflow and thermal conditions in Harbison, protecting the coldwater fishery of the creek. Taking the lead in the region, the Village of DeForest has adopted stringent stormwater requirements for new development that requires pre-development runoff conditions be maintained.

Cherokee Lake

Cherokee Lake is a 57-acre widening of the Yahara River between STH 19 and STH 113 north of Madison. It has a maximum depth of 20 feet. A large portion of its shoreline is publicly owned by the state, Dane County and the City of Madison. It supports a warmwater sport fishery including large-mouth bass, walleye, and northern pike. Agricultural and urban nonpoint source pollution brings sediment and nutrients to Cherokee Lake making it highly eutrophic. Implementation of Best Management Practices and other recommendations of the Lake Mendota Priority Watershed Plan could help improve conditions in the lake.

Lake Windsor

Lake Windsor is a highly eutrophic 10-acre impoundment of an unnamed tributary to the Yahara River. It has a maximum depth of six feet. Its immediate drainage area is residential, but its drainage area also includes agricultural lands and parts of a Town of Windsor industrial park. Its water quality problems are similar to those of other small, shallow impoundments in southern Wisconsin, including turbidity due to sediment and nutrient loading, and dissolved oxygen depletion. Its fishery is limited due to these water quality problems.[275]

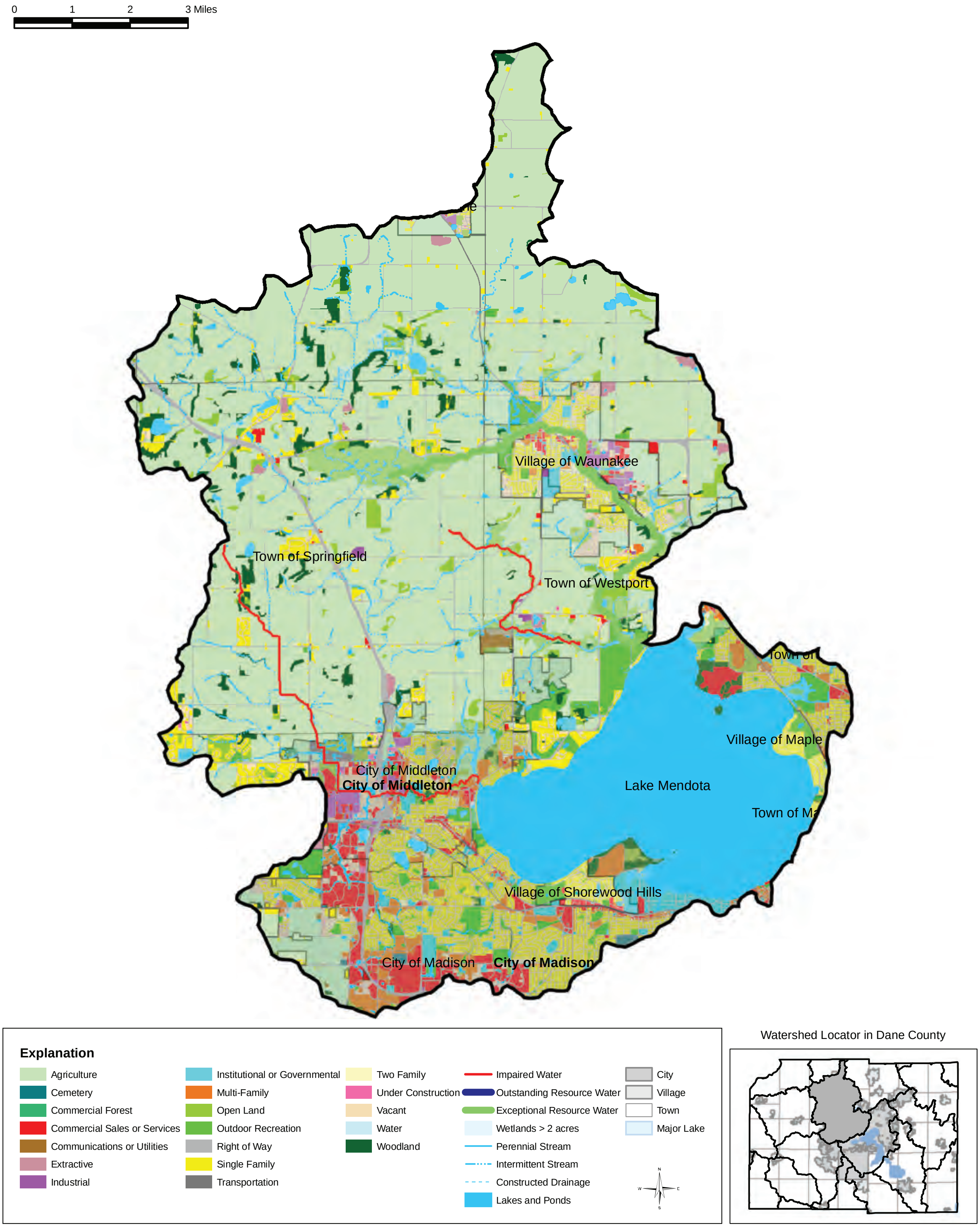
Small or Ephemeral Ponds

There are several small ponds, ephemeral ponds, and wetlands in the watershed that provide resting and feeding spots for migratory waterfowl and shorebirds, particularly during the spring migration season. Many of these are internally drained, having no outlet. The largest of these is a shallow marsh wetland along CTH V east of Schumacher Road. Little is known about the water quality of the ponds. These small or ephemeral ponds and wetlands are threatened by attempts to ditch or drain them to increase agriculturally productive land.

274 Michael Kakuska, Capital Area Regional Planning Commission. Personal Communication, 2011.

275 Sorge, 1996.

Six Mile and Pheasant Branch Creeks Watershed



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Six Mile and Pheasant Branch Creeks Watershed (LR10)	
Land Cover	**Acres**
Residential	9,248
Transportation	5,493
Industrial	737
Commercial	1,939
Institutional/Governmental	1,216
Communication/Utilities	163
Other Lands*	3,704
Agricultural	36,438
Outdoor Recreation	2,393
Woodland	2,113
Open Water	9,938
Wetlands	2,936
Hydric Soils**	6,474
Size of Watershed in Dane County	76,317

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Sixmile Creek and Pheasant Branch watershed is in the northwest part of Dane County. It is a 120 square mile watershed encompassing the Villages of Waunakee and Dane, parts of the Cities of Middleton and Madison, and parts of the Towns of Westport, Vienna, Dane, Springfield and Middleton. Principle streams in the watershed are Pheasant Branch (including the north and south forks), Sixmile Creek, and Dorn Creek, a tributary to Sixmile Creek. There are also small unnamed seasonal and perennial tributaries to the named streams. Most of the historic wetlands have been drained for agriculture or development. The Waunakee Marsh west of Waunakee is the only large wetlands complex in the watershed, although there are smaller ones both isolated and adjacent to waterways.

The soils in the watershed are very fertile and support generally very productive crop yields. Agriculture is the primary land use in the watershed although rapid urban and suburban development is occurring in Waunakee, Middleton, and parts of the Town of Middleton and Westport. There are several larger animal operations and intensive cultivation operations in the watershed. Sub-watersheds with some of the greatest sediment and phosphorus losses in the Rock River Basin are located in this watershed (**see** **Maps 8 and 9 Section VIII Future Horizons**).[276]

The Sixmile Pheasant Branch watershed was one of the first nonpoint source pollution abatement priority watersheds projects undertaken by the WDNR back in the early 1980s. However, it was not considered a success as there was low participation, out-of-state landowners, and inadequate BMP maintenance. This led to the watershed being chosen a second time as part of the larger Lake Mendota priority watershed project.

Sixmile Creek

Sixmile Creek originates in section two in the Town of Springfield. It flows east through the Waunakee Marsh and the Village of Waunakee before turning south to enter the north end of Lake Mendota. The creek is about 12 miles long with a relatively flat gradient of 7.2 ft/mi. Sixmile drains an area of approximately 48 square miles. Land use within its drainage area is predominately agriculture but there is significant development pressure in Waunakee and in the Town of Westport. Many of the historic wetlands adjacent to the creek have been drained. Waunakee Marsh is the remaining large wetland at over 1,000 acres. Another important wetland is between Woodland Drive and Lake Mendota. These wetlands provide important gamefish spawning areas.

Water quality in Sixmile Creek is generally "Fair." It supports a limited forage fishery west of STH 113, and a diverse warmwater sport fishery from STH 113 to Lake Mendota. The WDNR has designated Sixmile Creek as an Exceptional Resource Water (ERW) from just above Kingsley Road in the Waunakee Marsh downstream to Lake Mendota. The reach between STH 19 in Waunakee to just downstream of Mill Road has the best instream habitat. Further downstream the gradient decreases, water turbidity increases, and the stream bottom is fine, often deep silt.

276 Cadmus Group, 2010.

The 1997 WDNR priority watershed plan estimated that the Sixmile Creek sub-watershed delivered approximately 18.2 percent of the annual total sediment and phosphorus loading to Lake Mendota.[277] Total phosphorus concentrations in water samples from Sixmile Creek have shown a slight downward trend since 1990 based on analysis of USGS data (**Attachment C**). Suspended sediment concentrations appear more erratic over the same period. There has been considerable soil loss reduction in the towns within the watershed since 1988. Average annual soil loss is below "Tolerable" soil loss (T) in each case.[278]

Priority watershed appraisal monitoring done in 1994 and 1995 showed water quality conditions ranging from "Good" (HBI score=5.25) to "Poor" (HBI score=7.87) at four locations.[279] Monitoring done for the 1997 Priority watershed plan did find two intolerant forage fish species: the pearl dace and the northern redbelly dace at STH 113. A 1997 HBI sample indicated "Fair" water quality at STH 113. Monitoring done downstream of STH 113 showed the stream supported a warmwater sport fishery including three pollution intolerant forage species: the brook silverside, central stoneroller and pearl dace. Subsequent fish monitoring in 2000 found just the central stoneroller remaining of the intolerant forage fish mentioned in the 1997 report. This indicates a decline in forage species richness and supports a conclusion made by Marshall and others regarding the decline of forage fish species in the Rock River basin overall.[280]

Sixmile Creek at STH 113 in Waunakee

Photo: Steve Fix

277 Betz, 1997.
278 Dane County LWRD, 2008.
279 Sorge, 1996.
280 Marshall, 2004a.

Fish IBI monitoring done by the DNR at two locations on Sixmile in 2007 indicate "Poor" water quality based on fish assemblage while instream habitat had a habitat rating of "Fair". The 2007 IBI data is similar to IBIs done in 2000 indicating marginal, if any improvement in water quality base on fish assemblage. Intermittent IBI monitoring between 1998-2007 indicated "Fair" biotic integrity (range = 50-80, average = 68, n=3). M-IBI monitoring conducted between Hwy 113 and Mill Road indicated "Fair" biotic integrity (range = 2.68-4.42, average = 3.47, n=5). HBI monitoring conducted in 2007 also indicated "Fair" water quality. The reasons for the "Poor" IBI scores are not clear, but urban stormwater runoff creating flashy flow conditions and carrying pollutants to the creek, and fish migration blockage by the dam at Lake Mary, a small impoundment of the creek, may be factors. There have been fish kills on Sixmile in past years, including one in 2001 thought to be caused by high chlorine levels from the flushing of a new water main.[281] An M-IBI sample taken in 1995 at Kingsley Road indicated "Poor" biotic integrity (score = 2.11) believed to be the result of agricultural influences in the stream's headwaters.

Two small unnamed streams are tributary to Sixmile Creek. One rises north of Waunakee and flows southwesterly before emptying into Sixmile Creek just west of STH 113. It flows through agricultural land for about half its length. The remainder is through a small wetland and a developed area of Waunakee where it is well buffered. Parts of it have been channelized. Little is known of its water quality although water clarity is good.[282] The second tributary originates in section 10 of the Town of Westport and flows south through a residential subdivision to Sixmile Creek. This small narrow coldwater stream is well buffered by wetlands from Hogan Road downstream.[283] HBI monitoring conducted in 1994 and 1995 indicated "Good" water quality conditions.[284] M-IBI monitoring indicated "Poor" biotic integrity (average = 2.44, n=2).

The primary threats to water quality in Sixmile Creek and its two unnamed tributaries continue to be from urban nonpoint sources and runoff from impervious surfaces in the Village of Waunakee and the Town of Westport. Waunakee Marsh captures much of the sediment and nutrients from agricultural areas tributary to Sixmile Creek

281 Dane County OLW, 2008.
282 Steve Fix. Personal Observations, 2010.
283 Betz, 2000.
284 Sorge, 1996.

west of Waunakee adversely affecting the marsh ecology.[285] Some of these pollutants may leave the marsh during periods of high water and flows.

Dorn Creek

Dorn Creek rises in the Town of Springfield and flows southeasterly 6.5 miles through agricultural land and Governor Nelson State Park before meeting Sixmile Creek. The stream supports mainly a tolerant warmwater forage fishery. Two intolerant forage species are also known to inhabit the creek: the northern redbelly dace and pearl dace.[286] Land use is predominately agricultural upstream of CTH Q. Downstream of Highway Q, the stream passes through wetlands. These wetlands provide spawning areas for northern pike as well as wildlife habitat. The area downstream from CTH K is designated the Dorn Creek Fishery Area by the WDNR. The area is also included in the North Mendota Natural Resource Area identified in the Dane County Parks and Open Space Plan.

Dorn Creek's sub-watershed is slightly more than one-third the size of Sixmile's sub-watershed and was estimated to contribute 18 percent of the sediment and phosphorus loading to Lake Mendota, compared 18.2 percent from Sixmile Creek. This indicates the intense agricultural activities occurring in the sub-watershed. Dorn Creek has been listed as a 303(d) Impaired Water because of sediment loading impairing aquatic habitat. It has also been included in the Rock River Basin Total Maximum Daily Load (TMDL) project as a second level priority stream.[287]

The 1997 priority watershed plan HBI sampling results for Dorn Creek ranged from "Very Good" to "Poor." The better HBI values were near its headwaters upstream of Meffert Road, while the "Poor" values were at CTH Q and K. The stream suffers from heavy sedimentation and poor substrate conditions due to the intense agricultural activities in it sub-watershed. Monitoring in 2009 evaluation of Dorn Creek noted up to waist deep silt deposits at CTH Q. The heavy instream sedimentation was also evident at downstream locations. IBIs done at two sites indicated "Very Poor" conditions.[288]

The primary water quality problem and threat to Dorn Creek is from agricultural runoff carrying sediment and nutrients from barnyards and cultivated farm fields degrading water quality and habitat.

285 Johnson, 2002b.
286 Johnson R., 2002b.
287 WDNR, 2006.
288 WDNR, South Central Region Water Resources Files, accessed in 2010.

Pheasant Branch

Pheasant Branch is a 9-mile long stream that drains 22.7 square miles in west-central Dane County. It enters western Lake Mendota after flowing through the Pheasant Branch marsh that includes a large spring complex. Land use ranges from intense agricultural uses to the urbanized and urbanizing portions of Madison and Middleton. Stream gradient is estimated to be 19.7 ft/mi. That is misleading in that it reflects the steep gradient of the creek between USH 12 and Century Avenue (CTH M) and of the South Fork. A significant length of the North Fork above USH 12 is relatively flat. The lower end of Pheasant Branch flows through the Pheasant Branch wetlands complex that includes the Frederick Springs, a groundwater source for Lake Mendota. The wetlands are also important for providing fish spawning habitat and habitat for a number of aquatic species.

There are two forks draining to the Pheasant Branch mainstem. The South Fork is intermittent flowing north from its headwaters near Mineral Point Road to meet the North Fork near the USH 12 and 14 interchange in Middleton. The South Fork is primarily a stormwater drainageway for a large part of the westside of Madison and Middleton. The North Fork drainage area is predominately agriculture until it gets to Morey Field airport north of Airport Road. Much of Pheasant Branch upstream of Airport Road has been channelized and straightened to facilitate agricultural production. The stream and the drainage ditches leading to it generally have minimum vegetative buffer. There are also some large animal operations contributing sediment and nutrients to the stream. Fish kills related to manure spills or spreading have been noted in the North Fork of Pheasant Branch.[289]

Pheasant Branch flows through the Middleton commercial park between Airport Road and Parmenter Street. From Parmenter Street downstream to Century Avenue it flows through the mostly residential section of Middleton. The section through the commercial park had been channelized, but Middleton has re-meandered the stream within the floodway between Airport Road and Parmenter Street. Middleton has installed a large detention pond

289 Sorge, 1996.

just upstream of USH 12, designed to reduce peak flows and sediment loading. Pheasant Branch is rapidly eroding its channel through the terminal moraine and has carved a steep, narrow ravine between Parmenter Street and Century Avenue. The peak flows exacerbate the erosion downstream of Parmenter Street. Middleton has employed different types of bank stabilization efforts to reduce the erosion.

The existing biological use of the first mile of Pheasant Branch between Lake Mendota and the Pheasant Branch marsh is a warmwater sport fishery. The WDNR considers the remaining nine miles to support a tolerant limited forage fishery.[290] Pheasant Branch Creek is also on the state's 303(d) Impaired Waters list due to degraded aquatic habitat and low DO levels. It has also been included in the Rock River Basin TMDL project as a top priority stream due to phosphorus and sediment degrading habitat and causing low dissolved oxygen levels in the stream. The proposed target phosphorus concentration for Pheasant Branch is 0.075 mg/L, along with an average 94 percent reduction in total suspended solids.[291]

Failing Bank Stabilization Along Pheasant Branch in 2010

Photo: Steve Fix

Priority watershed HBI appraisal monitoring scores from 1994 to 1995 ranged from 7.01 to 7.90 indicating "Fairly Poor" to "Poor" water quality conditions for the reach between Parmenter Street (USH 12) and Century Avenue (CTH M). Only two species of fish were found in this reach which was surprising given what was considered good habitat conditions.[292] WDNR baseline fish IBI monitoring done in 2003 at two locations indicated the stream had "Very Poor" biotic integrity rating at both stations. This is consistent with earlier IBI monitoring done. HBI monitoring also indicate "Poor" water quality conditions.[293] However, M-IBI samples taken in 2002 and 2003 indicated "Fair" biotic integrity above Century Avenue (range = 2.75-3.52, average = 3.14, n=2) and "Good" biotic integrity below the Pheasant Branch Marsh. The reason for the discrepancy in results is unclear, although it may be associated with the low baseflow conditions in the upstream segment presenting an obstacle to fish, but not macroinvertebrates.

The 1997 Lake Mendota priority watershed report estimated that Pheasant Branch sub-watershed of the Lake Mendota watershed contributed 19 percent of the sediment and phosphorus loading to the lake. Both suspended sediment and phosphorus concentrations in baseflow have declined significantly since the early 1990s (**Attachment C**). The annual fluctuations are due to the number and intensity of annual storms and runoff events, which vary from year to year. Sediment and phosphorus loading to Pheasant Branch shows a fluctuating downward trend based on USGS monitoring data (**Figures 40 and 41**). It is important to note that while streamflow has been historically increasing, sediment and phosphorus loading has been decreasing. The pollution reduction is attributed to more effective and widespread conservation measures being employed in the watershed.

For the period 1993–2001, Pheasant Branch had the highest contributing load and yields to Lake Mendota for the three major streams discharging to the lake, but annual loads changed significantly after construction of the Confluence Pond in 2001 (Table 11).[294] Since that time, the annual sediment load for Pheasant Branch has decreased 45 percent and the annual phosphorus load has decreased 48 percent. In contrast, for the same period, the annual sediment load at the urban Spring Harbor Storm Sewer station decreased by 10 percent, while the annual sediment load at the agricultural Yahara River station decreased by 18 percent and the annual phosphorus load decreased by 3 percent. This difference in the change in loads for Pheasant Branch, compared with

290 Johnson, 2002b.
291 Cadmus Group, 2010.
292 Sorge, 1996.
293 WDNR, South Central Region Water Resources Management Files, Accessed in 2010.
294 USGS, 2012.

Table 11. Comparison of Annual Sediment and Phosphorus Loads for Three Major Streams Contributing to Lake Mendota, Wis., for the periods 1993, 1995–2001, and 2002–8

USGS station number	Stream Name	Contibuting dranage area (mi²)	Time Period	Annual suspended sediment load (tons)	Annual suspended sediment yield (tons/mi²)	Annual total phosphorus load (lb)	Annual total phosphorus yield (lb/mi²)
05427948	Pheasant Branch at Middleton	17.1	1993-2001 2002-2008	2,650 1,450	155 84.7	12,200 6,300	713 368
05429650	Spring Harbor Storm Sewer	3.29	1993-2001 2002-2008	321 287	97.6 87.2	- -	- -
05427718	Yahara River at Windsor	37.0	1993-2001 2002-2008	2,460 2,010	66.3,54.3	15,700 15,300	424 413

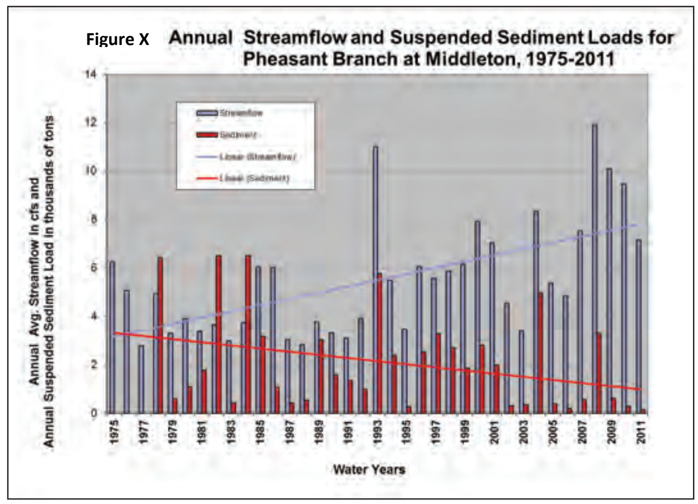
Source: U.S. Geological Survey, 2012.

the other streams, indicates that the Confluence Pond and other stormwater-management facilities constructed since 2001 have significantly reduced the loads from Pheasant Branch. Also, this decrease in loads occurred in spite of increased annual runoff and flood peaks, which normally produce higher sediment and phosphorus loads. After 2001, Pheasant Branch total phosphorus yields are less than those from Yahara River at Windsor. Both Pheasant Branch and Spring Harbor Storm Sewer, the urban streams, have higher suspended-sediment yields than Yahara River.

In 2001 the USGS published a study of the hydrologic effects of urbanization on the North Fork Pheasant Branch sub-watershed. The modeling indicated that low density development (i.e., an increase in impervious surfaces in the undeveloped parts of the sub-watershed with no mitigation measures being taken) would increase overland flow 84 percent, increase mean annual streamflow 53 percent, and decrease baseflow by 15 percent. This scenario would also decrease regional groundwater recharge by 10 percent.[295]

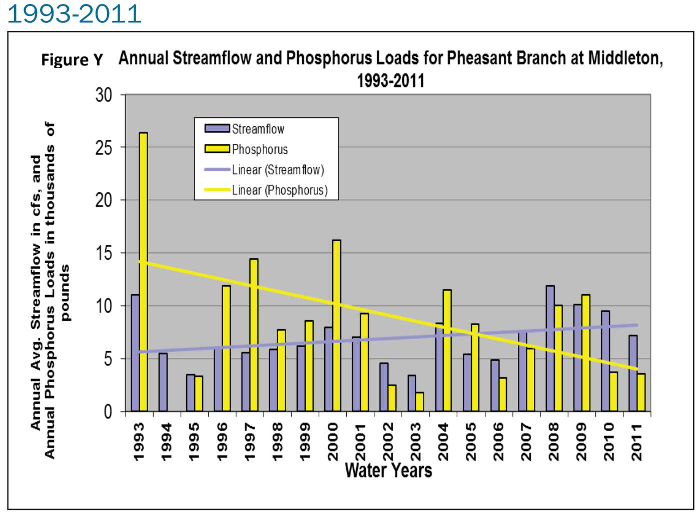
The increased overland flow and mean annual streamflow coupled with an overall decrease in baseflow indicates a system with more “flashy” stormflow events and greater erosive force or potential. A decrease in regional groundwater recharge due to impacts of urbanization could affect the Frederick Springs, a large springs complex in Pheasant Branch Marsh.[296] Much of the groundwater recharge area for Frederick Springs lies within the Pheasant Branch drainage area. The surface water drainage system is complexly coupled with the groundwater system making it difficult to reliably predict actual impacts of urbanization on surface water baseflow and spring flows.

Figure 40. Annual Streamflow and Suspended Sediment Loads for Pheasant Branch Creek at Middleton, 1975-2011



Source: U.S. Geological Survey

Figure 41. Annual Streamflow and Phosphorus Loads for Pheasant Branch at Middleton.
1993-2011



Source: U.S. Geological Survey

295 Steuer, 2001.
296 Hunt, 2000.

The results of the surface water hydrology modeling and the groundwater recharge done in the Pheasant Branch watershed provide the best estimate of what could happen without mitigation being taken and provides a first step in efforts to protect groundwater recharge and both surface water baseflow and flow from springs. Similar to other urban areas, efforts to maximize stormwater infiltration and groundwater recharge in both new and previously developed areas can help reduce destructive stormflows and pollutant loading and possibly even improve the health of the creek.

Willow Creek

Willow Creek is a local name for what is now an urban stormwater conveyance in the City of Madison. Its 3.2 square mile drainage area collects stormwater from the near westside of Madison, parts of Shorewood Hills, and the University of Wisconsin campus, and discharges it to Lake Mendota at University Bay. Willow Creek's drainage basin contributes the typical urban pollutants such as toxic substances from streets and parking lots, nutrients from lawns, sediment, and trash. Sediments carried by the drainage system to Lake Mendota have created a sediment plume in University Bay at the mouth of Willow Creek. A 1997 USGS report estimated a median total sediment loading of 143 tons per acre (range 80-293 tons per year) over a six year period of record.[297] The USGS no longer supports a monitoring station on Willow Creek.

Willow Creek at Observatory Drive

Photo: Steve Fix

297 Corsi, 1997.

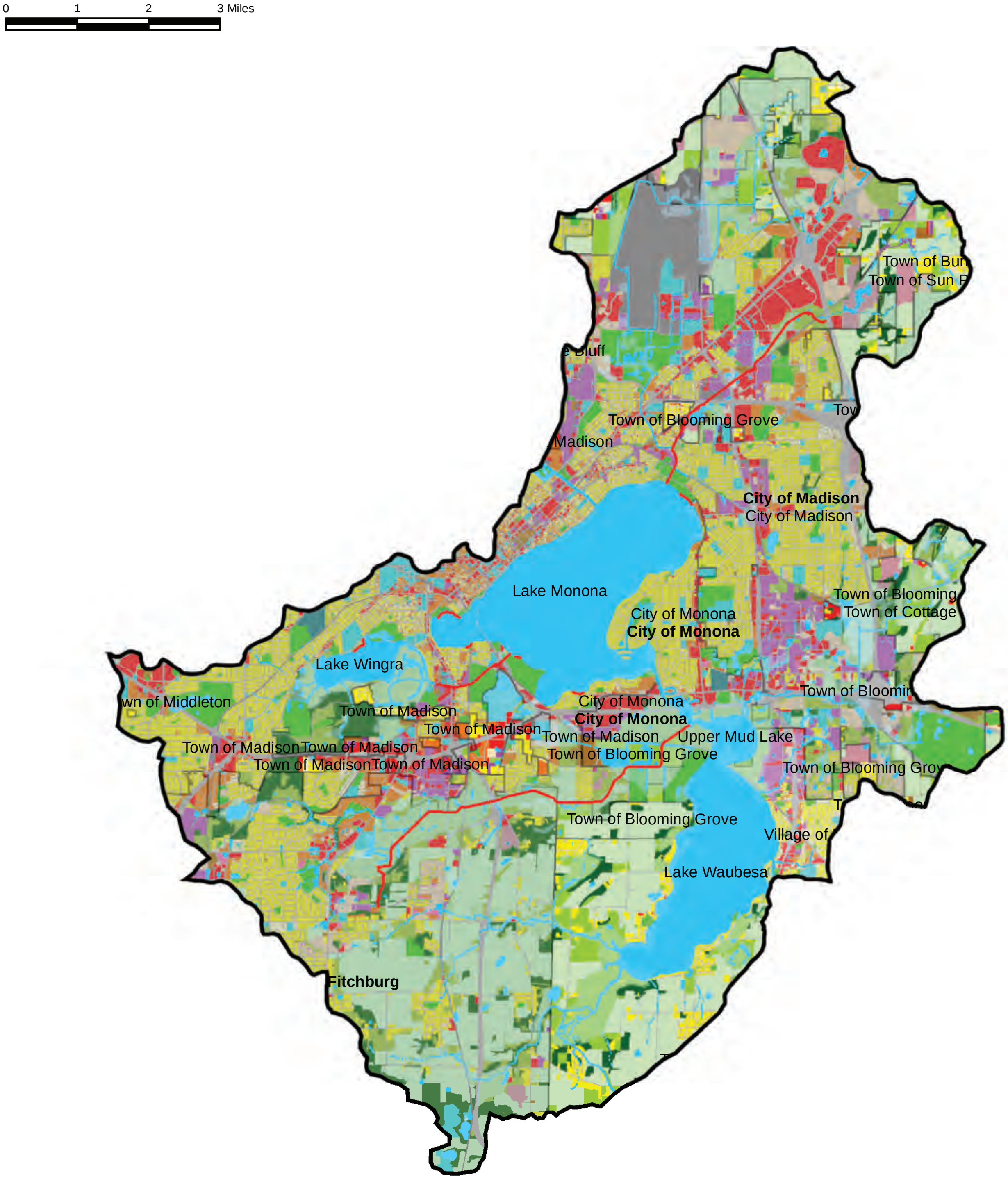
Brandenburg Lake

Brandenburg Lake is a 38-acre seepage lake at the edge of the Johnstown end moraine northwest of Middleton. It has a maximum depth of 9 feet. Much of its 2.7-square mile drainage area is in agriculture. The surrounding land is privately owned and public access is not available. Runoff from surrounding farm fields has impaired water quality. The lake was once used as a walleye fingerling rearing facility. Severe winterkill conditions prevent the establishment of a year-round fishery.

Esser's Pond (15 acres), Graber Pond (13 acres), Strikers Pond (15 acres) and Tiedeman's Pond (15 acres)

These four ponds are all glacial pothole seepage ponds in the developed and rapidly developing areas of Middleton and the westside of Madison. The water quality in each is affected by runoff from urban nonpoint pollution sources. All experience nuisance algae and plant growth in the summer. The ponds provide wildlife habitat to some migratory waterfowl, amphibians, and other wildlife in an otherwise urban landscape. Water level in Tiedeman's Pond had risen to the point that it threatens adjacent homes. Middleton solved this problem by pumping water from the pond to Lake Mendota. Madison and Middleton have taken some measures to protect the ponds. More could be done, particularly by individual property owners, in cooperation with city engineers.

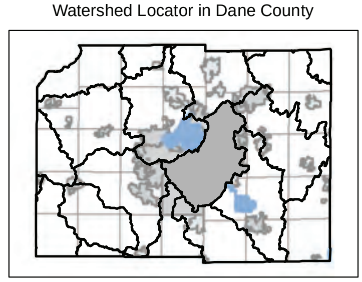
Yahara River and Lake Monona Watershed



Explanation

Agriculture	Institutional or Governmental	Two Family	Impaired Water	City
Cemetery	Multi-Family	Under Construction	Outstanding Resource Water	Village
Commercial Forest	Open Land	Vacant	Exceptional Resource Water	Town
Commercial Sales or Services	Outdoor Recreation	Water	Wetlands > 2 acres	Major Lake
Communications or Utilities	Right of Way	Woodland	Perennial Stream	
Extractive	Single Family		Intermittent Stream	
Industrial	Transportation		Constructed Drainage	
			Lakes and Ponds	

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Yahara River and Lake Monona Watershed (LR08)	
Land Cover	**Acres**
Residential	10,884
Transportation	9,356
Industrial	2,630
Commercial	2,924
Institutional/Governmental	1,725
Communication/Utilities	314
Other Lands*	5,971
Agricultural	9,073
Outdoor Recreation	3,018
Woodland	2,416
Open Water	5,899
Wetlands	5,767
Hydric Soils**	11,320
Size of Watershed in Dane County	59,977

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Yahara River – Lake Monona watershed covers about 94 square miles with nearly half (45 percent) being considered developed. It includes all streams draining to Lake Monona, Lake Waubesa and Lake Wingra. Parts of the cities of Madison and Fitchburg, all of the City of Monona and the Village of McFarland, and parts of the Towns of Blooming Grove, Burke, Dunn and Madison are in its drainage area. The water quality of the streams reflects the highly urban character of the watershed. Nutrients, sediment, contaminants attached to sediment, solids, oil and grease are flushed into the streams and lakes. Streams in the watershed include the Yahara River, Starkweather Creek, Wingra Creek, Murphys Creek, Swan Creek, and Nine Springs Creek. Other water features include Lake Monona, Lake Wingra, Lake Waubesa, Upper Mud Lake, the Nine Springs wetlands, the South Waubesa wetlands.

Starkweather Creek

Starkweather Creek is tributary to Lake Monona at the lake's north end at Olbrick Park in Madison. Starkweather has a drainage area of about 24 square miles. It has two branches, the East Branch and the West Branch. The two branches join south of Milwaukee Street to form the mainstem flowing to Lake Monona.

East Branch Starkweather Creek

The East Branch begins just west of I-39/90/94 near East Towne Mall. The stream drains much of the east side of Madison south of East Washington Avenue (USH 151). It is about 3.7 miles long and has a low stream gradient of about five ft/mi.[298] The WDNR considers it as supporting a limited forage fishery with the potential of becoming a warmwater sport fishery.

Currently, the East Branch can best be described as urban stormwater drainageway. It receives runoff from parking, lots, streets, and rooftops resulting in larger stormwater flows. The East Branch has been channelized and is choked with sediment, aquatic plant growth, and debris for much of its length. There is an area of springs just west of the Interstate that is a remaining natural attribute. These springs discharge about 600 gpm to the headwaters. This area is threatened by continued urban development that decreases infiltration of water into groundwater that supports the spring flow. There is a disturbed wetland complex in the southwest corner of the intersection of Highway 30 and Stoughton Road that serves as a buffer and may provide some baseflow support.

Severe diel (24-hour) dissolved oxygen (DO) fluctuations are common during low flow periods in the summer. Fish populations vary during the year reflecting seasonal migrations and low summer DO readings.[299] Runoff from a recycling facility has caused water quality problems in the past. Warmwater IBI monitoring done at two locations on the East Branch at STH 30 and 300 meters upstream in 2007 showed biotic integrity ratings of "Fair" (decreased fish species richness) and "Poor" (relatively few fish species) respectively.[300] M-IBI sampling conducted near USH 30 indicated "Fair" biotic integrity (range = 2.91-3.86, average = 3.38, n=2). Mean baseflow concentrations of phosphorus and sediment have declined over the past

298 DCRPC, 1992.
299 Johnson, 2002b.
300 WDNR South Central Region Water Resources Files and SWIMS data base 2010.

18 years while mean concentrations of chlorides have increased.[301] The East Branch is included on the state's 303(d) Impaired Waters list due to metals concentrations in sediment, low DO, sedimentation and total suspended solids.

West Branch Starkweather Creek

The West Branch originates in the Town of Burke, Section 10. It is about seven miles long with a stream gradient of 3.7 ft/mi. Water quality is considered very poor by the DNR. The stream has been extensively channelized and functions primarily as an urban stormwater waterway. It drains the area around the Dane County Regional Airport and a portion of the east side of Madison, receiving significant urban runoff. Sections of the creek near the airport have been put underground as the airport expanded. Contaminants in the runoff include oil, grease, lead, cadmium, ethylene glycol, and polyaromatic hydrocarbons. The Dane County Regional Airport has installed measures to reduce the amount of pollutants coming off its impervious surfaces.

Prior to the early 1970's, the West Branch received industrial point source discharges containing many different toxic substances including heavy metals and PCBs. While the point source discharges have been managed by various programs or ended, some of the former industrial sites posed problems for the creek's water quality. WDNR and Madison have dredged a portion of the West Branch to reduce those threats.[302] The airport constructed a $1 million collection system in 1993 to protect the West Branch Starkweather from ethylene glycol spills. Mean baseflow concentrations of sediment and phosphorus have shown a small downward trend since 1992, while mean concentrations of chloride have increased.[303] Madison has done streambank work on some sections to reduce bank erosion and make the area adjacent to the stream more aesthetically pleasing. The West Branch has not been assessed by the WDNR.

Starkweather Creek Mainstem

The Starkweather Creek mainstem begins south of Milwaukee Street and flows to Lake Monona at Olbrick Park. Its stream gradient is 0.5 ft/mi. The stream often acts as a backwater to Lake Monona due to low flows and flat gradient. Urban nonpoint sources of pollution are major water quality problems in the mainstem. The pollutants from the nonpoint sources include sediment, oil and grease, and trash contributed by the upstream branches. Heavy metals, PCBs, and other toxic constituents have been found in the stream bottom sediments. Portions of the stream were dredged, spoils disposed at an approved site, and streambanks were re-vegetated.[304] The mainstem is included on the state's 303(d) Impaired Waters list due to metals concentrations in sediment, low DO, sedimentation, and total suspended solids

Wingra Creek at Beld Street

Photo: Steve Fix

Wingra (Murphy) Creek

Wingra Creek is a channelized stream flowing approximately one mile from Lake Wingra eastward to Lake Monona at Olin Park. Its drainage area is 8.6 square miles and includes densely developed urban areas, parkland, and the UW-Madison Arboretum. The WDNR considers it a warmwater sport fishery. It has a very shallow stream gradient of 2.0 ft/mi. Wingra is often choked with aquatic plants and is periodically stagnate due to low baseflow conditions and the flat stream gradient. Water quality is generally poor due to urban runoff, aquatic plant growth, and sedimentation. Chloride levels are high, particularly in late winter and early spring due to runoff of road salt. Low dissolved oxygen levels and extreme diel (24 hour) fluctuations results in occasional fish kills. Despite these problems, Wingra seasonally supports good populations of bluegills. Walleye and northern pike are also present during spring spawning season.[305] The City of Madison has done streambank stabilization projects on sections of Wingra to reduce streambank erosion and improve the riparian aesthetics.

301 Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey
302 Johnson, 2002b.
303 Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey
304 Johnson, 2002b.
305 Johnson, 2002b.

Nine Springs Creek

Nine Springs Creek begins as a ditched intermittent stream at the outlet of Dunn's Marsh and flows east about six miles to discharge to the Yahara River just above Upper Mud Lake. Nine Springs Creek west of Fish Hatchery Road is intermittent and has a low stream gradient of 3.3 ft/mi. The creek drains a long 13-square mile valley in the City of Fitchburg and the south side of the City of Madison. Much of its drainage area is developed or experiencing rapid urban development that increases stormwater loading and flows. East of Fish Hatchery Road it enters the Nine Springs wetlands complex and flows over 5 miles from the Nevin State Fish Hatchery to the Yahara River. Nine Springs is channelized from the Nevin Fish Hatchery to the Yahara River. The extensive and continuing urban development in the Nine Springs sub-watershed has raised concerns about the impacts of urban development on spring water quality and flow.[306] The MMSD sludge lagoons were adjacent to Nine Springs Creek. One MMSD sludge lagoon was a Superfund site due to toxic substances found in bottom sediments. There was concern regarding the possibility of toxic substances migrating from the sludge lagoon to Nine Springs Creek. A Remediation Investigation (RI) was conducted as part of the Superfund evaluation of the lagoon. In 1995 the RI concluded that no toxic sludge constituents were migrating through the lagoon walls to Nine Springs Creek.[307] The former sludge lagoons are now functioning as wetlands providing habitat for migrating and nesting waterfowl as well as habitat for other wildlife and viewing area as part of an enhancement project sponsored by MMSD.

Nine Springs Creek and its associated wetlands are included in the Nine Springs E-Way Natural Resource Area and the Capital Springs Centennial State Park identified in the Dane County Parks and Open Space Plan. The area is a large environmental corridor that provides wildlife habitat, some water quality functions, and recreational opportunities.

The large Nine Springs wetland complex extends from Fish Hatchery Road on the west to the Yahara River and Lake Waubesa. It has several springs that provide significant baseflow to Nine Springs Creek. The wetlands have a history of disturbance including the straightening of Nine Springs Creek and placing the Beltline Highway through the wetlands. This has resulted in invasive species being introduced into the wetlands affecting its functional values such as habitat. There are pockets of higher quality wetlands with good native plant diversity within the wetlands complex.

Nine Springs Creek is included on the state's 303(d) Impaired Waters list as well as the Rock River Basin Total Maximum Daily Load (TMDL) project as a first priority stream due to phosphorus and sediment loading degrading habitat and causing low dissolved oxygen levels in the stream. The proposed target phosphorus concentration for Nine Springs Creek is 0.075 mg/L.[308] Summary of USGS data for Nine Springs indicates that mean baseflow concentrations have shown a downward trend while the trend of mean baseflow concentrations of chlorides is slightly up (Attachment C).[309]

MMSD Sludge Lagoon Restoration Project

Photo: Mike Kakuska

Murphys Creek

Murphys Creek, a small 5-mile long spring-fed creek, begins in a wetland complex adjacent USH 14 south of Byrne Road in the City of Fitchburg. It flows northeast to Lake Waubesa through the South Waubesa Marsh complex and Lake Waubesa Wetlands State Natural Area. The marsh is identified as a Natural Area in the Dane County Parks and Open Space Plan. The creek's sub-watershed has a large proportion of wetlands to total surface area. It has a stream gradient of 8 ft/mi. Flow in the creek is

306 Swanson, 2001.
307 Johnson, 2002b.

308 Cadmus Group, 2010.
309 Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.

generally low. Water quality, habitat, and the fishery are limited in the upper reaches by low flows. The WDNR considers the stream as supporting a warmwater forage fishery.[310] M-IBI samples collected in 2004 and 2010 indicated "Fair" biotic integrity (range = 4.12-5.14, average = 4.63, n=2). Groundwater seepage and the large wetland buffers contribute to good water quality and habitat in the lower reaches. Primary threats to water quality are from agricultural runoff and runoff from roads.

Of particular note, the South Waubesa Marsh is considered one of the highest quality and most diverse wetlands in Dane County.[311] It is recognized by the Wisconsin Wetlands Association as a Wisconsin wetlands gem.[312] The wetland complex is more than 500 acres in size containing high quality sedge meadows, shrub-carr, fen and marsh areas. There are also several springs in the wetlands. The diversity of wetland types and plant species provides habitat for nesting and migratory birds, amphibians, and spawning areas for fish. As one of the few high quality wetland in the county, it also serves as an important reference site for wetland restoration projects in the area.

Swan Creek

Swan Creek is a small cool water stream that begins in the eastern part of the City of Fitchburg and flows 4.4 miles east to the South Waubesa Marsh and Lake Waubesa in the Town of Dunn. A survey of non-game fish species in the Rock River basin found more forage fish species in the stream in 1998 than in the 1970's indicating an increase in species diversity.[313] An evaluation of the stream done for the Fitchburg McGaw Neighborhood Plan found signs of a healthy headwater stream even though there were high levels of sedimentation. Water in the stream is warmed by discharges from a stormwater pond discharge.[314] Primary water quality threats are from urban development in Fitchburg. Intermittent IBI samples taken in 1998 and 2004 at Lalor Road indicated "Fair" water quality conditions (score = 40 and 50, respectively). An M-IBI sample taken in 2004 indicated "Good" biotic integrity (score = 6.13).

310 Source: WDNR Lower Rock River Basin website; http://dnr.wi.gov/water/watershedWaters.aspx?Code=LR08
311 DCRPC, 2008.
312 Wisconsin Wetlands Association, 2009.
313 Marshall, 2004a.
314 Fitchburg Planning Department, 2010.

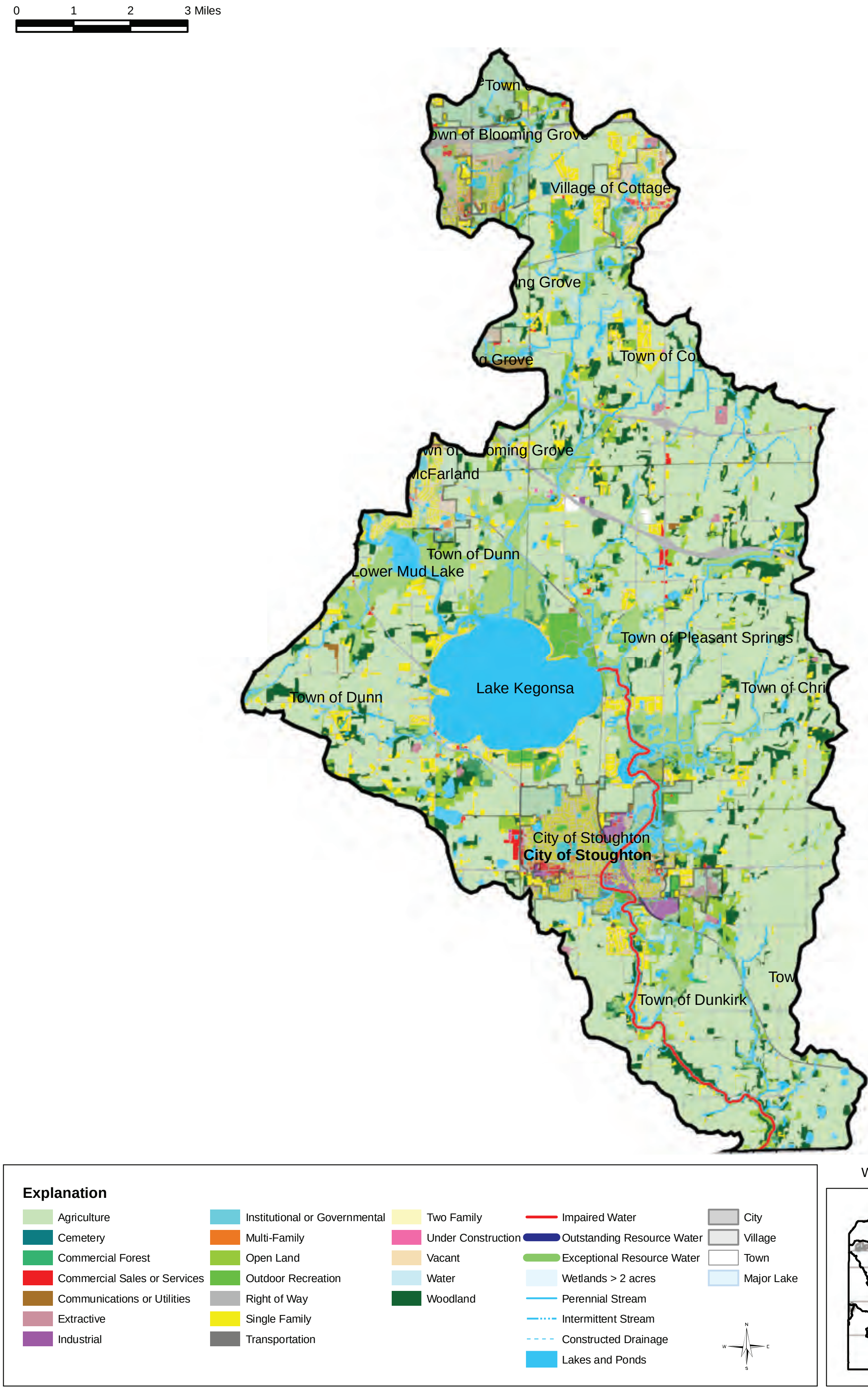
Swan Creek at Lalor Road

Photo: Steve Fix

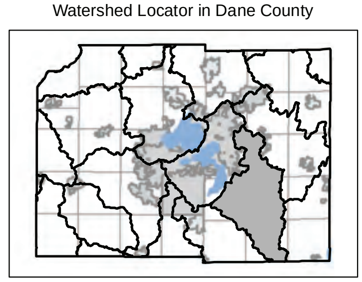
Yahara River (Madison)

The Yahara River between Lake Mendota and Monona is essentially a boat channel connecting the two lakes. It receives very heavy boating pressure during the boating season. The river receives large amounts of urban stormwater runoff that carries suspended solids, sediment, oil and grease, and other urban pollutants. The short reach between Lakes Monona and Waubesa is also heavily used by boaters. An M-IBI sample taken in 1979 indicated "Fair" biotic integrity. More current information is needed for these sections of river.

Yahara River and Lake Kegonsa Watershed



Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Yahara River and Lake Kegonsa Watershed (LR06)	
Land Cover	Acres
Residential	5,491
Transportation	3,993
Industrial	466
Commercial	283
Institutional/Governmental	364
Communication/Utilities	181
Other Lands*	4,968
Agricultural	35,541
Outdoor Recreation	1,194
Woodland	3,937
Open Water	3,883
Wetlands	6,391
Hydric Soils**	11,067
Size of Watershed in Dane County	66,691

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The 126-mile square Yahara River-Lake Kegonsa watershed lies in south central Dane County, extending into Rock County. About 104 square miles are in Dane County. The watershed stretches from the far eastside of Madison to the Dane-Rock county line south of Stoughton. The dominate land use in the watershed is agriculture. Soil fertility is good to very good. Municipalities in the Dane County portion of the watershed include all of the City of Stoughton and parts of the City of Madison, the Villages of Cottage Grove and McFarland, and parts of the Towns of Pleasant Springs, Dunn, Dunkirk, Rutland, Blooming Grove, Sun Prairie and Burke. Stoughton is the only municipal wastewater treatment plant that discharges to the Yahara River in Dane County.

The Yahara River is the principle and most important stream in the watershed. Other streams include Door Creek, Little Door Creek, Keenans Creek and Leuten Creek. There are several small unnamed tributaries to the named streams and lakes in the watershed. Most of these have been channelized to facilitate drainage and agricultural production. Large areas of historic wetlands have also been drained and converted to agriculture. This modification has increased sediment and nutrient loading to area waters. Other water resources include Lake Kegonsa (discussed in the Yahara Lakes section), Upper and Lower Mud Lakes, and the Stoughton Millpond. Sub-watersheds with some of the greatest sediment and phosphorus losses in the Rock River Basin are located in this watershed (**see Maps 8 and 9 Section VIII Future Horizons**).[315]

Yahara River

The Yahara River is 40 miles long with 20 miles being in the Yahara-Kegonsa watershed. The Yahara River in this watershed begins at the Babcock Park dam on Lake Waubesa in the Village of McFarland and flows south through Stoughton into Rock County emptying into the Rock River near the community of Fulton. There are four dams on the river between Lake Waubesa and the Dane-Rock county line: at Babcock Park, Lake Kegonsa outlet, Stoughton and Dunkirk. These dams affect flows and habitat in the river and prevent fish migration. The Yahara River is considered a diverse warmwater sport fishery (WWSF) supporting approximately 48 species.[316]

The Yahara River from Lake Kegonsa downstream to Badfish Creek in Rock County was added to the state's 303(d) Impaired Waters list in 1998. It has also been included as part of the Rock River basin TMDL project. Phosphorus, sediments and total suspended solids have led to impairment of acceptable dissolved oxygen levels and degraded habitat. A phosphorus water quality target of 0.10 mg/L has been proposed.[317] Except for the City of Stoughton, all municipal wastewater has been directed to the MMSD Nine Springs treatment facility. Rural nonpoint sources of pollution are now the primary threat to water quality. Urban nonpoint sources of pollution, while still a problem, are considered not as significant as rural sources.[318]

315 Cadmus Group, 2010.
316 Bardeen, 2001.
317 Cadmus Group, 2010.
318 Lathrop, 2010.

Yahara River at CTH N

Photo: Steve Fix

Baseflow in the Yahara River downstream of Lake Mendota has decreased about 35 percent since MMSD's sewage was diverted around the Yahara lakes in 1958.[319] Baseflow at Babcock Park, the outlet from Lake Waubesa, has decreased an estimated 45 percent due to the MMSD diversion and municipal groundwater withdrawals.[320] The decrease in baseflow coupled with the very shallow stream gradient occasionally leads to a stagnate water situation, low dissolved oxygen levels, and fish kills. The most constricted point is the reach between Lake Waubesa and Lake Kegonsa where the river drops only two feet over this three mile distance.[321] Regulatory dam operations of the dams at Babcock Park, the Kegonsa outlet, and Stoughton Millpond designed to maintain certain minimum and maximum pool elevations may exacerbate the low baseflow and dissolved oxygen conditions in the Yahara River between Lake Waubesa and the Stoughton Millpond during long periods of dry weather.

The river falls about 30 feet from the Dunkirk Millpond to the Dane-Rock county line. There are a series of riffles and runs in this reach. Warmwater IBI monitoring conducted at CTH N below the Dunkirk dam in 2007 showed a biotic integrity rating of "Good." HBI monitoring in 2007 indicated "Good" water quality conditions (score = 5.09).[322] An M-IBI sample at this location indicated "Poor" biotic integrity (score = 1.54). The reason for the mixed results is unclear. Additional sampling is needed.

319 DCRPC, 1992.
320 DCRPC, 2004b.
321 Habecker, 2002, UW-EX.
322 WDNR South Central Region Water Resources Files, 2010.

Primary threats to the Yahara River below Lake Waubesa are from agricultural nonpoint sources of pollution such as cropland erosion carrying sediment and nutrients to the river, barnyards and pesticides. Urban nonpoint sources of pollution in and around Stoughton may adversely affect water quality. Urban commercial and residential development and high development pressure for waterfront property also poses the threat of increased construction site erosion and stormwater runoff. The hydrologic modifications to the stream in the form of dams and decreased baseflow also are a continuing problem from a resource management standpoint.[323] Managing this very large, slowly responsive system to satisfy the desires of multiple, often conflicting user groups continues to pose significant challenges.

Upper Mud Lake

This shallow, fertile 223-acre lake between Lakes Monona and Waubesa is entirely surrounded by 1,000 acres of wetlands. The lake was formed by a railroad grade crossing a marsh at the inlet of the Yahara River to Lake Waubesa. The wetlands provide good spawning areas for northern pike in Lakes Monona and Waubesa and an excellent stopover for migratory waterfowl. The lake supports a good fishery for game fish found in the Yahara River system and receives moderate use. The lake's watershed is 11.5 square miles, and contains portions of the Town of Blooming Grove and the Cities of Monona and Madison. The Yahara River provides a large, constant source of nutrients into the lake. The WDNR considers its condition as being poor.[324] Polluted runoff from both agricultural and urban sources in the Yahara River watershed continues to be a concern and is being worked upon through a colloborative effort among public and private partners.[325]

In the late 1980s the Wisconsin Department of Transportation (WDOT) built a six-lane highway through a portion of the marsh to ease traffic congestion. The construction resulted in some wetland destruction, but other wetland areas were restored or created (about 25 acres) to compensate for the areas lost. Studies have shown, however, that the type of wetland lost, primarily wet meadow, have been replaced or mitigated with deep water marsh. These different habitat types support different wetland plants and perform somewhat different functions. Very good

323 Bardeen, 2001.
324 WDNR Data Water Viewer, 2012.
325 Yahara CLEAN, 2010.

fishing has been reported in some of the deep holes left by the dredging.

The Upper Mud Lake wetlands complex is diverse, ranging from shallow marsh with large monotypic cattail stands, to disturbed wet meadows with shrub willow stands. The large monotypic cattail stands, however, may not provide adequate spawning areas for northern pike. A number of waterfowl/wildlife ponds were constructed as part of WDOT mitigation to increase habitat diversity. Some of these ponds have been adversely affected by polluted urban runoff. The most serious threat to wetland water quality in the Upper Mud Lake complex is from urban stormwater runoff from the South Beltline and the City of Monona. Because of its location below Lake Monona, the fish consumption advisory there should probably be observed on this lake as well.

Boat traffic through Upper and Lower Mud lakes between Lakes Waubesa and Monona is heavy during the entire open water season. Wetlands of Upper Mud Lake are negatively affected by fast boat traffic through the open water areas. Fast boat traffic degrades established wetland vegetation and stirs the lake's sediment which reduces water clarity and inhibits the establishment of wetland plants. Fewer wetland plants means fewer nutrients taken up by aquatic plants and, thus, more phosphorus and nitrogen available for use by algae. The stirring of bottom sediment and degradation of wetland plants by boat traffic is a contentious water quality issue. The Dane County Lakes and Watershed Commission worked to pass a "no wake" zone on all the Yahara Lakes within 200 feet of the shoreline. The purpose is to protect existing vegetation, reduce accidents and hazards in nearshore areas, reduce shoreline erosion, and maintain or help improve water quality.

Lower Mud Lake

This shallow lake is located on the Yahara River between Lakes Waubesa and Kegonsa. It has a surface area of 195 acres and a maximum depth of 15 feet. It is completely encircled by shallow marsh and fresh meadow. Largemouth bass and northern pike are the dominant predator species, while bluegills and black bullheads are the most numerous panfish. The lake is used extensively by migrating waterfowl. The open water area of Lower Mud Lake is a particularly important resting area for migrating waterfowl during the spring because the water opens up early there. Ducks, geese, herons, and swans will stop to rest and feed there. It is also an important spawning area for northern pike and walleye.

The WDNR suspects the lake's overall condition as being poor.[326] Shallowness, excessive aquatic vegetation, and poor water quality currently limit the recreational value of this lake. Water quality problems exist as a result of heavy nutrient loads carried into the lake by the Yahara River, from direct runoff from adjacent agricultural fields, and from surrounding urban development. Fast boat traffic also degrades wetland plants and stirs bottom sediment, clouding the water and releasing stored nutrients in sediment. Because of its shallowness and high nutrient load, the lake experiences excessive aquatic plant growth. Occasional low flow conditions in the lake from the diversion of effluent around the Yahara Lakes can also exacerbate water quality problems during prolonged dry-weather periods. During flooding conditions, an aquatic plant management plan was prepared in 2007 for both Lower Mud Lake and Lake Kegonsa to help reduce impediments to flow in this section of the Yahara River and the associated damages upstream. Recommendations in the management plan include:

- Conducting large-scale mechanical harvesting to maintain flow between the inlet and outlet of Lower Mud Lake.
- Limiting the harvesting of wild celery in the river between Lower Mud Lake and Lake Kegonsa except during emergency high water and flood conditions. Cutting is confined to the deepest portion of the channel in an effort improve flow while historical structures are avoided.
- Chemical treatments should not be conducted in the lake given the general lack of riparian development. Uses within the natural shoreline eliminate the need for treatments typically used to clear swimming areas and piers.
- The Sensitive Areas designation should include the entire shoreline given the relatively undeveloped condition. The habitat functions in Lower Mud Lake may benefit Lake Kegonsa where critical aquatic plant habitats were scarce.

326 WDNR Data Water Viewer, 2012.

The Dane County Regional Planning Commission has ranked the Lower Mud Lake Wetlands as one of the most important in the county for management and protection.[327] Additional evaluations by WDNR characterize the lake and its wetlands as being threatened. In 1996 Dane County and the Village of McFarland received DNR grants to acquire land to protect the lake. The lake and surrounding wetlands are currently identified as a Natural Resource Area in the Dane County Parks and Open Space Plan. The Lower Mud Lake Resource Area acts to buffer the lake and wetlands from surrounding agricultural lands as well as protect the critical fish and wildlife habitat found there. Management objectives include:

- Creating a 1,700-acre preserve along the Yahara River and Lower Mud Lake, which has as its primary purpose the preservation and restoration of natural resources
- Preserving wetland, floodplain, springs, and related features to protect water quality along the Yahara Chain of Lakes,
- Providing for and protect natural habitat for fish, waterfowl, and wildlife, and
- Preserving archeological and historic resource sites.

Keenans Creek

Keenans Creek is a small two-mile tributary to Lower Mud Lake that flows through a large wetlands complex before entering the lake on the southwest end. This wetland and smaller ones upstream provide valuable wildlife habitat. Kennans Creek has an average stream gradient of 25 ft/mi. and drains an area of 3.6 square miles. Land use is agriculture and rural residential. The creek's wetlands area contains springs, a source of cool water for the stream. While it has been categorized as supporting a warmwater forage fishery, the WDNR considers it to be a cool to coldwater stream.[328] Keenans Creek is located in the Lower Mud Lake Natural Resource Area identified in the Dane County Parks and Open Space Plan. The wetlands are considered among the top priority wetlands in the county for management and protection.[329]

327 Bedford, 1974.
328 Johnson, 2010.
329 DCRPC 2008.

Door Creek

Door Creek is a tributary to the Yahara River. It begins in the southeast corner of the Town of Burke and flows south 14 miles, emptying into the north end of Lake Kegonsa. It is a sluggish stream with a flat gradient of 2.4 ft/mi. Door Creek and its tributaries drain 29.5 square miles of rolling agricultural land and the rapidly developing far east side of the City of Madison and the Village and Town of Cottage Grove. The primary water quality problems and threats to Door Creek are from agricultural nonpoint sources of pollution such as cropland erosion, sedimentation, and nutrient loading, as well as urban sources such as runoff from impervious surfaces. In addition, continued and increasing high capacity municipal well water withdrawals pumping groundwater to serve area residents will continue to affect stream baseflow, particularly in its headwaters area. Groundwater modeling predicted a 15 percent decrease in Door Creek baseflow between 2000 and 2030 (from 3.20 cfs to 2.50 cfs). This is in addition to an existing 31 percent decline that has already occurred, compared to pre-development conditions (estimated 4.64 cfs), for a total 46 percent anticipated decline.[330]

Much of Door Creek has been straightened and ditched to facilitate drainage. Sediment and nutrient loads are significant due to the ditching and stream straightening and also wetland drainage and agricultural runoff in the watershed.[331] The stream ditching and straightening allows heavy loads of sediments and nutrients to reach Lake Kegonsa. Re-meandering the creek through the Door Creek Wetlands north of Lake Kegonsa has been considered, but there is a concern that the effort would result in even more sediment loading to the lake and harm the higher quality wetland areas found there.

Door Creek is designated a limited forage fishery (LFF) stream. It is subject to high temperatures and low flows. Its biological and ecological potential has been limited by agricultural nonpoint source pollution and by natural conditions such as low baseflow and slow velocity. Water quality is generally poor due to heavy sedimentation reducing habitat. In 1982 the Village of Cottage Grove discontinued its wastewater discharge to Door Creek, sending it to MMSD for treatment instead. This removed a significant point source of pollution, but also reduced

330 DCRPC, 2004b.
331 DCRPC, 1992.

baseflow. Some improvement to water quality has been noted and may result in the stream being reclassified.[332] The creek has the potential to support a warmwater sport fishery. The WDNR has given it a high NPS priority ranking. Door Creek was assessed during the 2012 303(d) Impaired Waters listing cycle and total phosphorus data exceeded the listing criteria. However, biological data did not indicate biological impairment.

Door Creek Confluence to Lake Kegonsa

Photo: Mike Kakuska

Intermittent IBI monitoring at two locations on Door Creek (Vilas Hope Road and Hope Road) indicated "Fair" biotic integrity. Warmwater IBI monitoring done in 2008 at both locations indicated "Fair" biotic integrity. HBI monitoring done at Vilas Hope Road in 2008 indicated "Good" water quality (score = 5.26), while the HBI at Hope Road downstream was "Poor" (score = 8.05). Heavy stream bottom silt was noted at Hope Road.[333] M-IBI monitoring in 2001 and 2008 indicated "Fair" biotic integrity (range = 3.77-4.10, average = 3.93, n = 3).

The Door Creek wetlands at the mouth of the creek are a large 1100-acre wetland complex that provides important spawning habitat for northern pike and other fish species in the Yahara Lake Chain System. It also provides valuable habitat for other wetlands-dependent wildlife. The total wetlands acreage in the watershed was much larger prior to agricultural production activities in the watershed that drained large areas north of the railroad tracks. Door Creek has also been channelized through the wetlands, essentially short-circuiting them and delivering significant sediment and phosphorus loads directly to Lake Kegonsa. The wetlands are the focal point for the Door Creek Wetlands Resource Area, identified in the Dane County Parks and Open Space Plan, extending the entire length of the creek. In 2000 the Dane County Board adopted the Door Creek Wetlands Resource Area Plan.[334] The plan's objectives include:

- Establishing a Door Creek Wetlands Resource Area through public acquisitions,
- Providing northern pike spawning habitat,
- Promoting wetlands restoration, and
- Encouraging stormwater management to protect water quality

Little Door Creek

Little Door Creek is a small ditched stream that flows five miles to join Door Creek south of USH 12/18. It drains about 8.3 square miles and has an average stream gradient of 11.8 ft/mi. Several small wetlands are adjacent to the creek, although much of the historic wetlands have been drained. Agriculture is the dominant land use in its sub-watershed. Water quality is generally poor due to the hydrologic modifications and nonpoint source pollution. The low flow, turbidity induced by sedimentation, and hydrologic modification limit the fishery to forage species.[335] A 2001 IBI taken near Cottage Grove indicated "Fair" biotic integrity. Both HBI and M-IBI monitoring also indicated "Fair" conditions as well. An intermittent fish IBI at CTH N in 1998 showed "Poor" biotic integrity, indicating more recent improvement.

Leuten Creek

Leuten Creek is a small spring-fed stream beginning in the Town of Pleasant Springs and flowing three miles south and west to join the Yahara River below Lake Kegonsa. It is about five miles long and has an average stream gradient of 9.7 ft/mi. Much of the stream has been ditched and channelize and many of the wetlands in its sub-watershed drained. Water quality is considered below average due to agricultural nonpoint sources of pollution and hydrologic modifications. Turbidity and sedimentation have negatively affected aquatic habitat.[336] It currently supports a limited forage fishery (LFF).

332 Bardeen, 2001.
333 WDNR, 2010c.
334 DCRPC, 2000.
335 Bardeen, 2001.
336 Bardeen, 2001.

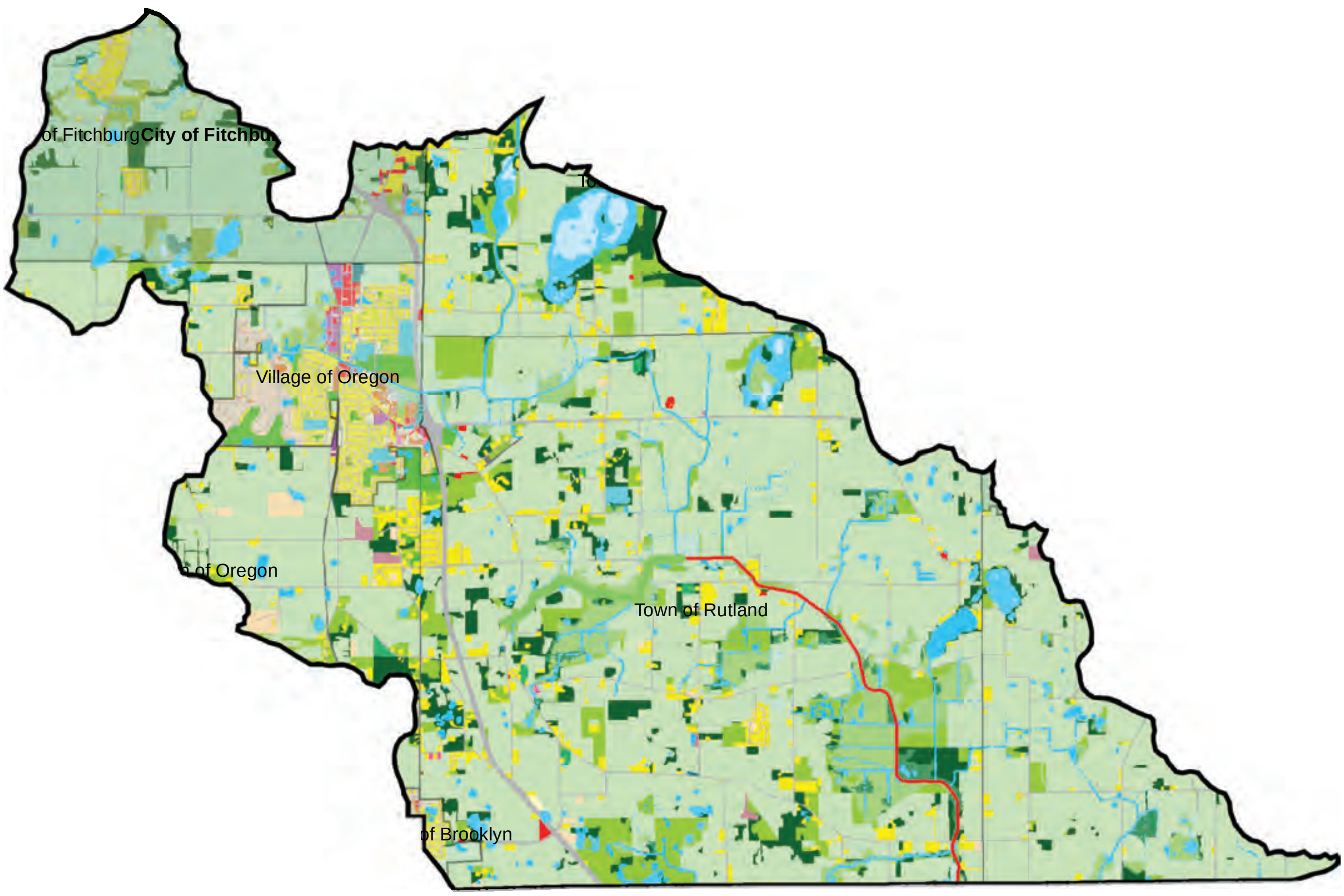
Stoughton Millpond

The Stoughton Millpond is a shallow impoundment of the Yahara River. It has a surface area of 82 acres, a maximum depth of 5 feet, and supports a diverse warm-water fishery. The majority of the millpond lies within the Stoughton city limits. The surrounding land is dominated by agriculture to the north and municipal and residential areas to the south. Nonpoint source pollution and urban stormwater runoff negatively impair the millpond. The WDNR considers its condition as being "Poor."[337] No major wetlands border the lake, but several small sedge and grass meadows provide limited habitat for waterfowl and muskrats. The lake bottom is mostly clay with sand, silt, and some detritus present as well. With the exception of cattail stands on the lake's east side, macrophytes are scarce as a result of the large carp population. The water is turbid, alkaline, and shows signs of eutrophication. Nuisance algae growths are common. Access is available at Stoughton and from the Yahara River by way of Viking County Park just north of the lake.

337 WDNR Data Water Viewer, 2012.

Badfish Creek Watershed

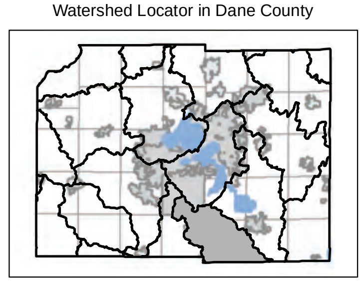
0 1 2 3 Miles



Explanation

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland
- Impaired Water
- Outstanding Resource Water
- Exceptional Resource Water
- Wetlands > 2 acres
- Perennial Stream
- Intermittent Stream
- Constructed Drainage
- Lakes and Ponds
- City
- Village
- Town
- Major Lake

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Badfish Creek Watershed (LR07)	
Land Cover	**Acres**
Residential	2,832
Transportation	1,876
Industrial	165
Commercial	127
Institutional/Governmental	205
Communication/Utilities	26
Other Lands*	3,939
Agricultural	25,996
Outdoor Recreation	394
Woodland	2,562
Open Water	276
Wetlands	3,347
Hydric Soils**	7,094
Size of Watershed in Dane County	41,744

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Badfish Creek watershed is in south central Dane County and flows southeast to join the Yahara River in the northwest corner of Rock County. The watershed has an area of 65.2 square miles. Part or all of the towns of Rutland, Dunn, and Oregon, the Village of Oregon and the southeast corner of the City of Fitchburg are in the watershed. Fitchburg and both the Village and Town of Oregon have experienced rapid urban growth over the past 20 years. The watershed is predominately rural. There are several rural residential areas due to its proximity to Madison. There are several horse farms or boarding facilities in the watershed in addition to the usual types of agricultural operations. The principle streams of the watershed are Badfish Creek, Rutland (Anthony) Branch, Oregon Branch, and MMSD's effluent ditch. There are also several wetland complexes that are either locally or regionally important. These include Hook Lake, the Lake Barney wetlands, and the wetlands of the Badfish Creek State Wildlife Area.

Badfish Creek

Badfish Creek begins at the confluence of the Oregon Branch and the Rutland Branch and is tributary to the Yahara River in Rock County. Most of its length has been channelized in Dane County. Badfish Creek has a low stream gradient of 4.1 ft/mi. It flows through the Badfish Creek State Wildlife Area, which has large wetland areas helping to buffer the stream. While much of its watershed is agricultural, Badfish is considered an effluent dominated stream due to its carrying highly treated effluent from MMSD's Nine Springs treatment plant, which serves the Madison Metropolitan area and areas north. The Village of Oregon wastewater treatment plant also contributes to the total effluent flow in Badfish. Badfish Creek is classified as a limited forage fishery (LFF) from the confluence of the Oregon and Rutland branches downstream to Dane CTH A. Below Highway A, the stream is classified as a warmwater sport fishery (WWSF). Badfish Creek is included on the state's 303(d) Impaired Waters list due to PCBs found in sediments. It had been considered a "high" priority stream for TMDL development, but that was changed to "low" priority in 2008.[338]

Badfish Creek at Old Stage Road

Photo: Steve Fix

Water quality was quite bad in the 1970's due to the large amount of effluent from MMSD and Oregon. MMSD has since completed several treatment plant upgrades that have significantly improved effluent quality and stream water quality. Biochemical oxygen demand (BOD), ammonia nitrogen, nitrite nitrogen and suspended solids levels have decreased, while dissolved oxygen levels

338 DNR TMDL Website, accessed 2011. http://dnr.wi.gov/water/impairedSearch.aspx

have increased resulting in improved water quality. Mean baseflow concentrations, measured in milligrams per liter (mg/L) of total phosphorus, ammonia nitrogen, coliform bacteria and suspended sediments have declined significantly over the past 20 years based on a summary of USGS data (Attachment C). HBI monitoring done at CTH A in 2003 showed "Fair" water quality (score = 5.7) indicating fairly significant organic pollution.[339] M-IBI samples taken in 2002 and 2003 indicated "Fair" biotic integrity (range = 2.71-3.56, n=2) at downstream and upstream locations, respectively.

MMSD has also conducted IBI monitoring at two locations on Badfish between 1990 and 1995: at CTH A downstream of Rutland Branch, and Old Stage Road. Wisconsin warmwater IBI ratings at both sites has ranged between "Poor" to "Very Poor." A coldwater IBI integrity rating of "Poor" was also calculated at both sites.[340] MMSD reports have shown that water quality and fish species richness has improved since MMSD began monitoring Badfish in the early 1980s. Assessment of MMSD's collected data suggests that MMSD's effluent quality is not inhibiting aquatic species from living in Badfish Creek.[341] Northern hog suckers, considered an intolerant fish species, have been found at the two MMSD monitoring sites on Badfish Creek.[342] MMSD regularly finds brown trout at both Badfish Creek sites during its surveys. The number of fish species has increased over the 27 years of MMSD monitoring. Water quality in Badfish improves until it reaches Old Stage Road. At that point non-effluent related factors such as agricultural nonpoint sources of pollution become the controlling water quality factors.[343] MMSD has found some dense eurasian water milfoil, a highly aggressive invasive aquatic plant, in Badfish over the last six surveys.[344]

Oregon Branch

Oregon Branch begins in the Village of Oregon and flows six miles southeast to its confluence with Rutland Branch to form Badfish Creek. Much of its drainage area is agricultural, with urban development in and near the Village of Oregon. The Oregon wastewater treatment plant discharges to the stream. About one mile east of Oregon, the MMSD effluent ditch joins Oregon Branch making it an effluent dominated stream. The urban development in and near Oregon have increased peak storm event flows in Oregon. The DNR has classified Oregon Branch as a limited aquatic life (LAL) stream indicating very poor water quality. So-called "variance" streams[345] have reduced water quality standards, accounting for natural or cultural limitations, such as low flow or existing municipal wastewater discharges.

MMSD has a monitoring site near Sunrise Road east of Oregon to monitor water quality conditions. The number of fish species collected at this site has increased over the period MMSD has been monitoring at this location. The five dominant fish species collected at this site in 2010 were green sunfish, white sucker, bluegill, central mudminnow, and hornyhead chub. A decline in the number of brown trout and northern hog suckers were noted. It was speculated that the lack of instream cover and the presence of northern pike may be part of the reason for the decline in numbers of these two species. Warmwater IBIs done at this site indicated "Poor" biotic integrity due to relatively few species.[346]

Rutland Branch

Rutland Branch, also known as Anthony Branch, is a small spring-fed, coldwater trout stream in south central Dane County. It is one of only a few coldwater streams in the glaciated part of Wisconsin. It flows east 2.6 miles and joins the Oregon Branch to form Badfish Creek. It is designated an Exceptional Resource Water (ERW). It has a stream gradient of 25.6 ft/mi. Portions of the stream have been channelized but the stream appears to be restoring itself. It has areas of good sand and gravel habitat in its upper reaches. It flows through a small open wetland above Dane CTH A in the Anthony Branch State Fishery Area. The primary water quality threats to Rutland Branch are for agricultural nonpoint sources of pollution.[347] Impoundment of springs not already protected could also affect water quality and coldwater habitat. A 2001 coldwater IBI done by the WDNR showed Rutland Branch to have "Fair" biotic integrity indicating the stream has experienced some moderate environmental degradation.[348]

339 WDNR, 2010d.
340 Jeff Stevens, MMSD, 2010.
341 MMSD, 2010.
342 MMSD, 2010.
343 Johnson, 2002b.
344 Jeff Stevens, MMSD, 2010.
345 NR 104.02(3).
346 Jeff Stevens, MMSD, 2010.
347 Johnson, 2002b.
348 WDNR, 2010d.

Frogpond Creek at Franklin Road

Photo: Steve Fix

Frogpond Creek

Frogpond Creek is a small spring-fed stream that begins in a U.S. Fish and Wildlife Service's (USFWS) Waterfowl Production Area (WPA) east of the Village of Brooklyn. It flows seven miles east along the Dane-Rock county line. The DNR has identified Frogpond Creek as being a warmwater forage fishery stream. It dips briefly into Rock County before re-entering Dane County to empty into Badfish Creek. The USFWS has restored wetlands and prairie areas within the WPA that buffer the stream headwaters area from agricultural sources of pollution. Frogpond flows through agricultural areas contributing some sediment and nutrient loading to the stream downstream of the WPA area. The stream does have good buffering through much of its length. A 1996 habitat evaluation described the stream's habitat at Willow Road as "Good."[349] HBI monitoring in 2004 at Franklin Road indicated Frogpond had "Very Good" water quality (score = 4.49), a sign of little organic pollution. An intermittent fish IBI done at Franklin Road in 2004 showed Frogpond had "Excellent" biotic integrity while a warmwater IBI indicated "Fair" biotic integrity.[350] An M-IBI sample taken in 2004 (score = 5.56) indicated "Good" biotic integrity.

349 Johnson, 2002b.
350 WDNR, 2010d.

Lakes and Wetlands

The Badfish Creek watershed has many smaller glacial pothole lakes and wetlands, some ephemeral, many perennial. Taken together they are regionally important, providing habitat for migratory and nesting waterfowl as well as other species dependent upon such aquatic habitat. Threats to these smaller glacial ponds and wetlands are from agricultural activities. Methodology does not currently exist for evaluating the condition of small lakes or ponds generally less than 10 acres. The WDNR is looking to emerging wetland assessment tools for guidance.

Bass Lake

Bass Lake is a 69-acre highly eutrophic glacial seepage lake in the Town of Rutland just north of the Badfish Creek State Wildlife Area. It has a maximum depth of 8 feet and is subject to winter fish kills. It is locally important for migratory waterfowl. There is some residential development along the northeast shoreline, but much of its shoreline is a narrow wooded buffer separating the lake from adjacent farm fields. WDNR considers its condition as being "Poor or Suspected Poor."[351]

Grass Lake (Town of Dunn)

Grass Lake is a 48-acre highly eutrophic glacial seepage lake with a maximum depth of 9 feet. It is subject to winter fish kills. It is a part of the Hook Lake State Wildlife Area. The DNR has described Grass Lake as "biologically unique" deep water wetland supporting deep marsh aquatic plants such as water lilies, pickerel, and duck potato.[352] WDNR considers its condition as being "Poor or Suspected Poor."[353]

Grass Lake (Town of Dunkirk)

This Grass Lake has 9 acres of open water. It is located northeast of Bass Lake. Portions of its surface are covered by floating sedge bog mats. It is locally important for migrating waterfowl and provides habitat for other aquatic species.

Hook Lake

Hook Lake is one of the most important wetlands in Dane County and Southern Wisconsin. It contains a northern forest bog with plant species commonly associated with

351 WDNR Water Data Viewer, 8/12.
352 WDNR. Hook Lake Wildlife Area http://dnr.wi.gov/topic/lands/wildlifeareas/hook.html accessed 2010.
353 WDNR Data Water Viewer, 8/12.

the acidic northern bogs. Much of its surface is covered with a floating sedge bog mat that has several plant species unique in Dane County such as the insectivorous round-leaf sundew, bogbean, leatherleaf, bog birch, tamarack and cotton grass.[354] Hook Lake is in the Hook Lake Wildlife Area. The Hook Lake Bog area has been designated a State Natural Area by the DNR. The lake and wetlands provides habitat for a range of aquatic animals.

Island Lake

Island Lake is a 10-acre glacial seepage lake with a maximum depth of 5 feet. It is in a U.S. Fish and Wildlife Service Waterfowl Production Area (WPA) located between Stoughton and Oregon. It is part of a wetlands complex that ranges from deep water to sedge meadow and provides habitat for a diversity of animal species.

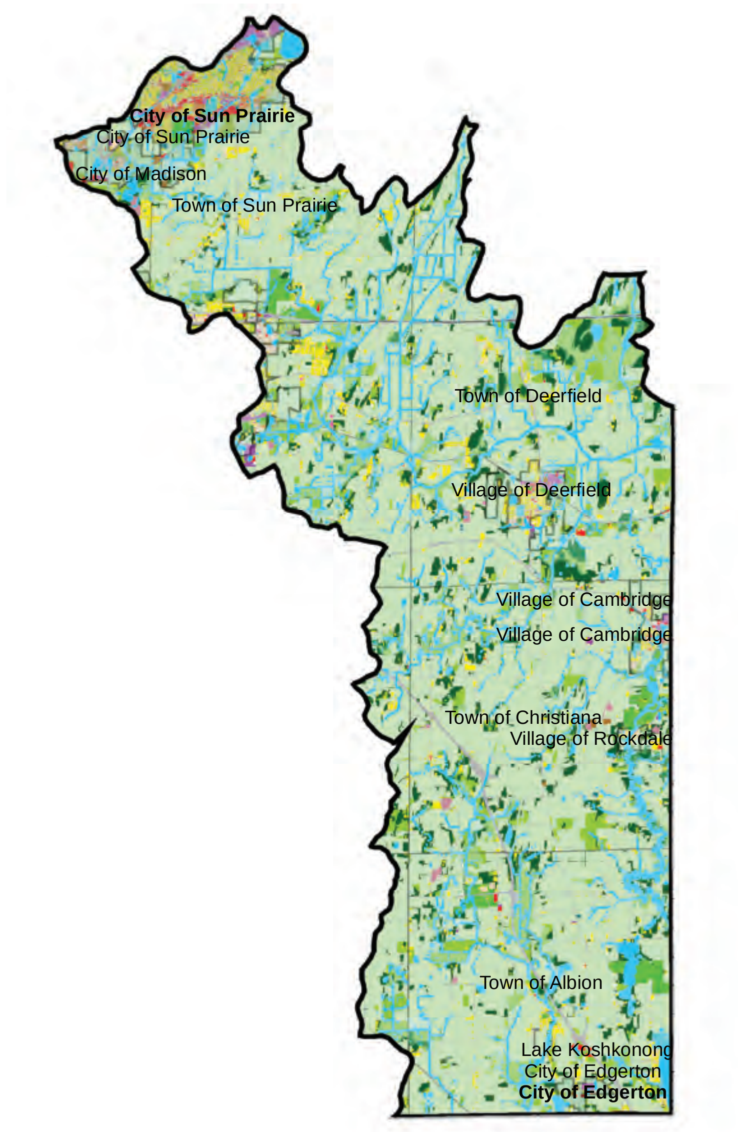
Lake Barney

Lake Barney is a 27-acre glacial seepage lake with a maximum depth of 6 feet. It is located in the southeast corner of Fitchburg. Its primary importance is as part of a larger wetlands complex stretching west from the lake to Fish Hatchery Road. The Lake Barney wetlands is a locally to regionally important stopping place for migratory waterfowl and songbirds. Lake Barney and its wetlands provide good habitat for wildlife partially or totally dependent on an aquatic ecosystem. The U.S. Fish and Wildlife Service own much of the wetlands west of Lake Barney. Satellite secchi data between 2003-05 indicate generally "Good" condition (range = 50-60).[355]

354 WDNR, Hook Lake Bog, http://dnr.wi.gov/topic/lands/naturalareas/index.asp?sna=242 accessed 2010.
355 www.LakeSat.org.

Koshkonong Creek Watershed

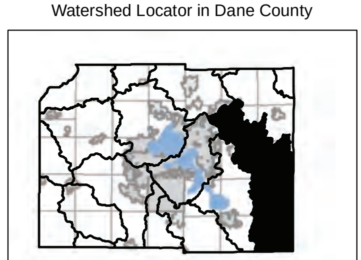
0 1 2 3 Miles



Explanation

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland
- Impaired Water
- Outstanding Resource Water
- Exceptional Resource Water
- Wetlands > 2 acres
- Perennial Stream
- Intermittent Stream
- Constructed Drainage
- Lakes and Ponds
- City
- Village
- Town
- Major Lake

Watershed Locator in Dane County



Source: Capital Area Regional Planning Commission 2005 Land Use Survey

5/4/2012

Koshkonong Creek Watershed (LR11 and LR12)	
Land Cover	**Acres**
Residential	5,420
Transportation	5,513
Industrial	817
Commercial	491
Institutional/Governmental	527
Communication/Utilities	178
Other Lands*	7,842
Agricultural	70,502
Outdoor Recreation	1,482
Woodland	7,475
Open Water	726
Wetlands	10,563
Hydric Soils**	29,876
Size of Watershed in Dane County	111,535

* Open, vacant, or under construction.
** May underlie other land use elements, therefore not included in the total.
Source: Capital Area Regional Planning Commission 2005 Land Use Data

The Koshkonong Creek watershed is in the drumlin and marsh physiographic region of eastern Dane County. The creek and its tributaries drain approximately 174 square miles in the county. Baseflow of streams in the watershed are generally low with warmwater temperatures due to low groundwater inputs. The watershed includes part or all of the City of Sun Prairie, City of Edgerton, the Villages of Cottage Grove, Cambridge and Deerfield, a number of small rural subdivisions, and the Towns of Sun Prairie, Cottage Grove, Medina, Deerfield, and Christiana. Other named streams in the watershed are Mud Creek near Deerfield and Saunders Creek near Albion.

The WDNR breaks the Koshkonong Creek watershed into two separate watersheds: the Upper Koshkonong and the Lower Koshkonong Creek watersheds. The two watersheds have been combined for this report. The Upper Koshkonong Creek has seen significant population growth over the last 20 years resulting in the conversion of predominantly agricultural land to residential and commercial uses in the areas south of the City of Sun Prairie and east of the Village of Cottage Grove. Approximately 12 percent of the watershed is considered urban. The majority of the land use is agricultural. A large percentage of original wetlands have been drained for this purpose. There are several active agricultural drainage districts in the Koshkonong Creek watershed. This wetland loss, coupled with stream ditching and widespread use of field tiles, allows significant nutrient loadings to reach the watershed streams and downstream receiving waters. Soil loss in the towns of Sun Prairie, Deerfield and Medina has declined significantly since 1988[356] and there have been small improvements for some water quality parameters (Attachment C).[357] Even so, water quality and instream habitat are still severely affected by agricultural sediment and nutrient loading.

Increasing stormwater flow and pollutant loading from urban parts of the watershed continues to be a problem. The Sun Prairie and Cottage Grove areas have seen rapid urbanization in the past twenty years. The increase in impervious surfaces has historically resulted in increased runoff to receiving waters. New development in Dane County must now meet stringent erosion control and stormwater management requirements including, more recently, infiltration controls.[358] Additional efforts are needed to control runoff from pre-existing urban areas in addition to ongoing agricultural production activities.

Koshkonong Creek

Koshkonong Creek rises on the south and east edge of the City of Sun Prairie. It flows southerly about 55 miles, draining about 174 square miles in eastern Dane County before joining the Rock River at Lake Koshkonong in Rock County. The creek has a very low gradient, 3.8 feet/mile and is mostly channelized above Rockdale. Below Rockdale the stream has a flatter gradient of 1.9 feet/mile and flows in its natural channel. There is a generally high quality floodplain forest in its lower reaches.

The first six miles of Koshkonong Creek is designated a Limited Aquatic Life (LAL) stream.[359] It is effluent dominated from the Sun Prairie wastewater treatment plant near Bailey Road to CTH T, where the classification

356 Dane County LWRD, 2008
357 Data from CARPC files.
358 Chapter 14, Dane County Code of Ordinances
359 NR 102 and NR 104.

changes to a warmwater sport fishery. Flow is intermittent in its headwaters with industrial cooling water, stormwater, and melt water runoff contributing the only flow above the Sun Prairie WWTP. Much of its length above USH 18 at Cambridge is channelized and has minimal stream buffer. The stream has naturally limiting conditions such as a flat gradient, low baseflow, and warm temperatures. A large percentage of the original wetlands in the watershed have been drained. The combination of drained wetlands, drainage ditches, fertile soil, and field tiles allow significant loading of sediment and nutrients to the creek and Lake Koshkonong downstream in Jefferson and Rock counties. Dane County Land Conservation Department information shows significant soil loss reduction in the towns through which the creek flows.[360] This is an indication of improved farming practices taking place in the watershed. The soil loss reduction should help to improve habitat and water quality in the creek but more detailed analysis is needed.

The Sun Prairie wastewater treatment plant discharges approximately 3.5 cfs of treated effluent to Koshkonong Creek, making it an effluent dominated stream in its headwater reach (groundwater contribution is estimated to be 0.2 cfs).[361] The stream also receives urban stormwater runoff from Sun Prairie and the village and town of Cottage Grove. Sun Prairie is in the process of upgrading its wastewater facility, improving the quality of its treated effluent. Additional monitoring will be necessary to determine if these improvements improve water quality of Koshkonong Creek.

Noticeable improvements have been documented in Koshkonong Creek due to earlier wastewater treatment plant upgrades (**Attachment C**). Instream ammonia levels have declined significantly since 1992 at both Bailey Road near Sun Prairie and at Rockdale. Total phosphorus and suspended sediment have also declined, although these are still well above the Rock River TMDL targets.[362] The average total P in 1999 was 2.08 mg/L, while in 2007 it had dropped to 0.39 mg/L. However, more work is needed. DNR rotational monitoring done in 2009 at Jefferson CTH O just east of the Dane-Jefferson line showed an NR 217 rolling median total P value of 0.259 mg/L. This is considerably above the target established in the Rock River TMDL of 0.075 mg/L. Average total suspended sediment reductions of 87 percent and 67 percent will be needed in the Upper and Lower Koshkonong Creek watersheds, respectively.

Koshkonong Creek at CTH N

Photo: Steve Fix

The headwaters reach of Koshkonong Creek does not exhibit good water quality. Fish-IBI and HBI monitoring done in 2000 at Bailey Road downstream of the Sun Prairie WWTP, a channelized headwaters reach, indicated “Poor” water quality conditions due to very significant organic pollution.

HBI monitoring at CTH TT (WWSF reach) in 1997 and 2003 indicated “Fair” water quality but with significant organic pollution (scores = 5.39 and 6.08, respectively). M-IBI scores at the same sites and dates indicated “Fair” biotic integrity (scores = 2.79 and 4.01, respectively). Downstream of Rockdale, Koshkonong Creek becomes more sluggish and meanders within its floodplain. There is a dense floodplain forest buffer that prevents significant grass stabilization of the bank, leaving the bank susceptible to erosion. Woody debris clogs the stream in spots in its lower reaches in Dane County and on into Jefferson and Rock counties.

The area of Koshkonong Creek stretching from the south edge of the City of Sun Prairie south to Interstate 94 has been identified as a Natural Resource Area in the Dane County Parks and Open Space Plan. The purpose is to promote flood mitigation, wetland restoration potential, and future recreational opportunities. In addition, WD-

360 Dane County LWRD, 2008.
361 James Krohelski, USGS, 2000.
362 Cadmus Group, 2010.

NR's Glacial Heritage Area Plan suggests establishing a "paddling" trail on Koshkonong Creek if access were improved. [363] The plan also proposes to provide more shore fishing opportunities along the creek.

Koshkonong Creek and Rockdale Millpond

The Rockdale Dam on Koshkonong Creek formed Rockdale Millpond, an impoundment of about 104 acres with a maximum depth of 5 feet and an average depth of about one foot. [364] It is estimated that the impoundment had accumulated about 287,000 cubic meters of sediment. By 2000, sedimentation had eliminated much of the water retention potential of the impoundment and had created a delta at the upstream end of the impoundment.[365] The dam was in poor condition and was breached in 2000 draining the impoundment and exposing mud flats. The DNR hoped the dam removal would result in enhanced water quality and biological integrity of Koshkonong Creek, restore the creek to a riverine nature, restore gamefish migration, and improve fish habitat.[366] The creek has been re-establishing a channel in the impoundment bed since dam removal. A study by Doyle, et.al. on channel adjustments following dam removal found that dam removal resulted in: 1) the significant export of fine sediment downstream, and 2) the conversion of the impoundment from a sediment sink to a sediment source. The sediment export was heaviest during the 72 hours immediately following the breaching. However, the sedimentation did not have a major effect on stream morphology downstream of the dam due to limited reservoir erosion.

The breaching of the dam and subsequent export of sediment did have a significant effect on unionid mussels.[367] Removal of the dam led to high mortality for mussels both within the former impoundment and in downstream reaches due to silt smothering (downstream) or exposure in the de-watered impoundment. One rare species, Quadrula pustulosa, was lost from the mussel community. The draining of the millpond also exposed some seepage springs that had some high quality wetlands plants species and these areas should not be disturbed. M-IBI monitoring between 1997-2002, both above and below the former millpond site, indicated generally consistent "Fair" biotic integrity scores (range = 3.92–4.80, average = 4.44, n=4).

One of the goals of the Rockdale dam removal was to restore the exposed impoundment bed to wet meadow, wet prairie, and lowland woodlands. The exposed impoundment bed was seeded with Canada wild-rye to provide some cover and with some wetland species shortly after the drawdown and the following spring. The impoundment site had significant plant growth in the first growing season after dam removal. There was an increase in the number of plant species (30) between 2001 and 2004 with 18 of them being native to Wisconsin. However, reed canary grass (*Phalaris arundinacea*) became more prevalent, but not dominant, by 2004.[368] No study of the effects of dam removal and wetland and prairie restoration on wildlife, particularly avian and amphibian, has been done.

Koshkonong Creek Upstream of Rockdale Dam Site

Photo: Steve Fix

Overall, water quality conditions in Koshkonong Creek have remained steady or improved slightly over the past 10 years based on biotic indices information. IBI and HBI data indicate "Fair" water quality in some reaches. USGS water chemistry data indicate some improvement since 1999, although nutrient loading is still high and significantly above the phosphorus goal set in the Rock River TMDL. Water quality problems still exist. An indication of continuing problems is a significant amount of filamentous algae and aquatic plant grow noted at the Ridge Road and West Ridge Road crossings in June of

363 WDNR, 2009d.
364 Orr, 2006.
365 Doyle, 2003.
366 WDNR, 2002d.
367 Suresh, 2004.
368 Orr, 2006.

2010.[369] Additional improvements could occur with more aggressive stormwater management measures in and around Sun Prairie, Cottage Grove, Deerfield, and Cambridge, and implementation of more conservation farming practices such as no-till and having wider stream buffers. Wetlands restoration and increasing buffer widths, particularly along ditched sections and tributaries, may help further reduce sediment and nutrient loading, although significant additional water quality and instream habitat improvements may be difficult to achieve. Maintaining a 120-foot continuous stream buffer natural vegetation or a combination of natural vegetation and forage or biomass crops can improve water quality and instream aquatic communities. Facilities and operational improvements at the Sun Prairie wastewater treatment plant may also improve water quality conditions of Koshkonong above CTH T. A broad study is also needed to assess current conditions in Koshkonong Creek upstream and downstream of the former Rockdale millpond to develop document and evaluate the changes to fisheries, stream morphology, water quality, aquatic communities, and instream habitat 10 years after the removal of the Rockdale Dam.

Mud Creek

Mud Creek is a major tributary to Koshkonong Creek. It rises in the town of Pleasant Springs and flows nine miles northeast to join Koshkonong Creek northeast of the Village of Deerfield. The stream has a low gradient of about six feet/mile. Mud Creek's watershed is about 22 square miles and is predominately agricultural. The Deerfield WWTP discharges treated effluent to Mud creek via an effluent channel.

Much of the stream has been ditched and wetlands drained for agriculture. Polluted agricultural runoff is considered the primary threat to existing water quality.[370] There is no measured flow data for Mud Creek. A large stand of Angelica (Angelica atropurpurea) in a streamside wetland was observed near Hillcrest Road[371] indicating a groundwater seep or fen helping to maintain the stream's limited baseflow. Other small pockets of wetlands or trees provide minimal buffers in some stream reaches. Extreme fluctuations in flow have been observed after major runoff events indicating the effectiveness of the agricultural drainage systems. The WDNR considers Mud Creek to be a warmwater forage fishery. Intermittent stream fish IBI scores calculated from 2004 monitoring at Hillcrest Road indicate "Fair" water quality conditions at that location. M-IBI monitoring between 2004-10 indicated "Fair" biotic integrity (average = 4.68, n=2).

Saunders Creek

Saunders Creek rises in southeast Dane County and flows 12 miles south to join the Rock River south of Edgerton in Rock County. It is a meandering creek draining 36 miles of predominately agricultural lands. Parts of the creek have been ditched and wetlands drained in its watershed. Polluted runoff from pastures and barnyards and erosion from fields, exacerbated by the ditching, carry sediments to the stream, affecting water quality. Remnant wet meadows between Edgerton and Albion and above Albion still exist, providing limited Northern pike spawning habitat wetlands. An unnamed tributary east of I39/90 flows through a larger wetland having pockets of higher quality wetlands. The WDNR considers the lower five miles in Rock County as being a warmwater sport fishery stream, although sedimentation has probably had a significant impact on instream habitat and water quality. The Dane County reach of Saunders Creek is considered by WDNR to be a warmwater forage fishery. Fish monitoring done on Saunders in 2003 at USH 51 in Rock County showed a fish assemblage dominated by forage fish with few game fish. Three intermittent IBI samples at three locations between 1998 and 2003 indicated "Good" fish biotic integrity (range = 70-100, average = 87). HBI monitoring done near Edgerton in 1998 and 2003 indicated "Fair" water quality. M-IBI monitoring conducted in 2010 indicated "Fair" biotic integrity (score = 3.00).

Unnamed Tributary to Koshkonong Creek (Goose Lake Tributary)

The Goose Lake Tributary is a small stream rises along the Dane-Jefferson county line in the Town of Medina and flows south to empty into Koshkonong Creek in the Town of Deerfield. It has been channelized over most of its length. The stream flows through the Goose Lake Wildlife Area. Intermittent IBI monitoring done in 1998 at CTH BB on the downstream end of the wildlife area showed "excellent" water quality conditions. Two pollution intolerant species and one species on the state's Special Concern list,[372] the banded killifish, were found. Populations of the

369 Steve Fix personal observation, 2010.
370 Johnson, 2002b.
371 Steve Fix, Personal Observation, 2010.
372 "Special Concern" is a state endangered and threatened category. It indicates rare species with small populations in Wisconsin or whose population is in decline. For a complete explanation and list of all species, go to

banded killifish have been documented to be in decline in southern Wisconsin.[373]

Goose Lake and Mud Lake

Goose Lake and Mud Lake are two shallow glacial potholes lakes. They are both within the boundaries of the Goose Lake State Wildlife Area in eastern Dane County. The wildlife area also contains the Goose Lake Drumlins State Natural Area. Goose Lake has an area of 63 acres with a maximum depth of 2 feet. It is more a shallow water wetland than an open water lake. Mud Lake is 33 acres in size with a maximum depth of 8 feet. Typical water clarity of Mud Lake is poor.

E. Yahara Chain of Lakes

The Yahara Chain of Lakes is the centerpiece of the county and vital for the region's economy. They are the most heavily used and, arguably, most highly valued natural resources in the region. The Yahara Lakes are mentioned as one of the primary reasons why the Madison area is ranked among the top most livable cities in the U.S. Recreational boating on Lake Mendota alone brings in an estimated $3 million per year to the local community. The lake is the fifth highest used waterbody in Wisconsin.[374] The combined water surface area of the Yahara Chain, including the major lakes (Mendota, Monona, Wingra, Waubesa and Kegonsa) along with small lakes and river channel, exceeds 19,000 acres of navigable waters and makes the Capital Region a particularly attractive destination for water-based recreation and tourism.

The Yahara lakes sustain a productive fishery that is both a regional attraction and economic booster. Recent WDNR surveys provided population estimates for Lake Mendota northern pike and walleye. These species are managed as trophy fish and for top-down biomanipulation to enhance water clarity in the lake. In 2009, fyke net surveys revealed northern pike up to 42.5 inches with a mean length of 25.7 inches. Walleyes were abundant (1,443) with the largest sampled at 29.4 inches and a mean length of 16.9 inches. Other catches included quality size bluegills and catfish as well as a possible state record yellow bass measuring 16.7 inches. Musky fishing in the Yahara lakes has never been better with substantiated accounts of 50+-inch fish caught and released. Lake Monona consistently produces lunker largemouth bass. Lake Waubesa yielded impressive bluegill samples with high numbers of fish seven inches or longer. Lake Wingra is recognized as one of Wisconsin's premier action lakes with a robust musky population, although common carp and stunted panfish are a problem.

The Yahara Lakes watershed encompasses 385 square miles of glaciated terrain in Dane County with a small portion of southern Columbia County. The watershed also lies within the greater Southeast Glacial Plains Ecological Landscape.[375] There are many opportunities within this landscape to restore natural communities that also benefit water quality.[376] Consistent with much of the Southeast Glacial Plains Landscape, the watershed is typified by glacial till plains and moraines. The lakes and wetlands were formed where deep glacial deposits dammed large pre-glacial valleys.

Each lake within the watershed has unique biological and chemical characteristics that reflect its position within the watershed, history, sources of pollution, and basin morphology. The physical characteristics for Lake Mendota, Lake Monona, Lake Wingra, Lake Waubesa and Lake Kegonsa are summarized in **Table 12**.

Lake Mendota is the largest and deepest of the Yahara lakes (**Table 12**). Maximum depth is an important factor that affects how nutrients are processed in each lake and water quality. Lake Mendota's large hypolimnetic area sustains thermal stratification longer than the other Yahara lakes. The Mendota watershed is approximately 230 square miles of predominantly agricultural land uses. About 20 percent of the watershed is urban with development expanding rapidly. Urban areas lie along the west, east, and southern parts of the lake and development is expanding in the north as well. In addition to urban areas directly adjacent to the lake (Madison, Middleton, Maple Bluff, and Shorewood Hills), developed areas in the upper watershed also include the City of Sun Prairie, Villages of Deforest, Waunakee, Dane, and the urbanizing Towns of Windsor and Burke.

http://dnr.wi.gov/topic/NHI/WList.html.
373 Marshall, 2004a.
374 Johnson, 2002b.
375 http://dnr.wi.gov/topic/landscapes/
376 WDNR, 2005b.

Table 12: Physical Characteristics of the Yahara Lakes

Characteristic	Mendota	Monona	Wingra	Waubesa	Kegonsa
Surface area (acres)*	9,781	3,358	345	2,074	3,209
Volume (gallons)	134 billion	29 billion	1.9 billion	10 billion	18 billion
Maximum depth (ft)	83	74	14	38	32
Mean depth (ft)	42	27	8.9	15	17
Surface July max. water temp. (F)	73.4 - 78.8	75.2 - 82.4	–	75.2 – 82.4	75.2 – 82.4
Bottom July min. water temp. (F)	50 – 53.6	51.8 – 57.2	–	59 – 69.8	62.6 – 77
Shoreline length (miles)**	22.9	14.4	4.2	9.9	9.5
Shoreline development factor (unitless)**	1.66	1.78	1.61	1.54	1.30
Flushing Rate (yrs.)	0.15	0.91	2	3.2	2.2
Dir. drainage (sq. mi.)	217	40.5	5.4	43.6	54.4
Drainage at outlet (sq. mi.)	232	278	5.4	325	385

* WDNR Surface Water Data Viewer, July 2012
** WDNR, 1985
Source: Lathrop, 2007

Lakes Monona, Wingra, and Waubesa are located within the 94 square mile Yahara Monona Watershed. Lake Monona is the second largest lake in the chain and thermally stratifies. Lake Wingra is the smallest of the five lakes and is off-channel from the Yahara Chain. Nonetheless, the relatively small 345-acre lake is an important and popular natural resource in the watershed. Lake Waubesa is much shallower than either Lake Mendota or Lake Monona. The relatively shallow lake has a propensity for internal phosphorus loading. The Yahara Monona Watershed is predominantly urban (approximately 46 percent) and includes municipalities of the City of Madison, City of Fitchburg, City of Monona, and Village of McFarland.

Lake Kegonsa is the last glacial lake in the Yahara Chain and behaves similar to Lake Waubesa since it is a relatively shallow and weakly stratified, with a high propensity for internal nutrient recycling. Lake Kegonsa is located within the 104 square mile Yahara Kegonsa Watershed. Upstream watershed lakes' water quality and nutrient loading are the principal factors that influence the water quality of Lake Kegonsa.

Both the economic value and legacy of environmental pollution of the Yahara lakes are widely recognized. Economic losses attributed to eutrophication include recreational uses linked to fish kills and toxic algae blooms.[377] The history of post-settlement eutrophication and water quality problems in the Yahara lakes are well documented. The earliest records of algal blooms date back to the late 1800's that coincided with watershed development. Additional records were established in part due to the close proximity to UW Madison (including early 1900's pioneer limnology work of Birge and Juday) and government-sponsored monitoring in response to declining water quality in the lakes.

Lathrop provided the most recent chronology and analysis of environmental problems in the lakes.[378] Early impacts to the lakes included shoreline erosion when the lakes were artificially raised, expanding agriculture, urbanization, and loss of wetlands. Untreated and poorly treated point source pollution had caused severe Cyanobacteria (blue-green algae) blooms in Lakes Monona, Waubesa, and Kegonsa. Dissolved reactive phosphorus was very high in these lakes but declined significantly in Lake Monona after municipal wastewater was diverted downstream to Lake Waubesa in 1936 (**Figure 42**). The very high nutrient levels in Lake Waubesa and Lake Kegonsa were sustained until 1958 or shortly thereafter when all of Madison's municipal wastewater was diverted to Badfish Creek. Levels of dissolved reactive phosphorus and inorganic nitrogen remained the lowest in Lake Mendota during this period. Eventually Lake Mendota phosphorus levels increased again due to intensive agriculture. In ad-

377 Carpenter, 2008

378 Lathrop, 2007.

dition, urbanization and nutrient levels from Lake Mendota's outlet became the main environmental driver for the lower lakes. These nutrient increases occurred even after all of the upstream point source dischargers had been diverted via connection to the Madison Metropolitan Sewerage District by 1971.

Long-term nutrient analysis of the Yahara Chain of Lakes revealed that both phosphorus and nitrogen can be limiting to algal growth.[379] Nitrogen can be limiting due to three factors: low iron concentrations for N2 fixation, high denitrification rates, and high phosphorus inputs. While nitrogen is often associated with hypoxia problems in the Gulf of Mexico and is a legitimate reason for reducing nitrogen runoff, these findings suggest that management efforts should focus on reducing both nutrients for improving the Yahara lakes.

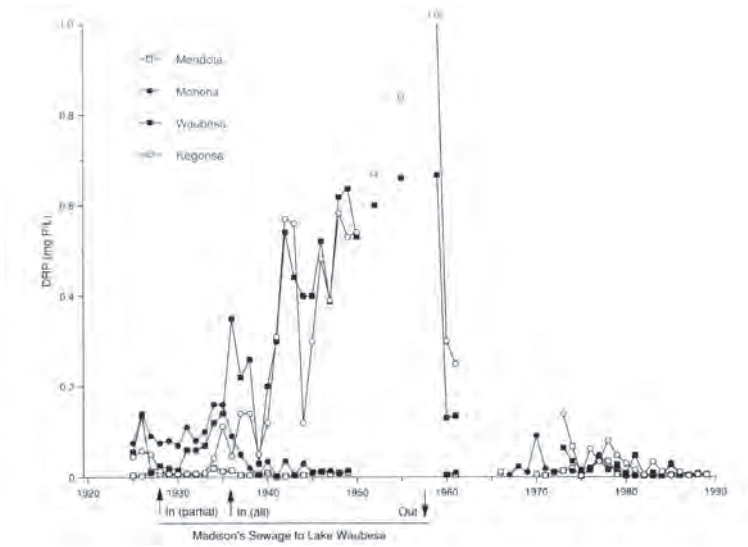
Relatively high sulfate concentrations are found in the Yahara lakes and are of significance in terms of phosphorus dynamics. Under anoxic conditions, sulfate is reduced to sulfide, which combines with reduced iron to form insoluble iron sulfide. The greater the amounts of sulfur available to bond with iron under anoxic conditions means there is less iron available to bond with phosphorous. As a result, more phosphorus remains in the water column and is available for recycling throughout the lake ecosystem. Consequently, the Yahara lakes have high capacities for internal phosphorus loading compared with lakes where sulfate levels are lower.

The management of the Yahara lakes evolved as a response to eutrophication. Lake management was initially reactive but eventually became science based. When blue-green blooms became excessive in Lake Monona during the 1920's, the management approach was to suppress algal growth with lake-wide copper sulfate treatments; an approach that largely treated the symptoms of eutrophication rather than the causes. The legacy of extensive copper sulfate treatment of algae and arsenic treatments of rooted vegetation in Lake Monona is the substantial accumulation of these metals in lake sediments. Common carp also thrived during the period of severe environmental degradation and eradication efforts were conducted from 1934 to 1969.[380]

379 Lathrop, 2007.
380 Lathrop, 2007.

Later management focused on causes of eutrophication beginning with point source pollution. Wastewater diversions had occurred in 1936 when municipal wastewater was diverted from Lake Monona to Lake Waubesa, in 1958 when municipal wastewater was diverted from Lake Waubesa to Badfish Creek, and in 1971 when wastewater was diverted from municipalities upstream of Lake Mendota to MMSD. Until full implementation of the Clean Water Act during the 1980's, the successive wastewater diversions had largely moved water quality problems to downstream waters.

Figure 42. Long-term Trends in Concentrations of Dissolved Reactive Phosphorus in the Yahara Lakes, July-August, 1925-89



Source: Lathrop, 1992

Beginning in the 1980s, the focus on controlling nutrients shifted to watershed management. Unlike the point source regulatory program (Wisconsin Pollution Discharge Elimination Program or WPDES), controlling watershed nutrients remains technically and socially challenging, but progress has been made. Under Wisconsin's Polluted Runoff Management Program (formerly Nonpoint Source Priority Watershed Program), watershed projects have included the Six Mile – Pheasant Branch Priority Watershed (1980), Yahara-Monona Priority Watershed (1988) and Lake Mendota Priority Watershed (1994). Additional county and municipal efforts to curb runoff pollution include the Starkweather Creek watershed protection efforts, municipal street sweeping, county and municipal stormwater erosion control ordinances, stormwater detention basins, protection of environmental corridors, ban on phosphorus-based lawn fertilizers, and completion of the first Lake Mendota watershed manure digester with capacity to generate $2 million worth of electricity per year.

In addition to managing the long term effects of nutrient runoff on Yahara lakes eutrophication, a number of county and local efforts focus on managing the specific problems associated with eutrophication. Dane County operates a fleet of mechanical harvesters that focus on managing invasive Eurasian watermilfoil and filamentous algae in the lakes. The county recently updated the aquatic plant management plans for the Yahara lakes as required for large-scale mechanical harvesting under Wisconsin Administrative Code NR 109. The county also coordinates the annual Take a Stake in the Lakes effort designed to coordinate citizen efforts to clean shorelines of litter and debris.

Each year private riparian landowners hire licensed aquatic herbicides applicators to chemically treat filamentous algae and weedy rooted plants like Eurasian watermilfoil. This program is administered by the Wisconsin Department of Natural Resources under NR 107. Historically, the chemical control of aquatic vegetation in the Yahara lakes had been very controversial due to concerns over unknown long-term impacts of herbicides on lake ecology.

Table 13. Incidence of Aquatic Invasive Species in Dane County Waters

	Eurasian Water Milfoil	Milfoil Hybrid	Curly Leaf Pond Weed	Big Head Carp	Grass Carp	Zebra Mussels	Spiny Waterflea
Lake Mendota	7/62		12/89			9/11	9/09
Lake Monona	1/90		12/90				10/09
Lake Waubesa	1/90		12/90				10/09
Lake Kegonsa	1/90		12/90				10/09
Lake Wingra	8/69	1/69	12/91				
Lower Mud Lake	7/06		-p-				
Crystal Lake	1/94		6/94				
Fish Lake	7/90	8/67	12/90				
Indian Lake	-p-		-p-				
Lake Koshkonong			-p-				
Marshal Millpond			7/11				
Stewart Lake			12/09				
Sugar River (below Lake Belle View)			6/09				
Barbian Pond	7/69						
Salmo Pond	10/06						
Verona Gravel Pit	12/98						
Lake Wisconsin (above Sauk Prairie dam)			8/92	7/11	4/11	1/08	
Wisconsin River (below Sauk Prairie dam				4/12			

p – present but date undetermined.

Source: WDNR Aquatic Invasive Species Program

While the negative ecological effects of common carp and Eurasian watermilfoil are well documented, the Dane County Office of Lakes and Watersheds recently prepared an invasive species prevention and control plan to address existing and potential new invasions that can undermine the Yahara lakes. [381] Zebra mussels had been found in isolated areas of Lake Monona while an invasive blue-green algae (Cylindrospermopsis) has been identified in Lake Waubesa and Lake Kegonsa. The exotic Cyanobacteria species has potential to produce toxins at greater frequency than native blue-greens. The spiny water flea (Bythotrephes longimanus) was recently discovered in Lake Mendota and has potential to alter the lake food web and undermine other zooplankton species that feed on algae. The plan identified other threatening invasive species that had been found elsewhere in the state and Midwest. **Table 13** shows the incidence of aquatic invasive species in the Yahara Lakes, as well as surrounding water bodies where this information has been documented.

Lake Mendota

Lake Mendota is one of the most extensively monitored and researched lakes in North America. The prominence of Lake Mendota reflects both the economic value as a particularly large inland lake and the location of the University of Wisconsin on the south shore. **Table 14** provides a glimpse of the extensive research that has focused on Lake Mendota water quality and ecology. Numerous peer reviewed articles, dissertations, and books have been published on Lake Mendota since 1992 when the last Surface Water Conditions Report was prepared. Given the surfeit of scientific data collected on the lake since that time, and before, only the highlights can be presented in this plan. Much of the following discussion here can be found in Lathrop (2007) and recent data obtained from UW Madison LTER database.

Lake Mendota is the largest lake in the county and is about three times larger than Lake Monona. The physical features of the lake and watershed appear in **Table 12**. Lake eutrophication had been well documented and the lake is currently on the state's 303(d) Impaired Waters list due to a fish consumption advisory for polychlorinated biphenyls or PCBs. Summer blue-green algae blooms had been reported since the late 1800s, after the lake level was raised and watershed converted to agriculture. More significant signs of eutrophication occurred by the mid-1940s and reflected nutrient inputs from upstream wastewater treatment facilities, urbanization and farming practices that increased corn production and use of commercial fertilizers. Higher levels of ammonia and dissolved reactive phosphorus were found in the Lake Mendota hypolimnion after many of these watershed changes had occurred. From about the 1970s, higher sulfate levels in the lake coincided with limited dissolved iron buildup in the hypolimnion. These changes likely indicated the formation of iron sulfide compounds that limited phosphorus precipitation and increased internal recycling.

Following the diversion of wastewater discharges away from Lake Mendota in 1971, nutrient levels have remained relatively high but are variable. For example, during dry periods such as in 1988, nutrient levels remain relatively low while much higher nutrient levels coincide with periods of heavy runoff, notably in 1993. The lake responses since the 1980s reflect substantial impacts of polluted runoff, particularly from agriculture, but lake responses during droughts also indicate potential for water quality improvements if inputs are reduced. Some of the variability in algal blooms also reflects top down predator effects on planktivore biomass or other factors that reduce planktivores.[382] Reduced planktivore numbers such as yellow perch or cisco can result in greater numbers of large bodied zooplankton Daphnia pulicaria that effectively graze algae.

Entrainment of nutrients across the thermocline can also cause algal blooms when external nutrient loading is low.[383]

381 Martin, 2009.

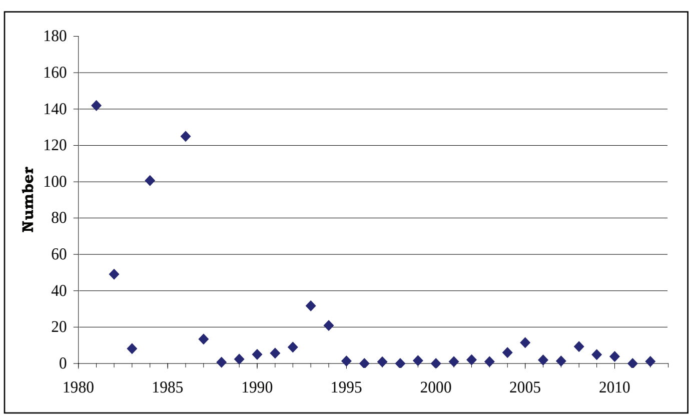
382 Animals that feed on plankton.
383 Kamarainen, 2009.

Table 14: Examples of Research Documents Produced Since the 1992 Appendix B report

Bennett, E.M., T. Reed-Anderson, J.N. Houser, J.R. Gabriel, and S.R. Carpenter. 1999. A phosphorus budget for the Lake Mendota watershed. Ecosystems 2:69-75.
Carpenter S.R. et al. 2006. The Ongoing Experiment: Restoration of Lake Mendota and its watershed (In) Magnuson, JJ et al. editors Long Term Dynamics of Lakes in the Landscape: Long Term Ecological Research. Oxford University Press.
Hurley, J.P., D.E. Armstrong, and A.L. DuVall. 1992. Historical interpretation of pigment stratigraphy in Lake Mendota sediments. Pages 49-68 in J.F. Kitchell (ed.), Food web management: a case study of Lake Mendota. Springer-Verlag, New York.
Johnson, T.B., and J.F. Kitchell. 1996. Long-term changes in zooplanktivorous fish community composition: implications for food webs. Can. J. Fish. Aquat. Sci. 53:2792-2803.
Johnson, T.B. 1995. Long-term dynamics of the zooplanktivorous fish community in Lake Mendota, Wisconsin. Ph.D. thesis. University of Wisconsin, Madison.
Johnson, B.M., and S.R. Carpenter. 1994. Functional and numerical responses: a framework for fish-angler interactions. Ecol. Appl. 4:808-21.
Johnson, B.M. 1993. Toward a holistic recreational fisheries management: fish-angler-management interactions in Lake Mendota, Wisconsin. Ph.D. thesis. . University of Wisconsin, Madison.
Kitchell, J.F. 1992. Food web management: a case study of Lake Mendota. Springer-Verlag, N. Y.
Lathrop, R.C. 1992. Lake Mendota and the Yahara River Chain. Pages 16-29 in J.F. Kitchell (ed.), Food web management: a case study of Lake Mendota. New York: Springer-Verlag.
Lathrop, R.C., S.B. Nehls, C.L. Brynildson, and K.R. Plass. 1992. The fishery of the Yahara Lakes. Technical Bulletin No. 181. Wisconsin Dept. Natural Resources, Madison, WI.
Lathrop, R.C., S.R. Carpenter, and D.M. Robertson. 1999. Summer water clarity responses to phosphorus, Daphnia grazing, and internal mixing in L Mendota. Limnol. Oceanogr. 44:137-146.
Lathrop, R.C. 1998. Water clarity responses to phosphorus and Daphnia in Lake Mendota. Ph.D. thesis. University of Wisconsin, Madison.
Lathrop, R.C. 1992. Decline in zoobenthos densities in the profundal sediments of Lake Mendota (Wisconsin, USA). Hydrobiologia 235/236:353-361.
Lathrop, R.C. 1998. Water clarity responses to phosphorus and Daphnia in Lake Mendota. Ph.D. thesis. University of Wisconsin, Madison.
Lathrop, R.C., S.R. Carpenter, C.A. Stow, P.A. Soranno, and J.C. Panuska. 1998. Phosphorus loading reductions needed to control blue-green algal blooms in Lake Mendota. Can. J. Fish. Aquat. Sci. 55:1169-1178.
Robertson, D.M., R.A. Ragotzkie, and J.J. Magnuson. 1992. Lake ice records used to detect historical and future climatic changes. Climatic Change 21:407-427.
Rudstam, L.G., R.C. Lathrop, and S.R. Carpenter. 1993. The rise and fall of a dominant planktivore: direct and indirect effects on zooplankton. Ecology 74(2):303-319.
Soranno, P.A., S.L. Hubler, S.R. Carpenter, and R.C. Lathrop. 1996. Phosphorus loads to surface waters: a simple model to account for spatial pattern of land use. Ecol. Appl. 6:865-878.
Soranno, P.A. 1995. Phosphorus cycling in the Lake Mendota ecosystem: internal versus external nutrient supply. Ph.D. thesis. University of Wisconsin, Madison.
Soranno, P.A., S.R. Carpenter, and R.C. Lathrop. 1997. Internal phosphorus loading in Lake Mendota: response to external loads and weather. Can. J. Fish. Aquat. Sci. 54:1883-1893.
Soranno, P.A. 1997. Factors affecting the timing of surface scums and epilimnetic blooms of blue-green algae in a eutrophic lake. Can. J. Fish. Aquat. Sci. 54:1965-1975.
Stow, C.A., S.R. Carpenter, and R.C. Lathrop. 1997. A Bayesian observation error model to predict cyanobacterial biovolume from spring T P in L Mendota. Can. J. Fish. Aquat. Sci. 54:464-473.
Weaver, M.J., J.J. Magnuson, and M.K. Clayton. 1997. Distribution of littoral fishes in structurally complex macrophytes. Can. J. Fish. Aquat. Sci. 54:2277-2289.
Winkler, M. G. (1994). Sensing plant community and climate change by charcoal-carbon isotope analysis. Ecoscience 1(4):340-345.

The cisco is native to Lake Mendota as well as other deep lakes in Wisconsin where water temperatures tend to be cooler and where lower nutrients help maintain less primary productivity (hence not as severe oxygen depletion in the hypolimnion). A substantial commercial fishery existed in Lake Mendota prior to a significant decline in the 1940s. Reasons for this decline were never conclusively demonstrated, but eutrophication was thought to be indirectly responsible.[384] Because of the following decade of poor reproductive success, researchers believed the cisco population at the end of 1953 to be at an "all time low." Ciscoes continued to be scarce from the 1950s through the mid-1970s, causing many people to think that they were essentially extirpated from Lake Mendota. However, because occasional cisco mortalities continued to occur, ciscoes were obviously still in the lake. In 1977 ciscoes began showing up in Lake Mendota again. In 1981, the cisco population in Mendota was estimated through the use of sonar to be 2 million fish – a remarkable comeback for a supposedly extirpated species. Cisco populations remained high until the large summer mortality in 1987. Most of the fish dying that year were from the 1977 year class. Water temperatures were particularly warm that summer, forcing the ciscoes (a coldwater species) to be stressed by temperatures that were too warm and too little oxygen. Ciscoes have not had a significant hatch since then (**Figure 43**).

Figure 43. Annual Fish Assemblage Sampling (Cisco, Coregonus artedii), Lake Mendota



Source: North Temperate Lakes LTER Network

The resurgence of this sensitive species in the 1970s was thought to be a sign that the lake was getting better. Cisco were remarkably effective in reducing populations of *Daphnia pulicaria*, the most important algae grazer among Lake Mendota's zooplankton. Despite rising hopes for restoration of the lake, ironically, loss of *Daphnia pulicaria* due to cisco predation led to more algae in the water and poorer water quality. Starting in 1986, state managers and University of Wisconsin scientists worked together to change the food web of Lake Mendota. Populations of piscivorous (fish-eating) walleye and northern pike were increased by massive stocking and restrictive harvest regulations. The goal was to decrease populations of planktivorous (plankton-eating) fishes through predation. If planktivorous fish populations could be reduced (such as cisco and yellow perch), predation on *Daphnia pulicaria* would decrease, leading to higher populations of *Daphnia pulicaria*, increased grazing of phytoplankton, and greater water clarity (so-called trophic cascade effect or biomanipulation[385]). In August 1987, an unexpected die-off of cisco accelerated the food web manipulation. By 1988, water clarity in Lake Mendota had improved. *Daphnia pulicaria* and clearer water have persisted since then (as compared to water quality dominated by the smaller-bodied *Daphnia galeata mendotae*), with considerable variability associated with weather and runoff events.

Nonpoint Source Pollution Abatement

Concerns with water quality in Lake Mendota and the Yahara Lakes have led to numerous efforts over the past few decades to address agricultural and urban nonpoint sources of pollution in the watershed. The primary concerns for Lake Mendota and its tributaries have consistently been sedimentation, excess nutrient loading leading to algae and aquatic plant growth, decreased water clarity, stream channelization, and streambank erosion. Other issues included low dissolved oxygen concentrations and thermal loading issues from urbanized areas.[386]

Efforts to control polluted runoff began with the Six Mile – Pheasant Branch Priority Watershed Project in 1980. This was the first priority watershed project in Wisconsin under the state's Nonpoint Source Pollution Abatement Program (NR 120). However, landowner participation was low as was project effectiveness, revealed by long term

384 Lathrop, 1992.

385 Carpenter, 1985.

386 Genskow and Betz, 2012.

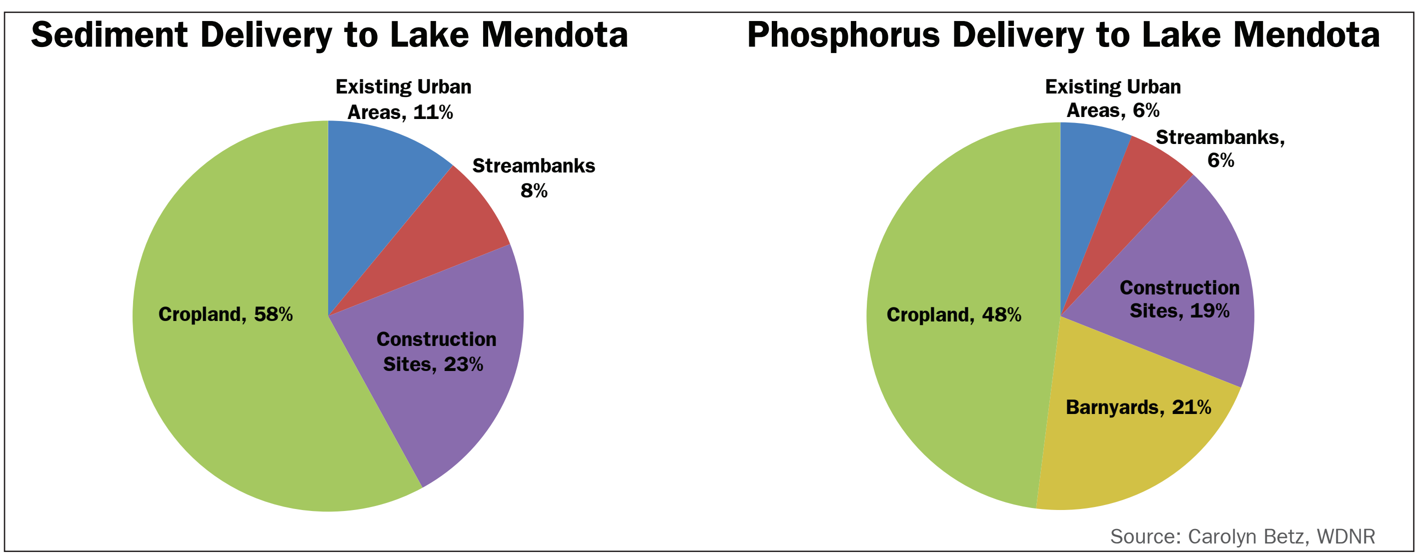
USGS monitoring data for Pheasant Branch Creek.[387] Limited project effectiveness reflected in part changing land uses and high nutrient inputs when decades of fertilized soils were developed.

The tributary monitoring data also revealed that most of the nutrient loading occurs during the late winter and early spring months when spreading manure on frozen ground occurs.[388] Since the 1940s, manure had become less valued as a resource while commercial fertilizer use increased along with increased numbers of animal units. Disposing of excess manure had become both a farm management problem as well as a major source of nutrients to the lakes.

Different modeling efforts have produced various loading estimates for sources of nutrients and sediment. For example, Montgomery Associates suggested through the use of the SWAT model that agricultural sources accounted for 90 percent of sediment loads and 84 percent of phosphorus loadings, while urban sources provided 10 percent of loading for sediment and 14 percent of phosphorus. [389] In contrast, the Lake Mendota Priority Watershed Plan suggested greater contributions from urban sources (up to 25 percent) particularly construction sites (**Figure 44**). [390, 391] According to the plan an estimated 35,000 lbs. of phosphorus was generated from upland areas. Eroding streambanks contributed an estimated 4,600 lbs. Urban and transitional areas delivered an estimated 17,600 lbs. each year. While the total rural area is greater than the urban area in the Mendota watershed, the amount of phosphorus delivered per unit area of land was greater from urban land. Annual soil loss in the watershed was estimated at 35,000 tons per year. However, because of deposition, not all the sediment that is delivered to streams and wetlands is delivered to Lake Mendota. An estimated 9,600 tons of sediment actually reaches Lake Mendota annually. Since phosphorus is often bound to sediment particles, efforts to control sediment reduces phosphorus as well.

Lathrop[392] analyzed phosphorus loading to the lake from 1980 – 2007. One of his important findings was that snowmelt and "drizzle-day" runoff events during January to March seasonal period constituted 43-48 percent of the subwatersheds' long-term phosphorus load through 2006. Not only is this load significantly important to the overall input, the phosphorus is much higher in its dissolved form compared to runoff events during warmer months when sediment concentrations are higher. Lathrop and Carpenter recommend that the overall phosphorus load to Lake Mendota should be reduced by 50

Figure 44. Sources of Sediment and Phosphorus Loading to Lake Mendota



387 Nowak, 2006.
388 Lathrop, 2007.
389 Montgomery Associates, 2011.
390 WDNR, 2000b.
391 Note, this modeling pre-dates current stormwater regulation in the State of Wisconsin, which have significantly reduced the sediment and phosphorus load from new development in urban areas

392 Lathrop, 2007.

percent in order to improve the quality of Lake Mendota and the downstream lakes.[393] This is consistent with therecommendation of the priority watershed project, as well as the analysis by Montgomery and Associates. While estimates and quantification of loadings to the tributaries and Lake Mendota vary somewhat, all of the studies are consistent in their conclusions: the water quality in the watershed is being compromised by excessive phosphorus and sedimentation, and management efforts to reduce the loadings will result in improved water quality.

More importantly, according to researchers, efforts to control phosphorus in the Lake Mendota watershed could have a cascading effect through the Yahara Lake Chain since approximately two-thirds of the phosphorus load to the downstream lakes comes from the upstream lakes, indicated in blue (**Figure 45**).[394] In addition, as evidenced during dry (low flow) years, Lake Mendota's water quality could improve relatively quickly if the amount of phosphorus flowing into the lake can be significantly reduced.[395]

Blue-Green Algae Bloom University Bay

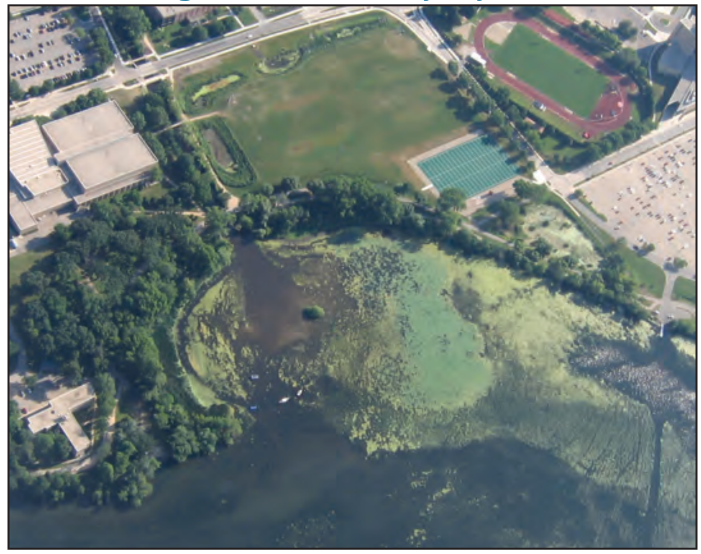
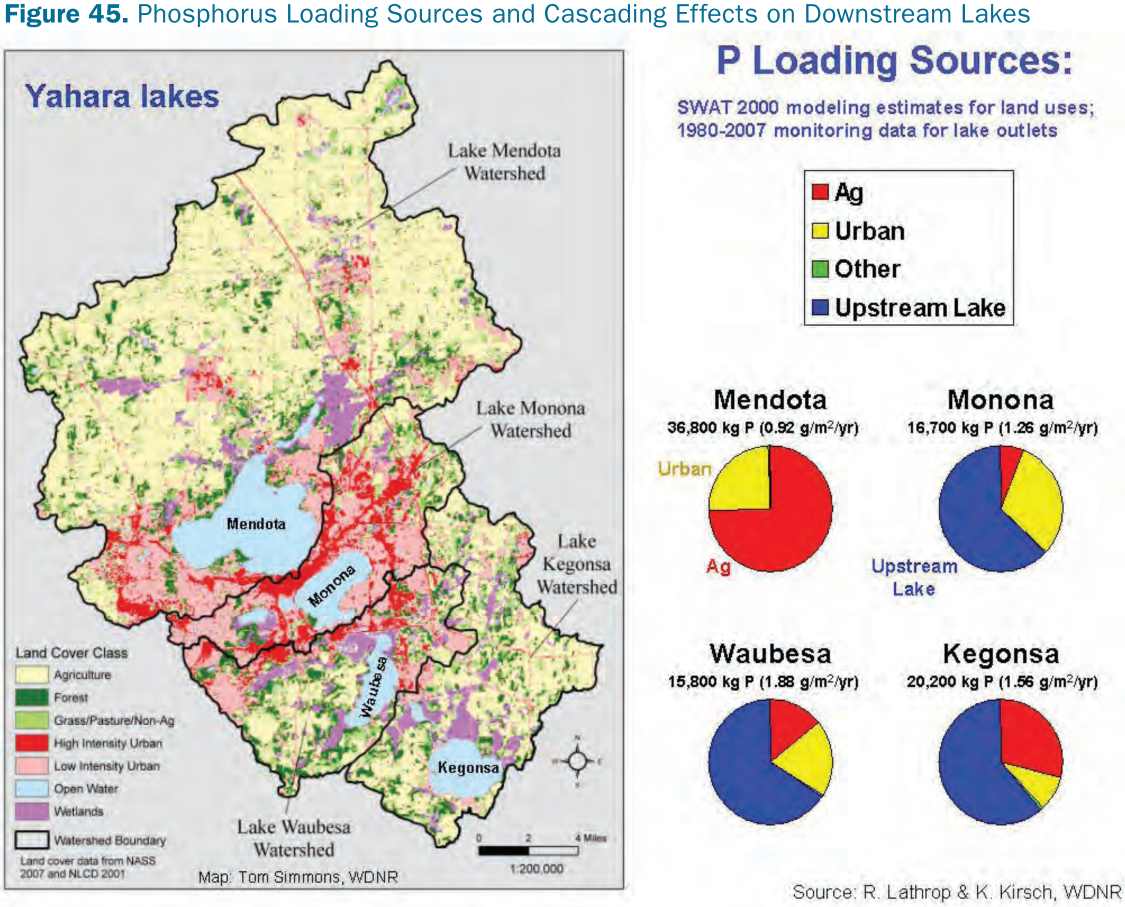


Photo: Mike Kakuska

Figure 45. Phosphorus Loading Sources and Cascading Effects on Downstream Lakes



393 Lathrop and Carpenter, 2011.
394 Lathrop, 2010.
395 Lathrop and Carpenter, 2011.

A useful and easily interpretable tool for evaluating water quality in the Yahara lakes is Carlson's (1977) Trophic State Index for total phosphorus concentrations (TP-TSI). A TP-TSI of 50, which corresponds to a TP concentration of 0.024 mg/L, represents the boundary between mesotrophy (moderately fertile) and eutrophy (fertile) with higher numbers representing eutrophy.[396] The researchers recommend that July and August be the months for the TP-TSI summer water quality evaluation and that June be excluded given each lake normally experiences a "clear-water phase" during June. (Thus, a TP-TSI based on median TP concentrations for July-August avoids the problem of outliers influencing the calculation of mean TP concentrations.)

Under current load conditions with the lake dominated by the *D. pulicaria* zooplankton grazer, the probability of lake TP being in the mesotrophic state was slightly less than 20 percent, or almost 2 out of 10 July-August days on average (**see arrow A Figure 23**). If average phosphorus loads were reduced by 50 percent in the future, then the probability of mesotrophy is predicted to be almost 4 out of 10 days (arrow B). However, if *D. pulicaria* were to be eliminated due to predation by planktivorous fish, the probability of lake TP being in the mesotrophic state is only about 5 percent, or 1 out of 20 days (arrow C). Under the same scenario but with a 50 percent phosphorus load reduction, the mesothrophic probability increases to about 15 percent, or 3 out of 20 days (arrow D).

According to the Lake Mendota Priority Watershed plan, approximately 75 percent of the phosphorus loading to Lake Mendota came from agricultural parts of the watershed. The priority watershed project was established to provide farm owners cost sharing for the installation of Best Management Practices designed to reduce the amount of sediment and phosphorus leaving farm fields and barnyards. The implementation phase of the project began in 1998 and ended at the end of 2009. The following Best Management Practices (BMPs) were installed:[397]

- 46 barnyard runoff systems,
- 10 water diversions,
- 58 acres of grassed waterways installed,
- 3,105 feet of streambank protection measures,
- 2 field terrace systems,
- 8 agricultural sediment basins or grade stabilization structures,
- 150 acres of grassed buffers along surface waters, and
- 19 acres of restored wetlands
- Nutrient management plans prepared for over 36,000 acres of croplands, approximately 37 percent of the total cropland in the watershed.

In addition, all 10 of the identified critical site animal lots and 80 critical site crop fields were addressed during the project. Dane County also adopted an ordinance addressing manure storage and winter spreading. A Farm Practices Inventory (FPI) survey was conducted early in the project to establish baseline data. The same participating producers were surveyed again in 2010 to identify changes that have occurred as a result of the priority watershed project. Results from the survey led to recommendations in the report focusing on supporting and engaging more farmers in the watershed including more innovative incentive programs as well as more targeted/effective outreach.[398]

The urban component of the priority watershed project funded the construction of several retention and detention facilities in Madison, Middleton, Sun Prairie, and DeForest. Non-structural BMP measures were also taken to reduce nutrient and sediment loading. These included the funding of municipal stormwater plans, additional street sweeping, and Dane County's enactment of an erosion control and storm water management ordinance.[399] Main goals of these measures has been to assure adequate erosion control and storm water management actions and facilities are utilized in developing areas, to reduce direct discharges to surface waters by 80 percent, and to reduce or control peak storm water flows from developing areas.

The ordinance, enacted in 2006, was developed to protect the county's ground and surface water resources. Increasing stormwater flow and pollutant loading from urban parts of the watershed has been a significant problem, historically. New developments are now re-

396 Lathrop and Carpenter, 2011
397 Dane County LWRD, 2010a.
398 Genskow, in draft.
399 Chapter 14, Dane County Code of Ordinances

quired to have stormwater detention and retention ponds to reduce runoff reaching surface waters. Stormwater management practices at new developments must be designed to match pre-development runoff rates and trap 5 micron and larger particles, preventing them from getting into surface waters.[400] In 2011 Dane County adopted infiltration standards requiring new development levels be maintained no less than 90 percent pre-development levels. Infiltration of runoff is being actively promoted in order to maintain stream baseflow and temperature, reduce overland runoff and associated pollutant loads. In addition, cities and villages in Dane County are required to meet the County's minimum standards.[401]

While much has been accomplished, more work is needed. According to WDNR research Dick Lathrop, who has been studying the lakes for more than 30 years,

> ***"No discernible effect of nonpoint phosphorus management has been observed (in Lake Mendota) because of an increase in frequency of large runoff events, slow depuration of P in soils, and other offsetting factors."[402]***

He also cites a worsening manure management problem (i.e., more animal units producing manure coupled with less land to spread it on). [403]

As part of the Yahara CLEAN project (see Clean Lake Initiatives below), Dane County has contracted with a consulting firm to provide updated phosphorus and sediment loading to the Yahara lakes using the Soil and Water Assessment Tool (SWAT). As part of the investigation, field specific monitoring using the SNAP-Plus model and Wisconsin's phosphorus index (PI) was done in the North Branch Pheasant Creek watershed. The SNAP-Plus model looked at phosphorus loading from specific fields using different manure spreading, tillage, and crop rotation scenarios. The intent is to identify field management practices to minimize phosphorus leaving the field. The effort also supports more cost-effective implementation and partnering opportunities through adaptive management and nutrient-trading strategies being promoted in the watershed. MMSD is partnering with the WDNR, Dane County, and multiple cities, villages, and towns in the watershed, along with agricultural, business, and environmental groups to help implement the best cost/mix of agricultural and urban phosphorus control practices. The purpose of this innovative project (the first in the nation) is to meet regulatory requirements beyond the traditional (and expensive) structural controls (e.g., wastewater treatment plant upgrades or stormwater retrofits in existing development).[404]

Unlike many parts of the Driftless Area where agricultural intensity had declined along with total animal units, the Lake Mendota watershed remains highly productive and intensive agriculture dominates the landscape. Bennett demonstrated the challenge of improving Lake Mendota water quality since the annual imports of phosphorus in the forms of commercial fertilizers and feeds exceed export of crops and animal products.[405] As a result, there has been a steady increase in phosphorus fertility in watershed soils along with increased manure production. The trend toward larger animal feeding operations in the watershed poses an additional threat to Lake Mendota in terms of nutrient loading. These operations will need additional cropland acreage on which to spread manure generated by their operation. This land needed for manure spreading is in competition with residential and commercial development also occurring in the watershed.

The construction of a manure digester on a large-scale dairy farm is one of the latest efforts to address expanding agricultural production and associated nutrient increases in the watershed. Located north of Waunakee, the digester will take liquid manure from three local dairy operations and about 2,500 cows. The manure will be pumped to three tanks in the mesophilic anaerobic digester facility where it will produce low-grade methane that will be used to produce up to two megawatts of electricity. The electricity generated will provide enough power for over 2,000 local residences. The heat from that process goes back to the digester, making it somewhat self-sustaining, and an advanced separation system will pull the solids from the liquids. The solids, which include most of the phosphorus, will leave the area as a soil amendment for landscapers while the nitrogen and potash will remain with the liquid portion that the farm-

400 Dane County LWRD, 2007.
401 1989 Wisconsin Act 324.
402 Lathrop, 2010.
403 Lathrop, personal communication 11/12

404 See Yahara WINS at http://www.madsewer.org/YaharaWINsHome.htm
405 Bennett, 1999.

ers will get back to fertilize their fields. It is expected that this operation will reduce the amount of phosphorus spread from these three facilities by about 60%. Due to this reduction in phosphorus in the land spread manure, the amount of phosphorus that would be making its way into surface water through runoff from participating farms is 8 percent based on SNAP modeling.[406] Planning has begun for a second digester to be located in the Dorn Creek watershed.

The University of Wisconsin Madison Center for Limnology conducts intensive water quality monitoring on Lake Mendota as part of the Long Term Ecological Research (LTER) Project. **Figures 46a and 46b** display total phosphorus and secchi data along with associated Trophic State Indices (TSI).[407] Lake Mendota remains moderately eutrophic with median July-September TSI values for total phosphorus and secchi at 54.5 and 52, respectively, indicating generally "Good" condition since 2000.[408] A median TSI secchi value of 53 over the last five years indicates a slight decline in condition, although still considered "Good." A median TSI(TP) > TSI(Secchi) value indicates zooplankton grazing, nitrogen, or some factor other than phosphorus is limiting algal biomass. Annual differences in TSI values may be due to several factors. For example, high phosphorus levels, relatively low chlorophyll a, and high water transparency may reflect biomanipulation such as high densities of large daphnia species or, in smaller lakes, high growths of rooted aquatics that suppress phytoplankton. The TSI values can reflect that even if water clarity is good during a specific period, the lake may still be eutrophic.

Dane County Community Manure Digester (domed structures, center) Serving Three Surrounding Farms

Photo: Mike Kakuska

While a major focus of Lake Mendota research and management has been addressing long term water clarity declines and levels of nuisance blue-green algae blooms, significant changes had occurred to nearshore areas. Lyons documented the loss of eight littoral zone fish species previously found in Lake Mendota including the pugnose shiner (State Threatened), common shiner, blackchin shiner, blacknose shiner, tadpole madtom, banded killifish (State Special Concern), blackstripe topminnow, and fantail darter.[409] This significant loss in biodiversity likely reflected changes in littoral zone habitats including reduction in native aquatic plant species, extensive aquatic herbicides treatments, and construction of piers and other structures. Many of the small fish species depend specifically on rooted aquatic plans (macrophyte obligates) and aquatic plant losses linked to herbicides treatments and structures can destroy and fragment their habitat.[410]

Beyond the nearshore areas, Dane County operates large-scale mechanical harvesting equipment to manage the Eurasian watermilfoil beds that thrive in deeper littoral zones in Lake Mendota. As part of the regulatory process administered by WDNR under NR 109, the county updated the aquatic plant management plan for Lake Mendota in 2007. A total of 633 sites were sampled across the lake. Coontail was the dominant plant in terms of relative frequency and density and Eurasian watermilfoil was the second most common species found. Native species richness had increased compared to surveys conducted during the early 1990s. Recommendations from the plan include:

1. Conduct large-scale mechanical harvesting in areas not designated as Sensitive Areas (public lands) and where Eurasian watermilfoil undermines boating access and recreation.

2. Prohibit chemical herbicide treatments and mechanical harvesting within Sensitive Areas. Sensitive Areas are undeveloped areas sup-

406 WDNR, Environmental Impact Statement, 2010.
407 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.
408 Whereas Carlson 1977 provides an equation to convert phosphorus concentrations to TSI, the WDNR is not currently using that equation for General Condition Assessments. It is used for 303(d) listing.

409 Lyons, 1989.
410 Garrison, 2005.

porting coarse woody debris, floating-leaf plants including American lotus (*Nelumbo lutea*), white water lily (*Nymphaea odorata*); and submersed native plant species including clasping-leaf pondweed (*Potamogeton richardsonii*), sago pondweed (*Struckenia pectinatus*), leafy pondweed (*Potamogeton foliosus*), flatstem pondweed (*Potamogeton zosteriformes*), water stargrass (*Heteranthera dubia*), wild celery (*Vallisneria Americana*), muskgrass (*Chara*), and horned pondweed (*Zannichelia palustris*).

3. Chemical herbicide treatments should focus on the selective control of Eurasian watermilfoil – EWM (*Myriophyllum spicatum*) since several native pondweeds and other valuable native species have increased in the lake.
4. Consider options for reducing motorboat impacts to floating-leaf plants (American lotus and white water lily) in University Bay and Governor's Island sheltered coves.
5. Consider expanding floating-leaf plant beds and introducing high value species (historically found in the lake) within proposed Sensitive Areas, University Bay and Governor's Island sheltered coves.

Figure 46a. Recent Surface Total Phosphorus Levels in Lake Mendota and Associated Trophic State Index Values (50 – 70 = eutrophic)

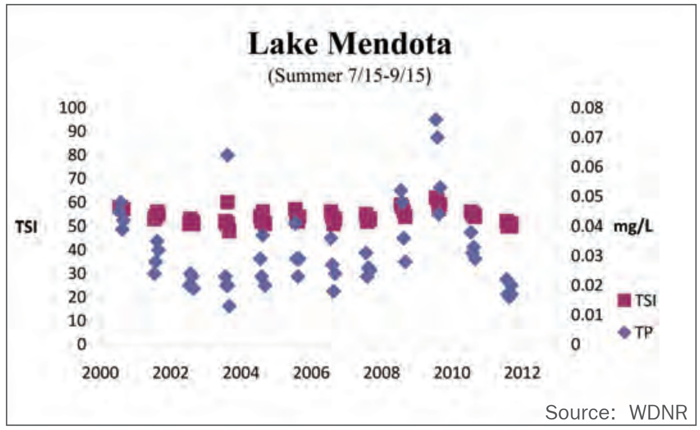
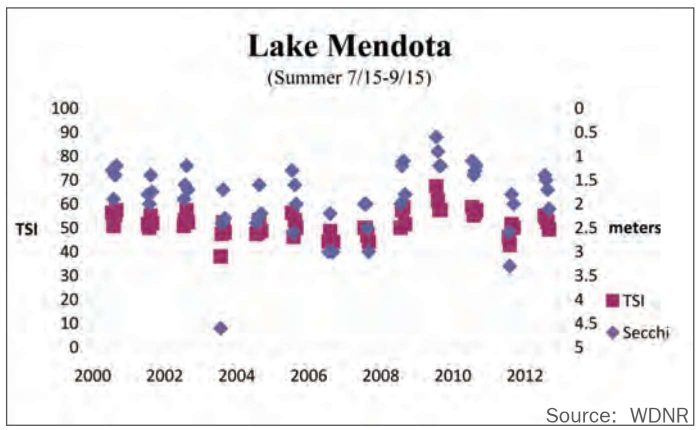


Figure 46b. Recent Secchi Measurements in Lake Mendota and Associated Trophic State Index Values (50 – 70 = eutrophic)



Lake Monona

Lake Monona is the second largest lake in the county. Physical features of the lake and watershed appear in **Table 12**. The lake has a long history of water quality degradation linked to untreated wastewater discharges and urbanization. The legacy of environmental degradation is found in the lake sediments that hold high levels of mercury, lead, copper, arsenic, and organic compounds such as PCBs. Mercury sources included unpermitted industrial discharges to Starkweather Creek, located on the east side of the lake. Copper and arsenic compounds accumulated in sediments as a result of cosmetic efforts to chemically reduce severe blue-green algae blooms when the impacts of wastewater discharges were severe. Between 1925 and 1960 over 1,545,000 pounds of copper sulfate were applied to control odors associated with planktonic algae in Lake Monona.[411] The chemically suppressed algae resulted in clearer water at times when copper sulfate application rates were high. In 1935, the maximum depth of the littoral zone reached 18 feet during chemically induced clear water conditions. However, the total area of rooted plant growth was limited since nearshore areas were treated with sodium arsenite, a chemical that was banned in 1964. Lead sources were likely widespread in urban runoff when leaded gasoline was standard. In all cases above, higher levels of contaminants occur in deeper sediment layers and reflect contaminant reduction in later years. Lake Monona is currently on the state's 303(d) Impaired Waters list for PCB fish consumption advisories. It was delisted for mercury in 2010 after 2008 data indicated no specific advisory should exist.

Recent efforts to reduce runoff pollutants to Lake Monona began in 1988 with the establishment of the Yahara Monona Watershed Project. The three major goals of the project were to reduce heavy metal loading, reduce suspended solids loading, and reduce phosphorus loading within the 94 square mile watershed that is considered 45 percent developed. Priority watershed grants to the Cities of Madison, Monona and Fitchburg and the Village of McFarland funded a number of activities to benefit water quality, including an innovative stormwater outlet design at Interlake Park; stormwater management training; storm sewer outfall inventory; development of Monona wetland conservancy ponds; Winnequah Park shoreline stabilization; acquisition of the Sand County Foundation Wetland; and stormwater sampling to evaluate the effectiveness of Best Management Practices. Additional watershed projects included the restoration of Starkweather Creek; development of an outlet structure for lowering the water level of Dunn's Marsh to maintain the wetland's natural hydraulics and functional values (despite increasing stormwater flows); development of stormwater buffers adjacent to Edna Taylor Marsh; Cottage Grove Road/ Highway 51 stormwater management plan; Wingra Creek streambank stabilization project; the Jenni-Kyle Preserve channel stabilization project; and a pilot street sweeping project for stormwater quality improvements. Results from the pilot street sweeping project indicate reductions in suspended solids and the heavy metals cadmium, chromium, copper and lead from pre-sweeping stormwater to post-sweeping stormwater.

Groundwater depletion is a concern in the watershed as a cone of depression has formed in response to increasing municipal well water withdrawals and associated wastewater diversion, along with expansion of impervious surfaces that limit surface water infiltration and groundwater recharge. Both of these changes (pumping/diversion and groundwater recharge loss) affect baseflow and thus water temperature and quality in streams. A trend of elevated chloride and sodium levels in the watershed lakes and streams is another concern, associated with the use of road salt.

For many decades Lake Monona had been significantly more degraded than Lake Mendota. However, in recent decades Lake Mendota became the primary environmental driver for Lake Monona by contributing 57 percent of the annual phosphorus load, estimated at 25,080 lbs/ yr.[412] Lake Monona water clarity is typically only slightly lower than Lake Mendota in recent years and reflects more significant internal loading in Lake Monona.[413] Summer secchi readings typically fall between 1 to 2.5 meters. Even though Lake Monona is shallower than Lake Mendota and displays a greater propensity for internal loading, a review of LTER monitoring data over the past decade indicate that Lake Monona displays a similar degree of eutrophication as Lake Mendota. Median July-September Lake Monona TSI values for total phosphorus and secchi were 55 and 54, respectively, indicating gen-

411 DCRPC, 1979.

412 Lathrop, 2011.

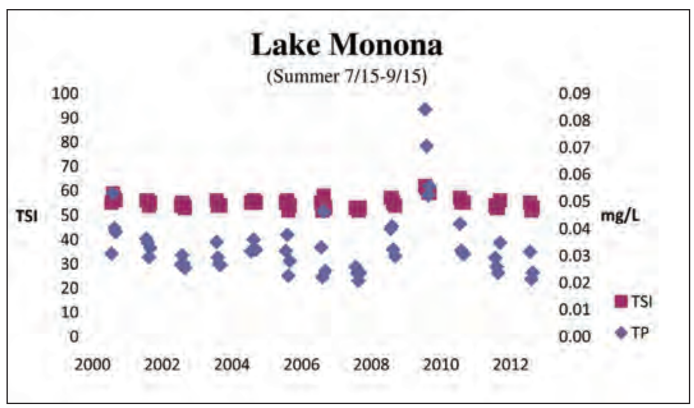
413 Lathrop, 2007.

erally “Good” condition since 2000.[414] However, a median TSI secchi value of 56 over the last five years indicates a recent decline in condition to “Fair.” The TSI parameters and values for Lake Monona appear in **Figures 47a and 47b**.

From the 1960s through the 1980s, significant Eurasian watermilfoil growth pulses undermined recreational uses and navigation. Management efforts to control the invasive plant have involved both large-scale mechanical harvesting and nearshore herbicides treatments. In 2008, Dane County updated the aquatic plant management plan as required under NR 109.04(d) to guide mechanical harvesting activities and the effective management of aquatic plants in Lake Monona. A point intercept aquatic plant survey was conducted as part of the planning process. A total of 754 sites were sampled across the lake with 280 of the sites located in Monona Bay. Results of the point intercept survey indicated that Eurasian watermilfoil (EWM) and coontail were the most frequently collected rooted plants in 2008, a consistent pattern in recent decades. Coontail was the most dominant plant in Monona Bay and reflected a pronounced EWM decline within the bay in 2008. Macrophyte species richness was much higher in the primary lake basin (12) than in Monona Bay (5). While species richness did not increase compared to surveys performed from 1990 to 1992, a few species were revealed that had not been found in decades. American lotus had not been collected since 1961 and stiff water crowfoot had not been collected since 1929 in the larger basin. Recommendations of the aquatic plant management plan include:

1. Conduct large-scale mechanical harvesting in areas where EWM grows in dense monotypic stands. Goals for managing EWM are to improve boating access, fish habitat improvement and expanding native rooted plant species.
2. Prohibit chemical herbicide treatments in Sensitive Areas except in areas where monotypic stands of EWM occur and goals should include improving fish habitat and expanding native rooted plants. Sensitive Areas are relatively undeveloped areas supporting coarse woody debris, floating-leaf plants including American lotus (*Nelumbo lutea*), white water lily (*Nymphaea odorata*); and submersed native plant species including clasping-leaf pondweed (*Potamogeton richardsonii*), sago pondweed (*Struckenia pectinatus*), leafy pondweed (*Potamogeton foliosus*), water stargrass (*Heteranthera dubia*), and wild celery (*Vallisneria Americana*).
3. Chemical herbicide treatments should focus on the selective control of Eurasian watermilfoil – EWM (*Myriophyllum spicatum*) since several native pondweeds and other valuable native species have increased in the lake. Research on experimental early season chemical control and other techniques should continue.
4. Consider options for reducing motorboat impacts to floating-leaf plants (American lotus and white water lily) in Turville Bay.
5. Consider expanding floating-leaf plant beds and introducing high value species (historically found in the lake) within sheltered bays.

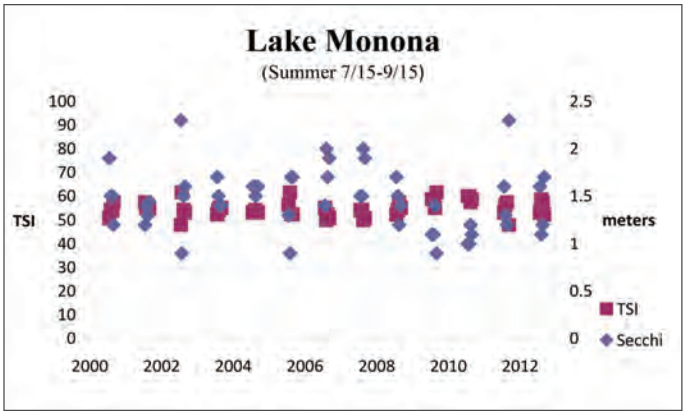
Figure 47a. Recent Surface Concentrations of Total Phosphorus in Lake Monona and Associated Trophic State Index Values (50 – 70 = eutrophic)



Source: WSLOH

414 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.

Figure 47b. Recent Secchi Measurements in Lake Monona and Associated Trophic State Index Values (50 – 70 = eutrophic)



Source: UW LTER

Lake Wingra

Lake Wingra is the smallest and shallowest of the Yahara lakes. Physical features of the lake and watershed appear in **Table 11**. Lake Wingra is located off-channel from the Yahara River and lies within the Yahara Monona Watershed. Lake Wingra is connected to Lake Monona by Wingra Creek, an urbanized channelized stream. Lake Wingra is also highly urbanized and recent management has focused on reducing urban sources of runoff pollution and lake responses that have historically resulted in hypereutrophic conditions. Lake Wingra had a long history of watershed and wetland modifications including dredging, draining, construction, and polluted runoff affecting water quality. Other factors that compounded the hydrologic modifications and pollution sources included carp and Eurasian watermilfoil (EWM) invasions.

In spite of the urban setting, Lake Wingra is very popular for recreation and most of the shoreline is protected by public ownership. Lake Wingra has also been a laboratory for in-lake ecosystem studies as have the other Yahara lakes. It has been the focus of considerable research involving Wisconsin DNR, University of Wisconsin Madison, and Edgewood College that borders the lake. The invasion and impacts of Eurasian watermilfoil in Lake Wingra are well documented. The lake is often cited as an example of how Eurasian watermilfoil often declines following initial invasions.

Even though Lake Wingra is highly urbanized, the lake sediments are relatively clean compared to Lake Monona and Waubesa. The lake does not have a history of industrial discharges or inorganic herbicides treatments. Of particular concern for Lake Wingra is the demonstrated rise in sodium and chloride levels that are linked to road salt use. In Lake Wingra, levels of sodium and chloride have increased by nearly 100% since 1975.[415] While the City of Madison and Dane County have made efforts to reduce road salt applications near the Yahara lakes, overall applications have more than doubled since the 1980s. Chloride levels in Lake Wingra have increased steadily from 5 mg/L in 1945 to 112 mg/L in 2009.

Lake Wingra is highly eutrophic and that condition reflects a number of factors including historic watershed modifications, shallow depth, and exotic species. Lake Wingra is not deep enough to sustain thermal stratification and therefore displays a high propensity for internal phosphorus loading. Common carp have been a long term problem in Lake Wingra, reducing rooted plants in the lake and sustaining turbid water due to heavy blue-green algae blooms. Lathrop and others recently conducted an experiment by constructing a common carp exclusion barrier in the lake. Results demonstrated that littoral areas without common carp produce greater densities of rooted aquatic plants and water clarity is much better. This pilot study has evolved in a more concerted effort to reduce common carp in the lake and change the alternative shallow lake from turbid to macrophyte dominated and clear. The timing of this management effort appears to be right since the initial Eurasian water milfoil invasion had long passed and a more diverse native aquatic plant community is now found in the lake. Reducing the negative influences of common carp should expand native plant beds and their ecological functions.

One sign the lake restoration is working is that water clarity as measured by Secchi disc readings increased soon after the carp removals. In both 2008 and 2009, Secchi readings have been greater than the average seasonal reading for the previous 12 years of record (**Figure 48**). In fact, many seasonal readings in 2008 and especially 2009 have been greater than the maximum seasonal reading observed during the previous 12 years, a condition that is particularly pronounced in the summer months when blue-green algal blooms have been dense.

415 Wenta, 2010.

Lake Wingra Carp Exclusion Project

Photo: Mike Kakuska

Dane County operates large-scale mechanical harvesters infrequently on Lake Wingra that coincide with special events. An aquatic plant management plan was prepared in 2007 as required under NR 109. Wisconsin DNR Bureau of Integrated Science Services had conducted a point intercept survey of aquatic plants in the lake in 2005. Results of that survey demonstrated that Lake Wingra does support a relatively diverse native plant community along with a number of environmentally sensitive species not found in the other Yahara lakes. The 2005 point intercept survey indicated that Eurasian watermilfoil (*Myriophyllum spicatum*) and coontail (*Ceratophyllum demersum*) were the dominant plants in Lake Wingra. Consistent with surveys performed in the early 1990's, Eurasian watermilfoil remained at a much lower density than when the exotic plant initially invaded the lake in the 1960s. Species richness was higher in Lake Wingra than in the other Yahara lakes and included species that were not found elsewhere in the Yahara lakes chain. These species included spatterdock (*Nuphar variegata*), bushy pondweed (*Najas flexilis*), variable leaf pondweed (*Potamogeton gramineus*), Illinois pondweed (*Potamogeton illinoensis*), white stem pondweed (*Potamogeton praelongis*), small pondweed (*Potamogeton pusillus*), and common bladderwort (*Utricularia vulgaris*). The presence of these high value species and greater species richness suggest that the littoral zone habitat in Lake Wingra is in better condition than most lakes in the county. Recommendations from the aquatic plant management plan include:

1. Mechanical harvesting should focus on Eurasian watermilfoil control, in areas where the exotic plant impedes lake access or if open water is needed for special events such as competition rowing or swimming.
2. Mechanical harvesting should avoid nearshore areas to protect the diverse plant community.
3. Chemical treatments are not recommended and may undermine the ecologically diverse plant community in the lake. (Lake Wingra had not been chemically treated in the recent past and Eurasian watermilfoil declined significantly due to ecological factors and not intensive management).
4. Ecologically acceptable methods to remove carp from Lake Wingra are recommended since both water clarity and native plant distribution will likely improve.
5. Consider sampling nearshore nongame fish populations to assess the ecological health of Lake Wingra.

Lake Wingra is another Madison area lake that is frequently monitored under the LTER program. Recent surface total phosphorus and secchi data appear in **Figures 49a and 49b** along with the transformed TSI values.[416] The data demonstrates the high degree of eutrophication but also establishes a baseline to assess long term common carp management in the lake. Median July-September Lake Wingra TSI values for total phosphorus and secchi are 59 and 64, respectively, indicating generally "Fair" condition.[417] TSI values for total phosphorus and secchi disk after 2008 are 55 and 59, respectively, indicating an improved condition to "Good" attributed to the carp removal project. This is particularly evident in **Figure 49b**. A TSI(TP) < TSI(Secchi) indicates the algae biomass is limited by phosphorus.

416 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.

417 Whereas Carlson 1977 provides an equation to convert phosphorus concentrations to TSI, the WDNR is not currently using that equation for General Condition Assessments. It is used for 303(d) listing.

Figure 48. Secchi disc data for Lake Wingra showing much greater readings throughout the open water period of 2007 and 2008, as compared to the previous 12 years (1996-2007) following carp removal in March 2008

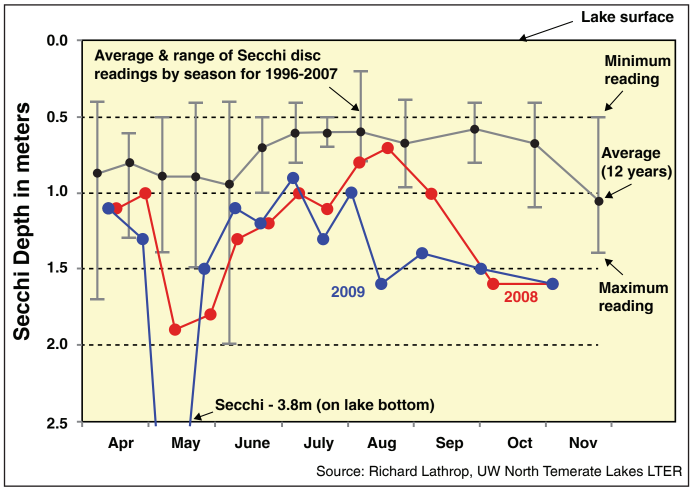
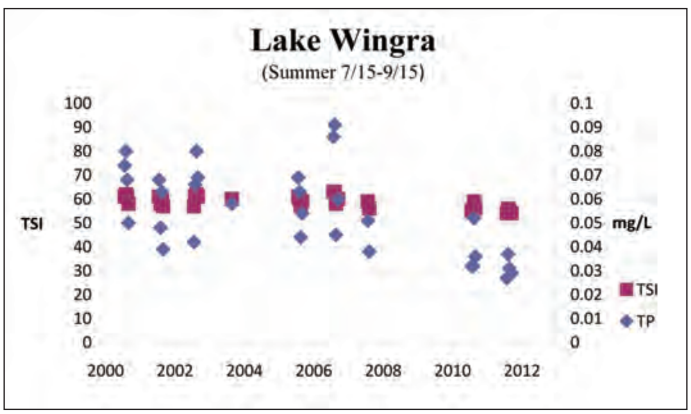
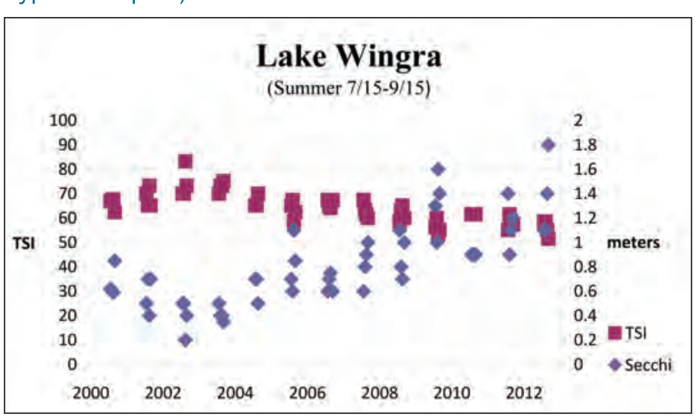


Figure 49a. Recent Surface Total Phosphorus Data from Lake Wingra and Trophic State Index values (>50 – 70 = eutrophic, > 70 = hypereutrophic)



Source: WDNR

Figure 49b. Recent Secchi Data from Lake Wingra and Trophic State Index Values (>50 – 70 = eutrophic, > 70 = hypereutrophic)



Source: UW LTER

Lake Waubesa

Lake Waubesa lies downstream of Lake Monona and upstream of Lake Kegonsa. The lake has a maximum depth of 34 feet and shoreline length of 9.4 miles. Physical features of the lake and watershed appear in **Table 12**. It is third in a series of lakes that were formed by moraines damming pre-glacial Yahara River. Excluding the land area that drains into the upper Yahara Lakes, the direct watershed area surrounding Lake Waubesa is 47.1 square miles of mixed agriculture and urban landscapes. The lake also lies within the Yahara Monona Watershed that was the focus of controlling polluted runoff from 1988 to 1998.

Lake Waubesa typically displays more advanced eutrophic conditions such as reduced water clarity and blue-green algae blooms than both Lake Monona and Lake Mendota. Since the upper lakes are the primary environmental driver for Lake Waubesa, contributing 78 percent of the annual phosphorus load (estimated at 22,800 lbs/yr.), [418] lack of sustained thermal stratification and internal nutrient loading is the primary factor sustaining a greater level of eutrophication in the lake. Median July-September secchi disc readings are typically much lower and averaged only about 1 meter from 1980-present.[419] **Figures 50a and 50b** display total phospqhorus and secchi data along with associated Trophic State Indices (TSI).[420] Lake Waubesa remains moderately eutrophic with median July-September TSI values for total phosphorus and secchi at 59 and 63, respectively, indicating generally "Fair" condition.[421] A TSI(TP) < TSI(Secchi) indicates the algae biomass is limited by phosphorus. TSI values appear to be trending upward. Additional data needs to be collected to determine what is causing this trend.

In spite of the eutrophic conditions in Lake Waubesa, water quality had improved in recent decades largely due to the diversion of municipal wastewater from the lake in 1958. The legacy of point source pollution can be found in the deeper lake sediment where mercury levels are high. In 1998 Lake Waubesa was included on WDNR's 303(d) Impaired Waters list due to a fish consumption

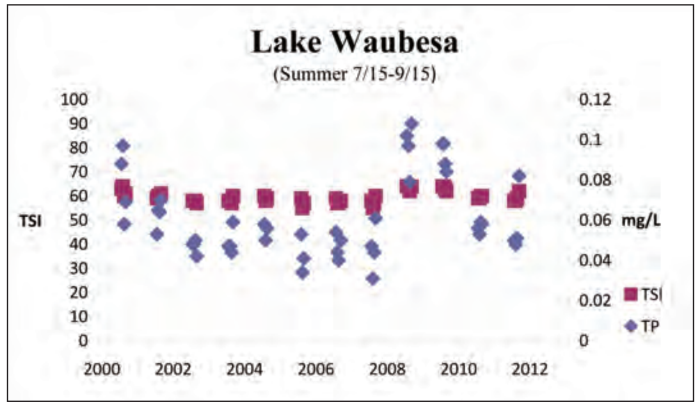
418 Lathrop, 2011.
419 Lathrop, 2007.
420 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.
421 Whereas Carlson 1977 provides an equation to convert phosphorus concentrations to TSI, the WDNR is not currently using that equation for General Condition Assessments. It is used for 303(d) listing.

advisory for mercury. It was de-listed in 2006 after monitoring data showed that general consumption advice was adequate.

Eurasian watermilfoil beds are periodically a problem for recreation and boating on Lake Waubesa and Dane County operates large-scale mechanic harvesters as needed. As required under NR 109, the county updated the aquatic plant management plan for Lake Waubesa in 2008 and conducting a point intercept survey was part of that process. A total of 520 sites were sampled across the lake but only 225 sites supported aquatic vegetation of one type or another. Filamentous algae and/or duckweed were the only plant forms found at some of the 225 sites. The relative scarcity of plants in Lake Waubesa reflected a major decline in Eurasian watermilfoil (EWM) in 2008. Milfoils including EWM, northern watermilfoil or hybrid were only collected at 44 sites while coontail was the most abundant rooted plant and it was collected at 144 sites. Recommendations from that plan include:

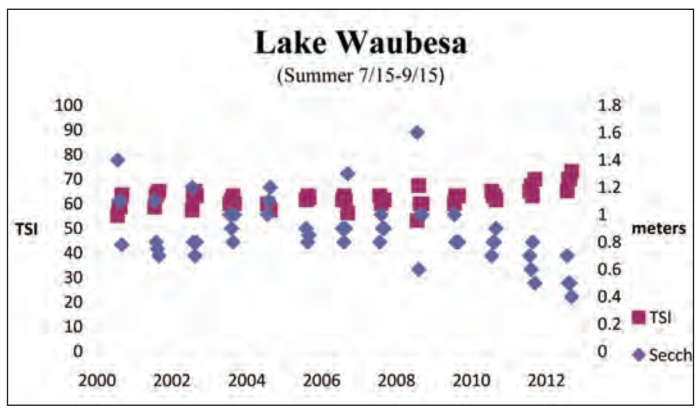
1. Conduct large-scale mechanical harvesting in areas where EWM grows in dense monotypic stands.
2. Goals for managing EWM are to improve boating access, fish habitat improvement and expanding native rooted plant species.
3. Prohibit chemical herbicide treatments within Sensitive Areas except in areas where monotypic stands of EWM occur. Goals should include improving fish habitat and expanding native rooted plants. Sensitive Areas are relatively undeveloped areas supporting coarse woody debris, floating-leaf plants including spatterdock (*Nuphar variegata*), white water lily (*Nymphaea odorata*); and submersed native plant species including clasping-leaf pondweed (*Potamogeton richardsonii*), sago pondweed (*Struckenia pectinatus*), leafy pondweed (*Potamogeton foliosus*), water stargrass (*Heteranthera dubia*), muskgrass (*Chara*), and wild celery (*Vallisneria Americana*).
4. Chemical herbicide treatments should focus on the selective control of Eurasian watermilfoil – EWM (*Myriophyllum spicatum*).
5. Adopt the "Natural Shorelines" identified in the 1993 aquatic plant management plan as Sensitive Areas.[422]

Figure 50a. Recent Surface Total Phosphorus Data from Lake Waubesa and Trophic State Index Values (50 – 70 = eutrophic, > 70 = hypereutrophic)



Source: WDNR

Figure 50b. Recent Secchi Measurements in Lake Waubesa and Associated Trophic State Index Values (50 – 70 = eutrophic)



Source: UW Ctr. for Limnology

422 Winkelman, 1993.

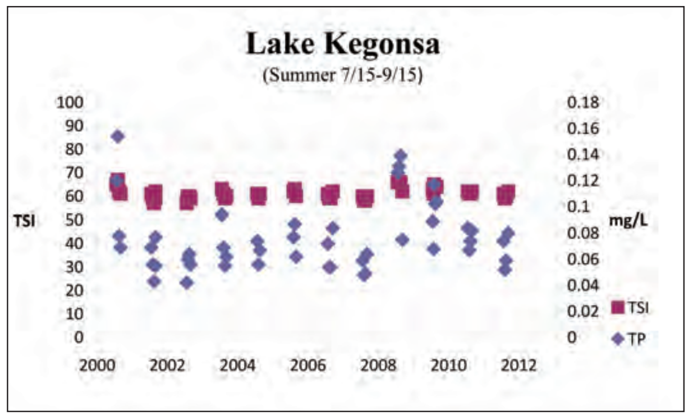
Lake Kegonsa

Lake Kegonsa is last in the line of the major Yahara lakes and displays similar characteristics as Lake Waubesa. The bowl shaped lake has a maximum depth of only 31 feet and morphology that plays an important role how the lake responds to nutrient inputs. Physical features of the lake and watershed appear in **Table 12**. The watershed encompasses gently rolling to hilly glaciated terrain with productive farmland and expanding urbanization. The position of the lake in the watershed has played a significant role in the long term water quality and ecological history of the lake. For decades, Lake Kegonsa had the highest phosphorus and chlorophyll-a concentrations and lowest water clarity in the Yahara Chain. These conditions reflected in part the combination of long term polluted runoff from the large watershed and historic wastewater discharges. While conditions have generally improved in the lake since the diversion of municipal wastewater discharges from the watershed, lack of sustained thermal stratification allows mixing of nutrient rich bottom water to fuel blue-green algal blooms during the summer.

Lake Kegonsa lies within the Yahara Kegonsa Watershed where agriculture is the dominant land use (53 percent). Nutrient loading from agricultural sources and rapid urbanization are a concern. County efforts are underway to identify, assess and prioritize Best Management Practices to reduce nutrient and sediment loads. Internal loading of long term cultural phosphorus sources has contributed to periodic toxic blue-green blooms and fish kills. Internal loading is also a significant factor that influences the water quality of Lake Kegonsa. The moderately shallow lake intermittently stratifies followed by warm-season mixing and internal nutrient recycling. Consistent with Lake Monona and Lake Waubesa, the upper lakes strongly influence environmental conditions in Lake Kegonsa since as much as 71 percent (estimated 27,500 lbs/yr.) of the annual phosphorus load originates upstream.[423]

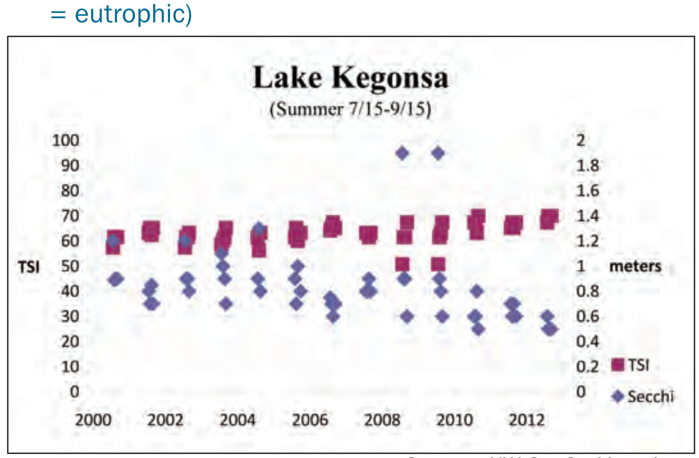
Lake Kegonsa is also algae dominated. Secchi disc readings from 1980-present were typically a meter or less.[424] **Figures 51a and 51b** display total phosphorus and secchi data along with associated TSIs.[425] Lake Kegonsa remains moderately eutrophic with median July-September values equal to 61 and 63, respectively, indicating generally "Fair" condition.[426] A TSI(TP) < TSI(Secchi) indicates the algae biomass is limited by phosphorus. Similar to Lake Waubesa, TSI values appear to be trending upward in Lake Kegonsa, possibly the result of the outflow from Lake Waubesa. A median TSI secchi value of 65 over the last five years indicates a recent decline in condition.

Figure 51a. Recent Surface Concentrations of Total Phosphorus in Lake Kegonsa and Associated Trophic State Index Values (50 – 70 = eutrophic)



Source: WDNR

Figure 51b. Recent Secchi Measurements in Lake Kegonsa and Associated Trophic State Index Values (50 – 70 = eutrophic)



Source: UW Ctr. for Limnology

423 Lathrop, 2011.
424 Lathrop, 2012.
425 Long term chlorophyll data is not currently available due to issues resulting from mid-term changes in methodology and instrumentation, which are being resolved by the UW.

426 Whereas Carlson 1977 provides an equation to convert phosphorus concentrations to TSI, the WDNR is not currently using that equation for General Condition Assessments. It is used for 303(d) listing.

The relatively low light penetration in the lake has suppressed macrophyte growths that were never abundant historically. Nonetheless, Dane County occasionally operates large-scale mechanical harvesting equipment on the lake and an aquatic plant management plan was prepared in 2007 for both Lake Kegonsa and adjoining Lower Mud Lake. Point intercept aquatic plant surveys were performed in 2006. A total of 681 sites were sampled in the two lakes. Results from the Lake Kegonsa survey indicated that aquatic plant beds were relatively sparse, however species diversity improved significantly since the early 1990s. While Eurasian watermilfoil remained the dominant plant in the lake, the weedy exotic plant had declined significantly since 1991. The Eurasian watermilfoil decline and native species increase were positive indicators of lake ecological health. Species richness increased from 3 native species in the early 1990s to 8 native species in 2006. Species sampled in 2006 but were not found in 1990-91 included clasping-leaf pondweed, leafy pondweed, common waterweed, wild celery, and horned pondweed. The latter species had not been found in the Yahara Chain of Lakes for decades. Healthy beds of wild celery and water stargrass were found near the mouth of the Yahara River.

Upstream of Lake Kegonsa, aquatic plant densities and diversity were greater in Lower Mud Lake. Coontail was collected in the greatest frequency in Lower Mud Lake followed by filamentous algae and sago pondweed. The shallow lake also supported ecologically valuable species including buttercup, water stargrass, wild celery, white water lily, sago pondweed clasping-leaf pondweed and muskgrass. The latter algal species had not been found in the Yahara Chain of Lakes for many years. Connecting Lower Mud Lake and Lake Kegonsa, the Yahara River supports abundant beds of wild celery and waterstar grass. The collective results of the surveys suggest that the aquatic plant communities have improved in the lower lakes and may mirror trends of declining Eurasian watermilfoil and improved water quality. Recommendations in the aquatic plant management plan include:

1. Conduct large-scale mechanical harvesting if Eurasian watermilfoil significantly expands in the lake. Low density of the exotic plant and other species did not warrant significant management in 2006.
2. Chemical treatments should be limited due to low EWM densities found within nearshore areas. The sparse plant beds in nearshore areas likely reflected the scoured sandy substrates and low water clarity.
3. Consider experimental plantings of white or yellow water lilies along protected shorelines given the relative dearth of high value plant beds in the lake.
4. Sensitive Areas should include undeveloped portions of the lake including Fish Camp, Lake Kegonsa State Park, and the Door Creek wetlands.
5. Limit the harvesting of wild celery in the river between Lake Kegonsa and Lower Mud Lake except during emergency high water and flood conditions. Cutting is confined to the deepest portion of the channel in an effort improve flow while historical structures are also avoided.

Clean Lake Initiatives

There have been a number of initiatives aimed at cleaning up and addressing long-term threats to the Yahara Chain of Lakes. Some of the more prominent efforts include:

Yahara CLEAN.[427] Developed through the Yahara Lakes Legacy Partnership, the Yahara CLEAN initiative began as a memorandum of understanding between the City of Madison, Dane County, the Departments of Natural Resources (DNR), and Agriculture, Trade and Consumer Protection (DATCP) to improve water quality of the Yahara Chain of Lakes. A consultant was hired and completed a SWAT model for the 411 sq. mile watershed. A SNAP Plus[428] analysis for a sub-watershed that was found to be one of the heaviest loading tributaries was also completed. SNAP-Plus is a nutrient management planning software program designed for the preparation of nutrient management plans in accordance with Wisconsin's Nutrient Management Standard Code 590. A lake response model has been developed to determine the load reductions needed to maintain a mesotrophic state (greater than 2-meter Secchi disk reading or surface water total phosphorus less than 0.024 mg/L).[429] Overall,

427 http://www.yaharawatershed.org/
428 http://www.snapplus.net/
429 Lathrop, 2011.

the CLEAN partners identified 70 specific actions that will reduce phosphorus, sediment, and beach bacteria.[430] In addition, the Yahara CLEAN Strategic Action Plan for Phosphorus Reduction enumerates 14 actions with clear achievable phosphorus reduction goals to clean the lakes (**Table 15**).[431] The 20-year present value net cost to implement the Yahara CLEAN actions is estimated to be $78.6 million dollars, after a deduction of $49.5 million in private business investment in community digesters. The remaining funds are to be raised through a combination of public and private sources.

Yahara WINS.[432] The Yahara Watershed Improvement Network was announced in June 2012 to comply with new state regulations requiring significant reductions in phosphorus from urban and rural point and nonpoint pollution sources. The partnership includes MMSD, Dane County, area cities, villages, towns, and environmental, farm, and business groups to meet regulatory requirements to reduce phosphorus loads to area waters. The four-year pilot project, targeted to the Sixmile Creek and Dorn Creek watersheds, is the first of its kind in the nation to use an innovative approach called adaptive management. The goal is to work collaboratively to implement the most cost effective phosphorus control practices throughout the area.

Clean Lakes Alliance.[433] Another unique public/private partnership that has been very successful at involving area businesses in lake management and cleanup issues. The group has a goal of working with farmers and municipalities to reduce phosphorus pollution by 50 percent.

Take a Stake in the Lakes.[434] Led by Dane County's office of Lakes and Watersheds along with the Clean Lakes Alliance, this annual celebration has become a popular way for people to not only enjoy special activities on the lakes but to also pitch in with shore cleanup projects and restoration.

Friends of Lake Wingra. [435] One of the most effective grass-roots lake cleanup efforts has been mounted by this group over the last 15 years. The lake's clarity has improved dramatically after a carp removal project was conducted there in 2008.[436]

However, sediment and nutrient loading reductions to surface water and the Yahara lakes could be negated if there is an increase in the frequency and intensity of spring and summer storms occurs as projected by some climatologic models. Data from the Wisconsin Initiative on Climate Change Impacts (WICCI) show the average annual precipitation increasing between 4.5 to 7 inches in Dane County between 1950 and 2006.[437] The frequency of 3-inch rainfall events has increased significantly over the last 10 years.[438] Current runoff models used for stormwater management, and management assumptions and decisions based on those models, may have to be altered if this trend continues. Additional and more robust rural and urban storm water management practices may need to be implemented if water quality of Lake Mendota and the downstream Yahara lakes is to improve. It should be noted that June 2008 and March 2009 were the wettest months on record for Madison, and these two months also were record months for phosphorus and sediment loading based on USGS data. The effects of climate change is, and will continue to be, a complicating factor that needs more in-depth study in this area.

430 *A CLEAN Future for the Yahara Lakes: Solutions for Tomorrow, Starting Today* .http://yaharawatershed.org/documents/doc/CLEAN_Report_090910.pdf
431 Clean Lakes Alliance. 2012.
432 http://www.madsewer.org/YaharaWINsHome.htm
433 http://www.cleanlakesalliance.com/
434 http://www.takeastakeinthelakes.com/
435 http://lakewingra.org/
436 http://lter.limnology.wisc.edu/research/research_highlight/water-clarity-responses-carp-reduction-shallow-eutrophic-lake-wingra
437 Map: Change in Average Precipitation in Wisconsin's Changing Climate: Impacts and Adaptations, 2011.
438 Lathrop, 2010.

Table 15. Yahara CLEAN Strategic Action Plan

All Lakes	Total P Diverted Per Year (lbs)	Goal	Lead Agency	Present Value Cost over 20-Year Period (Millions)	Present Value Cost per lb Diverted (20-Year)
Urban Actions					
Improve Leaf Management	4,100	20% increase in collections	MAMSWaP[1] and each municipality	$4.1	$50
Improve Control of Construction Erosion	3,600	Reduce sediment runoff in new development by 80%	Dane County	$1.7	$25
Maintain Permitted Stormwater Facilities	2,500	Achieve compliance from 400 (out of 1500 total) noncompliant facilities	Dane County	$1.7	$34
Stabilize Urban Waterway Banks	2,100	13,700 linear feet	Each Municipality	$4.7	$113
Reduce TSS in Municipal Stormwater	1,100	Achieve 40% target for all facilities	Department of Natural Resources	$17.6	$860
Urban Subtotal	13,400			$29.8	$111
Rural Actions					
Improve Cropping, Tillage, and In-Field Practices	14,800	54,900 acres per year	Dane County	$14.5	$49
Build Community Digesters	7,700	5 systems	Dane County	$60.0	$390
Adjustment for Business Investment in Digesters				-$49.5	-$322
Subtotal for Community Digesters				$10.5	$68
Remove Additional P at Digesters	5,100	5 systems	Dane County	$10.0	$98
Manage Manure (m) and Nutrients (n)	2,100	11,572 (m) plus 15,700 (n) acres per year	Dane County	$3.2	$81
Stabilize Rural Waterway Banks	1,000	17,000 linear feet	Dane County	$2.1	$104
Dredge Drainage Ditches	600	2.5 miles per year	Dane County	$2.4	$218
Relocate or Cover Livestock Facilities	600	14 sites	Dane County	$2.1	$174
Harvest Wetland Plants	600	1,700 acres (once/3years)	Dane County	$2.0	$170
Promote Restoration of Wetlands	300	100 acres/year	Dane County and Natural Heritage Land Trust	$2.0	$328
Rural Subtotal	32,800			$48.8	$74
Total All Lake Direct Drainage Load Reductions	46,200			$78.6	$85
Total All Lake Direct Drainage Load Inputs	95,000				
Percent All Lake Load Reduction Achieved	49%				

[1] Madison Area Municipal Storm Water Partnership

VII. Proposed Expanded Cooperative Water Resources Monitoring Program

From 1976 to 1979, a significant surface water monitoring effort was conducted as part of development of the *Dane County Water Quality Plan*. The Plan provides a comprehensive overview of water quality conditions and problems in the region and serves as the policy framework and guidance for addressing those problems. However, the surface water monitoring effort was substantially reduced in 1980 due to cutbacks in funding. Since that time, only very limited surface water quality data has been gathered to guide and provide the basis for water quality management decisions in the region. Yet, substantial changes in impacts and management practices have occurred over the last 30 years. For example, many wastewater treatment plants in the region have been upgraded and improved, accelerated nonpoint source pollution control programs have been undertaken, and agricultural soil conservation and waste management programs have changed considerably during this period. In addition, the region continues to experience significant growth and development pressures.

In an attempt to continue and augment this information the CARPC helps coordinate a Cooperative Water Resources Monitoring Program (**Table 16**). Basic lake monitoring on the Yahara Lakes is conducted by the WDNR Bureau of Research. The Cities of Madison, Middleton, Dane County, and WDNR (in cooperation with USGS) have supported continuous flow, phosphorus, and sediment monitoring on the major tributaries to the Yahara Lakes. Nitrogen sampling was recently added to help characterize problems associated with manure spreading in the Mendota watershed. In addition, the City of Madison monitors various water quality parameters at the outflows from each of the Yahara lakes. Dane County manages lake levels. The Madison metropolitan Sewerage District (MMSD) monitors Badfish Creek, Badger Mill Creek, and the Sugar River. The WDNR has also conducted a few short-term monitoring and appraisal investigations directed at specific locations, pollution sources, and projects (e.g., Priority Watershed Projects).

The purpose of an expanded Regional Cooperative Water Resources Monitoring Program is to help fill important data gaps to provide a more solid basis for future management decisions and efforts. This is especially timely since CARPC is collaborating with local municipalities in developing Future Urban Development Area (FUDA) Plans.

An expanded Cooperative Water Resources Monitoring Program would provide the necessary information to establish baseline information for evaluating historical changes and trends, directing more detailed site investigations, as well as indicating future impacts or success of mitigating strategies associated with agricultural and urban Best Management Practices and other resource conservation efforts.

There are three basic kinds of surface water monitoring activities of critical importance to continuing management activities and decision-making in the region. These include lake monitoring, storm event monitoring, and stream baseflow monitoring as described in the following sections. A fourth element, conducting general assessments using biological indicators to drive and direct more specific site assessments, is a more recent approach being promoted by WDNR. The WisCALM guidance[439] promotes a more systematic and cost-effective approach to monitoring our surface waters than in the past. This is in large part due to our greater understanding and experience gained over the last four decades implementing the provisions of the Federal Clean Water Act, as well as increased efforts directed to more diffuse nonpoint pollution sources. Whereas lake, storm event, and stream baseflow monitoring is generally adequate in the region, biological information representing an aquatic community's response to human activities in the watershed is currently lacking and needs to be expanded, as described below.

439 WDNR, 2009c.

Table 16. 2013 Capital Area Cooperative Water Resources Monitoring Program 5/7/12

Data Collection Site	USGS	Dane County	DNR	West-port	Madison	Middleton	Total
1. **Spring Harbor Storm Sewer**							
- Streamflow (continuous)	2,665				3,514		6,179
- Suspended sediment sampling and loads based on 150 samples (USGS KY Lab)	5,053				6,439		11,492
Subtotal	**$7,718**				**$9,953**		**$17,671**
2. **Pheasant Branch at USH 12, Middleton**							
- Streamflow (continuous)	4,585					5,796	10,381
- Suspended sediment sampling and loads based on 55 samples (USGS KY Lab)	5,368					6,663	12,031
- Total P, nitrate plus nitrite, ammonium, and total Kjeldahl nitrogen sampling and loads based on 55 samples; and dissolved ortho-P sampling based on 20 samples	2,175	2,729					4,904
- Phosphorus and nitrogen lab analyses (State Lab)			—[1]				—
Subtotal	**$12,128**	**$2,729**				**$12,459**	**$27,316**
3. **Yahara River at Windsor**							
- Streamflow (continuous)	4,585	5,796					10,381
- Suspended sediment, total P, nitrate plus nitrite, ammonium, and total Kjeldahl nitrogen sampling and loads based on 55 samples; and dissolved ortho-P sampling based on 20 samples	5,629	7,118					12,747
- Phosphorus and nitrogen lab analyses (State Lab)			—[1]				—
Subtotal	**$10,214**	**$12,914**					**$23,128**
4. **Yahara River at SH 113, Madison**							
- Streamflow (AVM, continuous)	2,620	1,750	—[2]	1,860			6,230
- Total P and suspended sediment (USGS KY Lab) sampling and loads based on 55 samples and dissolved ortho-P based on 20 samples	2,620	1,750	—[2]	1,860			6,230
- Phosphorus lab analyses (State Lab)			—[1]				—
Subtotal	**$5,240**	**$3,500**		**$3,720**			**$12,460**
5. **Baseflow Sampling (4 Sites)**							
- Dissolved oxygen, E. Coli, pH, specific conductance, and temperature. Analysis of suspended sediment, phosphorus, and nitrogen at USGS NWQL	4,266	6,399					10,665
Subtotal	**$4,266**	**$6,399**					**$10,665**
6. **Lake Level Gages**							
Lakes Mendota, Monona, Kegonsa, and Waubesa	8,000	11,000					19,000
Subtotal	**$8,000**	**$11,000**					**$19,000**
7. **Streamflow Gages**							
- Yahara River at Madison, McFarland, and Stoughton; Black Earth Creek at Black Earth	21,300	33,400					54,700
Subtotal	**$21,300**	**$33,400**					**$54,700**
Grand Total	**$68,866**	**$69,942**		**$3,720**	**$9,953**	**$12,459**	**$164,940**

[1] Phosphorus and nitrogen lab analyses service performed by the State Lab of Hygiene through separate agreement between SLOH and DNR for Pheasant Branch and Windsor gages ($12,710) and Yahara River at SH 113 ($1,631).

[2] Does not include funding for streamflow, sampling and loads ($19,760) provided through separate agreement between USGS and DNR for DNR share of Yahara R. at SH113.

A. Lake Monitoring

Lake monitoring is needed to determine lake water quality conditions and suitability for uses. In addition, information is needed to ascertain any long-term trends in lake conditions, which are often slow and subtle as well as masked by short-term variations. This requires a commitment to long-term, regular, and consistent monitoring. Also, lake monitoring is important in understanding the physical and biological behavior and response of complex lake ecosystems, which are highly variable both on a seasonal and short-term basis. It is important, for example, to have this understanding in order to judge the effectiveness and impacts of programs controlling external pollutant loading, since in-lake processes could delay, reduce, or even negate the effects of those efforts. This aspect of needed information requires relatively frequent monitoring.

WDNR has continued a basic program of lake monitoring on the Yahara Lakes since the development of the Water Quality Plan in 1979. This provides the information needed to assess long-term trends in lake conditions and helps to increase understanding of the basic physical and biological characteristics and processes of the lakes. WDNR and Dane County have also conducted some limited investigations of pollutants in lake sediments and mercury concentration in fish in Lakes Monona and Waubesa. In addition, the City of Madison regularly measures water quality parameters in lake outflows, and both the City and the County monitor swimming beaches in the summer.

The water quality and condition of the Yahara Lakes has been a long-standing priority and collaborative effort shared by a very broad and diverse public and private constituency in the county and southern Wisconsin. Overall, the current lake monitoring effort is generally sufficient for providing the basic information needed for management decisions and assessing long-term trends. The priority here is on continuing the present basic lake monitoring program on the Yahara Lakes. Additional monitoring of other lakes in the county should be conducted if the current information is found to be significantly out of date or missing. WDNR lake planning and lake protection grants are available to help conduct these more detailed investigations and remediation work. The continued protection and improvement of the Yahara Lake system is a particularly large, ongoing effort involving millions of dollars in annual funding and significant effort, on the part of federal, state, and local resource management agencies, private interest groups, and citizens. For the Yahara Chain of Lakes, these efforts are being coordinated and implemented primarily through the Rock River TMDL and Yahara CLEAN projects (See Future Horizons).

B. Storm Event Monitoring

The basic usefulness or need for storm event monitoring is twofold: (a) to characterize total loading of pollutants to receiving water bodies during storm events; and (b) to characterize water quality conditions in the stream during the storm event itself. The first purpose – determination of pollutant loading – is of primary concern when the receiving water bodies are lakes or impounded streams. This is accomplished by measuring flow and concentration of pollutants of concern (often nutrients such as phosphorous and sediment) throughout the runoff event. There is considerable variability in both flow and individual pollutant concentrations during each runoff event. There are also important seasonal variations and, of course, annual climatic variations from the long-term averages. In order to arrive at statistically reliable conclusions on average or annual non-point source pollutant loading, it is necessary to obtain a large number of flow and pollutant concentration measurements over a number of representative storms during different seasons. This is particularly important in developing and calibrating stormwater runoff and response models. This monitoring is usually complex and costly and, therefore, not conducted on a widespread basis.

To be practical, storm event or nonpoint source monitoring needs to be limited to parameters of the greatest concern and to a few selected locations of particular importance. Historically, stormflow monitoring has been conducted on the three major tributaries to Lake Mendota, including:

Pheasant Branch Creek in Middleton – an urbanizing watershed undergoing rapid change with serious erosion and pollutant loading to Lake Mendota. It has a significant historical and continuing amount of nonpoint source (sediment and phosphorus) monitoring data for comparison.

Yahara River at Windsor and USH 113 – a large, primarily agricultural watershed and principal tributary to the Yahara Lakes.

Spring Harbor Storm Sewer in Madison – a large urban watershed with significant historical and continuing nonpoint source monitoring.

Lake Mendota is of particular importance because it is the major phosphorus contributor to the downstream Yahara Lakes. Efforts to control phosphorus in the Lake Mendota watershed will have cascading effects through the downstream lakes.

Using continuous stormflow information generated by these stations, various stormwater/runoff models (e.g., SLAMM, SWAT, SNAP-Plus, etc.) have been developed and calibrated by researchers and water quality managers in the region associated with the Lake Mendota Priority Watershed Project, the Rock River TMDL, Yahara CLEAN, among other research investigations. These models allow pollution loading analyses to be conducted and provide important tools for evaluating, prioritizing, and guiding alternative pollutant reduction strategies in critical areas of the watershed. Nonpoint source monitoring data is also available for stations in the *Black Earth Creek* and *Sugar River* watersheds. Storm event modeling and watershed planning should be conducted to guide pollutant reduction strategies in these watersheds as well.

Overall, the current storm event monitoring effort is generally sufficient for providing the basic information needed for management decisions and assessing long-term trends. The priority here is on continuing the present storm even monitoring for the Yahara Chain of Lakes, with possible expansion to include other priority watersheds as resources allow (e.g., Sugar River, Black Earth Creek). In terms of the latter, this will entail a more pro-active approach– to address problems *before* a water body becomes impaired as well as possibly *improving* its current condition.

An immediate priority is to establish a long-term runoff monitoring station on Sixmile Creek to improve phosphorus loading information for Lake Mendota. Collecting phosphorus loads on that stream would be useful in evaluating upstream land management practices in a subwateshed where farm animal densities have increased over time and also where a manure digester with phosphorus capture has begun operation recently. This is important because reductions in phosphorus loads to Lake Mendota will have a significant cascading effect downstream through the entire Yahara Lake Chain system.

C. Stream Baseflow Monitoring

Stream baseflow in the region consists primarily of groundwater discharge to streams supplemented by continuous point source wastewater discharges from treatment plants or industries, where they exist. Baseflow is less variable than storm event runoff, so less frequent monitoring is necessary. **Map 6** indicates the network of basflow water quality monitoring stations on representative streams in which a full suite of chemical parameters have been sampled over the last 30 years (**Attachments A and B**). Overall, the current baseflow monitoring effort is generally sufficient for providing the basic information needed for management decisions and assessing long-term trends.

Whereas federal and state legislation has successfully reduced point source pollution over the past 30 years (as evidenced by the graphs), nonpoint source pollution continues to degrade water quality in the region, as well as throughout Wisconsin and the U.S. While the current program of baseflow monitoring should be continued, more attention or priority should be directed to characterizing and controlling urban and agricultural *nonpoint* source pollution running off the land. Also because of the significant expense associated with nonpoint source monitoring, more effort should also be focused on biological indicators to direct more specific and cost-effective site assessments using WDNR's tiered approach – See Section IV Surface Water Monitoring and below.

D. General Condition Assessments Using Biological Indicators

There is a serious need to substantially expand the information-gathering effort on aquatic life and stream habitat conditions, especially in urbanizing areas of the region. These are the areas where land use changes are in greatest flux. Biotic index determinations are particularly helpful as indicators for assessing both chronic and long-term effects of water quality and habitat changes on aquatic organisms and ecological communities. These measures reflect the cumulative effects of many different variables that cannot all be measured directly or very easily revealed.

Field surveys and assessments of biological and habitat conditions are especially needed to establish baseline conditions, track impacts due to land use changes, and document improvements that result from mitigation and restoration strategies. Whereas WDNR collects this data statewide, its scope is limited due to staffing and financial constraints. A more frequent and extensive data collection effort is needed to direct efforts in this region. This is particularly important as it relates to directing and tailoring water resources management activities for particular water bodies.

Important stream sites for providing the basic program framework for accomplishing this are indicated on **Map 7**. Overall, there are 30 proposed sites, not including those currently being monitored by MMSD. These sites have been co-located with sites having historic chemical monitoring, where possible. Some municipalities may want to locate an additional site upstream to help distinguish agricultural and urban effects. Sites on predominantly rural streams could be added, depending on the suitability of existing data and the status of resource conservation/restoration plans. Water quality conditions in predominantly rural streams are already pretty well established due to historical information and land use practices that are less subject to change, as compared to urbanizing areas.

Approximate annual program costs are included in **Table 17**. Costs could be shared among communities draining to a particular water body in support of associated monitoring stations. Additional sites could be selected in rural areas in cooperation/partnership with the Dane County LWRD. WDNR has tentatively agreed to conduct fish IBI sampling on 10 sites per year at an estimated cost of $200 per site. It is more practical to contract with WDNR for this service since they can provide the necessary equipment, staff, and experience as well as avoid difficulties associated with permitting and potential mortality associated with electroshocking fish. Because of limited WDNR availability, it is proposed the 10 sites would be conducted on a returning 3-year monitoring interval which would then include all 30 sites. The supporting surveys, assessments, analyses, and reporting at all 30 sites could be accomplished in year 1 to establish baseline conditions. Additional monitoring stations could be added depending on available funding. Subsequent years' sampling could also reoccur on a 3-year monitoring interval to correspond with the fish IBI sampling and be used to track trends associated with future land use changes and changing conditions.

Table 17. Proposed Biological Monitoring Program Budget (general estimate)

	Per Station	Yr. 1 (30 stations*)	Yr. 2 and beyond (10 stations)
F-IBI Survey[1] (contractual WDNR)	$200	$2,000*	$2,000
M-IBI Survey[2] (1 hr., lab ID, 2/yr)	320	9,600	3,200
Fish Habitat Survey[3] (0.5 person-day)	180	5,400	1,800
Riparian Assessment[4] (0.5 person-day)	180	5,400	1,800
Supplies (DO, temperature, msc. equip.)	65	1,950	650
Analysis and Reporting (2.0 person-days)	720	21,600	7,200
Prescriptive Planning (8.0 person-days)	2,930**	–	29,300**
Total	$4,595†	$45,950†	$45,950†

* Note IBI surveyed at only 10 stations
** General estimate depending largely on the conclusions from the analysis and reporting
† Does not include the cost for additional assessment monitoring, designs, implementation projects, or grant funds associated with a particular watershed, waterbody, or site.

[1] Lyons 1992, 1996, 2001, and 2003

[2] Weigel, 2003

[3] Simonson et. al., 1993

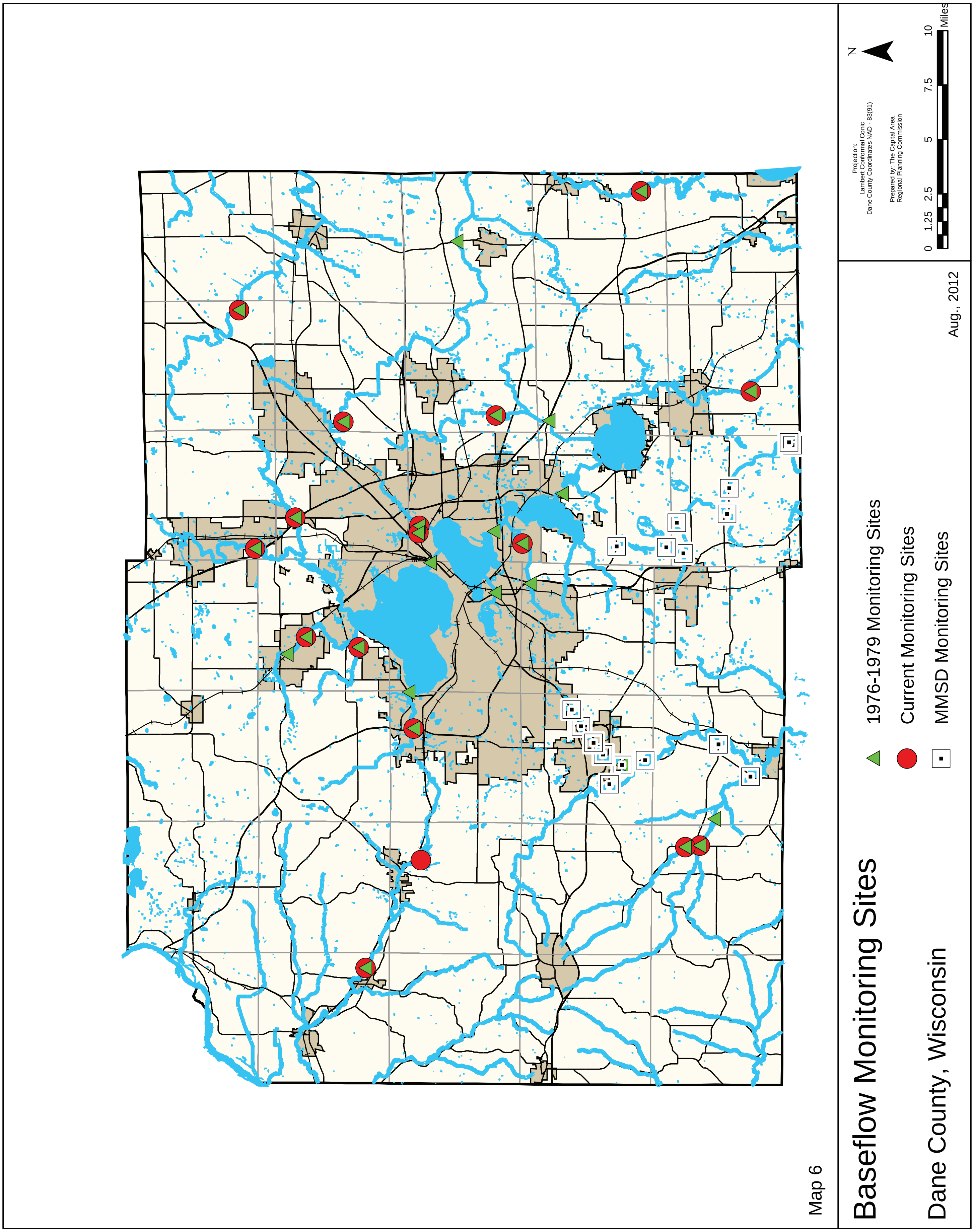
[4] USDA NRCS 2004, Shannon-Weaver 1948, and Simpson 1949

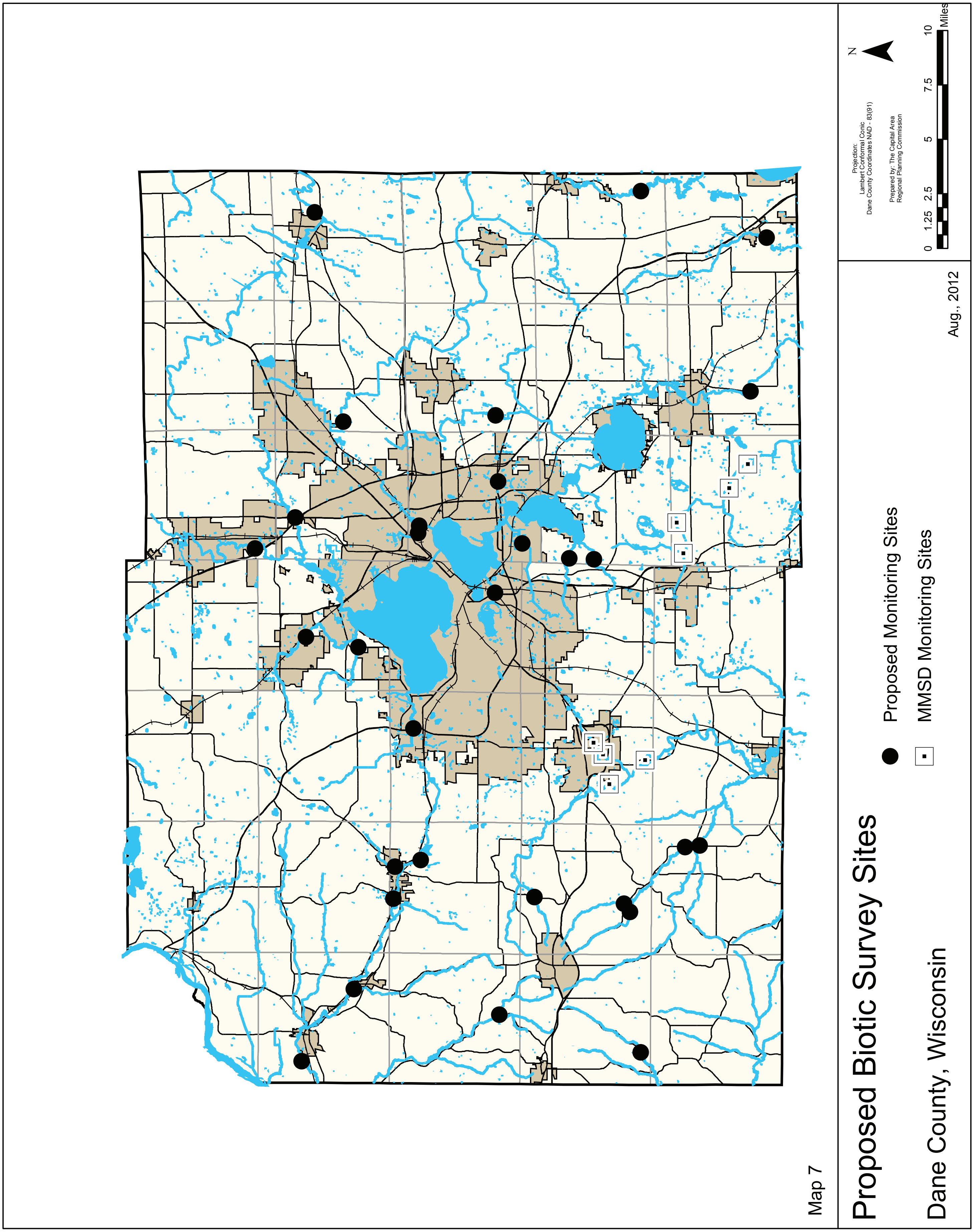
An important aspect of the analysis and reporting for each site would be whether more specific chemical/physical/biological monitoring is needed and, if so, the monitoring design, cost and potential funding sources (i.e., Tier 2 Targeted Evaluation Monitoring – see Surface Water Monitoring Section IV).

Prescriptive planning could also be conducted to help identify, target and design more detailed resource protection or restoration projects and activities. Funding to conduct these more detailed plans and designs is available through various federal, state, and local grant programs. For example, WDNR's Targeted Resource Management, Urban Nonpoint Source and Stormwater Management, and River and Lake Planning and Protection Grant Programs are specifically designed for these purposes. The analysis and reporting conducted as part of the expanded monitoring program would provide the necessary information and justification for applying for and leveraging these outside resources, along with local match.

Because of financial limitations at the local level and the large number of surface water features throughout the region, this baseline general assessment is intended to provide the basic program framework and justification for possibly more detailed investigation following the protocol outlined in WDNR's Consolidated Assessment and Listing Methodology (WisCALM). This allows for more systematic and cost-effective monitoring and analysis, along with follow-up actions being recommended, depending on the particular situation and circumstances. These follow-up plans, actions, and designs should be driven by previous plans and efforts (where they exist), including prospects for a positive response, as well as financial resources and partnerships that can be developed among the associated stakeholders. Depending on the results of the analysis, prescriptive management plans and activities should be developed including, for example:

- **Collecting more detailed water quality monitoring and trends information** (e.g., more systematic and specific condition assessments and analyses for individual sites and watersheds – i.e., Tier 2 Targeted Evaluation Monitoring, if warranted);
- **Directing resources to halt the decline, and improve water quality conditions in impaired water bodies** (e.g., nutrient trading to promote more efficient and cost-effective pollution controls);
- **Protecting and maintaining existing water quality conditions in water bodies that are threatened or vulnerable** (e.g., aggressive urban and agricultural Best Management Practices directed to both water quality and quantity considerations);
- **Improving conditions where opportunities are present** (e.g., urban stormwater retrofits, agricultural land conservation practices, and stream, riparian, and wetland restoration projects)


Map 6
Baseflow Monitoring Sites
Dane County, Wisconsin
1976-1979 Monitoring Sites
Current Monitoring Sites
MMSD Monitoring Sites
Aug., 2012
Projection:
Lambert Conformal Conic
Dane County Coordinates NAD - 83(91)
Prepared by: The Capital Area
Regional Planning Commission
N
0 1.25 2.5 5 7.5 10
Miles


Map 7
Proposed Biotic Survey Sites
Dane County, Wisconsin
Proposed Monitoring Sites
MMSD Monitoring Sites
Aug., 2012
Projection:
Lambert Conformal Conic
Dane County Coordinates NAD - 83(91)
Prepared by: The Capital Area
Regional Planning Commission
N
0 1.25 2.5 5 7.5 10
Miles

E. Agency Roles, Responsibilities, and Funding

Continuing and expanding a regional surface water monitoring program is best accomplished through a cooperative effort among the agencies involved, drawing upon the expertise and responsibilities of each. This approach also helps distribute the cost of monitoring overall. Present responsibilities and funding for existing monitoring activities should continue through the Cooperative Water Resources Monitoring Program and that an expanded biological component should be added as outlined above. The following roles would apply in this expanded effort:

Local Municipalities: Funding support for General Assessment monitoring on streams associated with Urban Service Areas.

Dane County: Staff assistance, information dissemination, potential funding for General Assessment monitoring on rural streams.

Department of Natural Resources: Technical assistance, consulting services, and funding for Specific Assessments.

Capital Area RPC: Overall program coordination, staff assistance, analysis, and write-up of survey information including the development of watershed management plans for priority areas in cooperation with local, state, and federal partners.

VIII. FUTURE HORIZONS

A. Water Quality – Rock River TMDL

Over the last 15 years, the WDNR has placed various waters in the region on the state's 303(d) Impaired Waters list, and has ranked the waters in terms of priority for the development of TMDLs to address the impairments caused primarily by excess phosphorus and sediment loading. These impairments include degraded habitat and elevated water temperature due to excessive sediment, and low dissolved oxygen and eutrophication due to excessive phosphorus.

In September 2011 the U.S. EPA approved the Rock River Basin TMDL, which includes the Yahara River Valley along with other waters in eastern Dane County and the south and southeast portions of the state. The TMDL identifies phosphorus and sediment reduction targets needed for waters in the Rock River Basin to meet water quality goals. With EPA's approval of the TMDL, the WDNR is moving forward with implementation planning in collaboration with urban and rural partners. Water quality improvements and attainment of the TMDL targets will be evaluated by comparing annual summer median water column total phosphorus concentrations during critical conditions (May through October). In 2010 NR 102.06 was amended establishing total phosphorus criteria for rivers, streams, lakes, and impoundments. The numeric phosphorus criteria were developed by studying relationships between phosphorus and aquatic biological health.[440]

There are no existing or proposed statewide numeric standards for sediment concentrations, so numeric targets were developed for the Rock River Basin TMDL based on relationships between sediment and phosphorus loading. Sediment loads from nonpoint sources are correlated with phosphorus loads because much of the phosphorus that is delivered to streams is bound to sediment. Therefore, the observed relationships between phosphorus and biological characteristics of surface waters are related to sediment as well. In addition, sediment control is widely recognized and used as an indicator or surrogate for water quality protection practices and structural designs (both agricultural and urban).

Two models were used to calculate loads of phosphorus and sediment from nonpoint sources under baseline conditions. The Soil and Water Assessment Tool (SWAT)[441] was used to calculate loads from agricultural and natural areas (i.e., forests and wetlands) and the Source Loading and Management Model (SLAMM)[442] was used to calculate loads from urban areas. **Maps 8 and 9** show the median annual baseline total phosphorus (TP) and total suspended solids (TSS) loading by sub-basin in the Rock River Basin. Sediment and phosphorus reduction targets have been established for each stream reach.[443] The TMDL will be implemented through enforcement of existing regulations, financial incentives, and various local, state, and federal water pollution control programs.

In addition, the WDNR has developed a water quality trading framework for Wisconsin, based on U.S. EPA guidance. Developed in conjunction with stakeholders, it is built on a philosophy of encouraging water quality trading in a way that maximizes environmental benefits in the most efficient and cost-effective manner. Water quality trading allows dischargers to take advantage of economies of scale and treatment efficiencies that vary from source to source; reducing the overall costs of achieving water quality objectives in a watershed. For example, agricultural Best Management Practices (BMPs) can cost as much as two orders of magnitude less than urban practices in terms of phosphorus removal – i.e., $10 versus $1,000 per pound of phosphorus removed, as shown in **Figure 52**. Additional environmental benefits can include achieving water quality objectives more quickly; encouraging further adoption of pollutant prevention and innovative technologies; engaging more nonpoint sources in solving water quality problems; and providing collateral benefits, such as improved habitat and ecosystem protection. From a societal standpoint, trading efforts have helped foster dialogue among watershed stakeholders and helped create incentives for water quality improvement from a full range of dischargers.[444]

For example, the Yahara CLEAN initiative is a memorandum of understanding between the City of Madison, Dane County, and the Departments of Natural Resources and Agriculture, Trade and Consumer Protection to improve water quality of the Yahara Chain of Lakes - Mendota, Monona, Waubesa, Kegonsa and Wingra. A consultant was hired and completed a SWAT model for the 411 sq.

440 Robertson, 2006 and 2008.

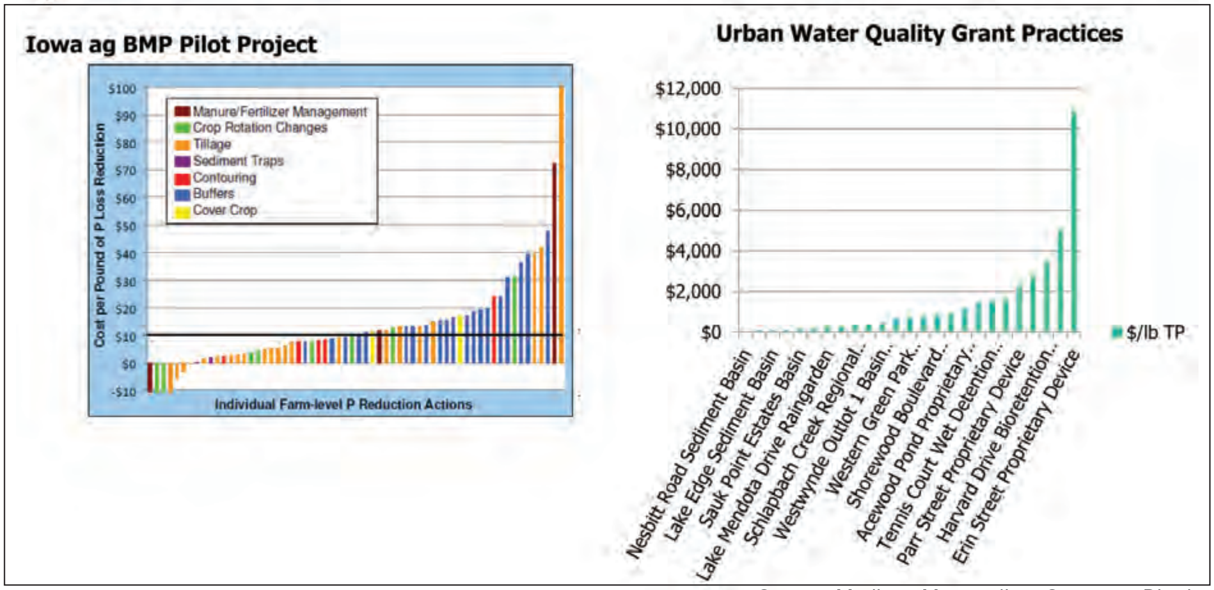
441 http://swatmodel.tamu.edu/

442 http://wi.water.usgs.gov/slamm/

443 Cadmus Group, 2010.

444 WDNR, 2011.

Figure 52. Cost Comparisons Between Agricultural and Urban Best Management Practices



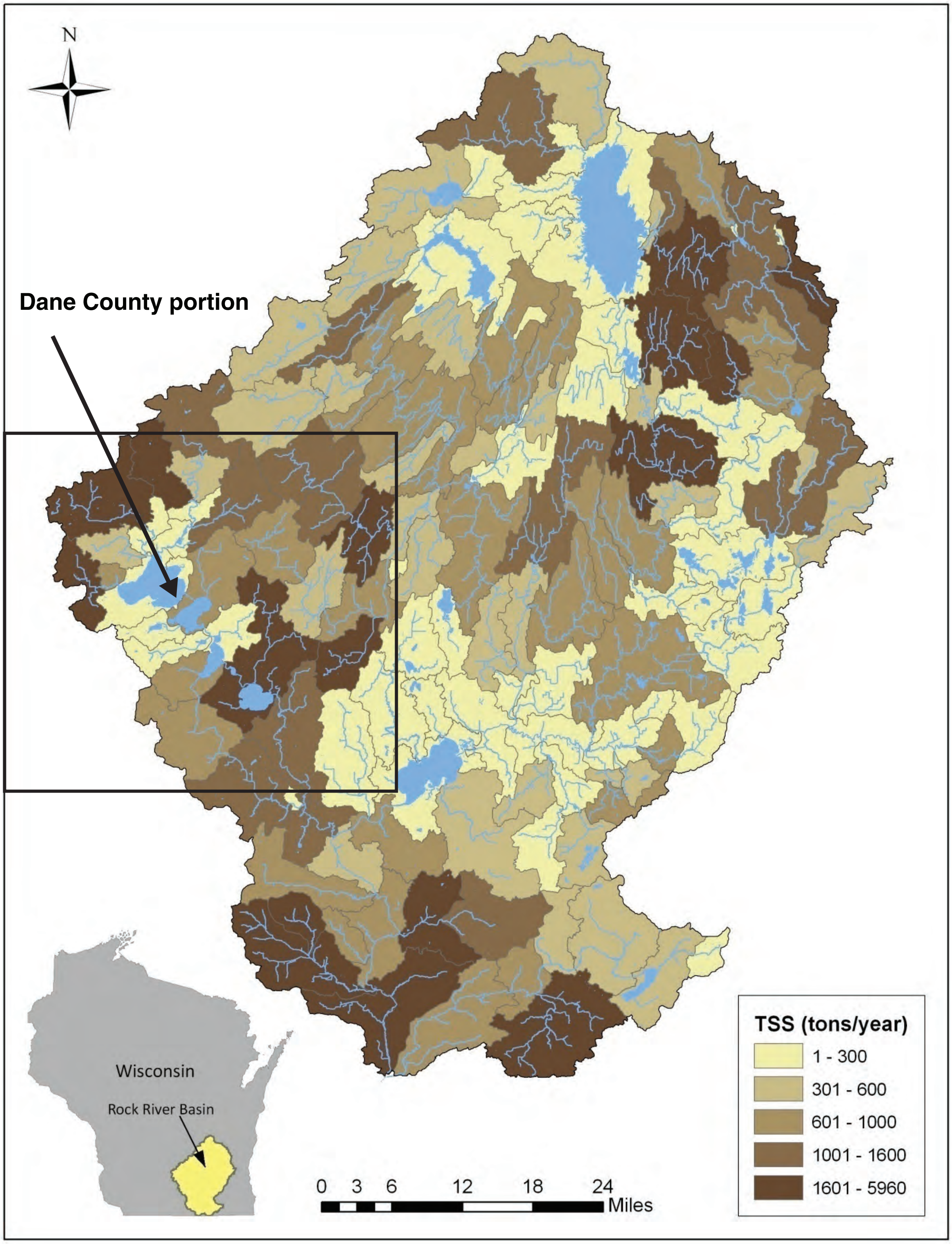
Source: Madison Metropolitan Sewerage District

mile watershed. A graduate student also completed a SNAP Plus analysis for a sub-watershed that was found to be one of the heaviest loading tributaries in the SWAT model. SNAP-Plus[445] is a nutrient management planning software program designed for the preparation of nutrient management plans in accordance with Wisconsin's Nutrient Management Standard Code 590. A lake response model has been developed to determine the load reductions needed to maintain a mesotrophic state (greater than 2-meter Secchi disk reading or surface water total phosphorus less than 0.024 mg/L).[446] Overall, the CLEAN partners identified 70 actions that will reduce phosphorus, sediment, and beach bacteria, many of which address more than one of the stated targets. For more detailed information, please refer to the report *A CLEAN Future for the Yahara Lakes: Solutions for Tomorrow, Starting Today*.[447] More specifically, the Y*ahara CLEAN Strategic Action Plan for Reducing Phosphorus* enumerates 14 priority actions with clear and achievable phosphorus reduction goals to clean the lakes.[448] The 20-year present value net cost to implement the Yahara CLEAN actions is estimated to be $78.6 million dollars.

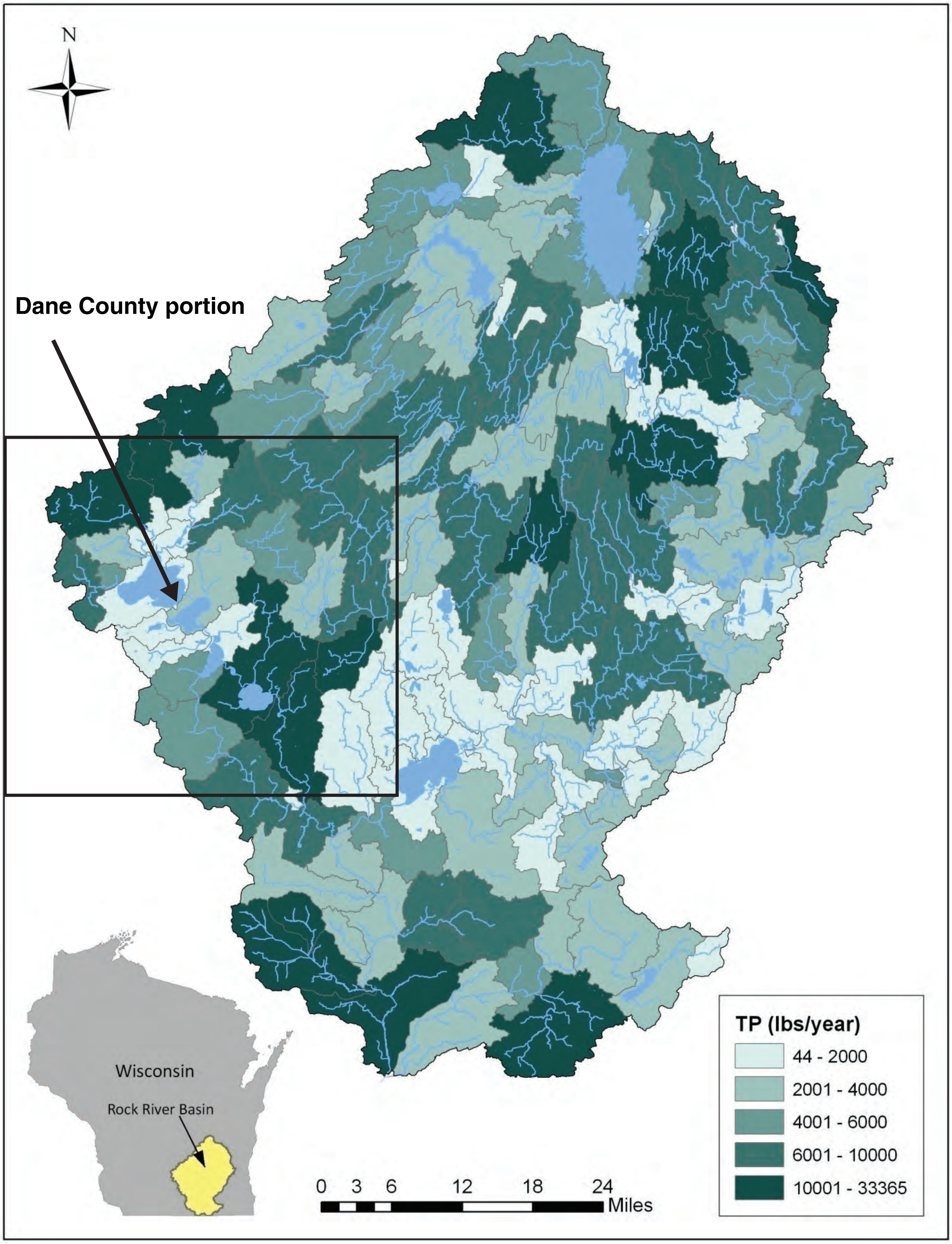
Follow-up monitoring and assessment will be an integral part of the TMDL implementation plan. WDNR has assembled a team representing various groups and agencies to discuss and create a monitoring and assessment strategy. The first objective is to use the nonpoint source loading maps developed in the TMDL report to help decide where watershed work should begin. Implementation activities will need to be focused in areas where they can have the greatest beneficial impact. The second task of the team is to decide on a monitoring strategy: what parameters to measure, where to monitor, what protocol will be used, and who will conduct the monitoring. TP and TSS concentrations will be used to evaluate compliance with water quality standards, and biological sampling (e.g., F-IBI or M-IBI) will be used to evaluate restoration of designated uses. Monitoring will likely be the task of the WDNR, but could also include a citizen component. Other groups doing monitoring could also include the U.S. Geological Survey, UW-extension, and local land and water resource agencies. In Dane County, similar modeling and monitoring efforts should be conducted for other priority watersheds in the region (e.g., Black Earth Creek, Sugar River, etc.), following WDNR's methodology and approach. This should be conducted in a manner to *avoid* water resource impairments in the future as well as *improve* conditions, where opportunities permit.

445 http://www.snapplus.net/
446 Lathrop, 2011.
447 http://yaharawatershed.org/documents/doc/CLEAN_Report_090910.pdf
448 http://www.cleanlakesalliance.com/wp-content/uploads/2012/11/Strategic-Action-Plan-11092012.pdf

Map 8. Median Annual Baseline Total Suspended Solids Loading by Sub-Basin in the Rock River Basin



Map 9. Median Annual Baseline Total Phosphorus Loading by Sub-Basin in the Rock River Basin



B. Water Quantity – Ecological Limits of Hydrologic Alteration

It is important to emphasize or reiterate that flow regime is a primary determinant of the structure, function, and health associated with rivers and streams. Indeed, streamflow has been called the "Master Variable," [449] or the "Maestro…that orchestrates pattern and processes in rivers."[450] Much evidence exists that modification of streamflow induces ecological alteration. Thus, both ecological theory and abundant evidence of ecological degradation in flow-altered rivers and streams support the need for environmental flow management. [451] In addition, strategies that focus on reducing runoff also reduce pollutant loads – since flow is a principle aspect of pollutant concentrations and loading. Certainly, environmental factors other than streamflow have been recognized. But as society struggles to conserve and restore freshwater ecosystems, flow management is needed to ensure that existing ecological conditions do not decline any further, and that it may also be possible for these resources to be improved.[452]

The Ecological Limits of Hydrologic Alteration (ELOHA) is a new management framework offering a flexible, scientifically defensible approach for broadly assessing environmental flow needs when in-depth studies cannot be performed for all rivers and streams in a given region.[453] ELOHA builds upon the wealth of knowledge gained from decades of river-specific studies and applies that knowledge to specific geographic areas. In practice, ELOHA synthesizes existing hydrologic and ecological databases from many rivers and streams within a region to generate flow alteration/ecological response relationships for other rivers and streams with similar hydrologic regimes. These relationships correlate measures of ecological condition, which can be difficult to manage directly, to streamflow conditions, which can be managed through water-use strategies and policies. Detailed site-specific data need not be obtained for each individual river or stream in a region.

For example, the State of Michigan has proposed a standard on groundwater pumping that protects fisheries resources for each of the 11 classes of streams in the state.[454] The state has also launched a web-based Water Withdrawal Assessment Tool (WWAT)[455] designed to estimate the likely impacts of a proposed water withdrawal on a nearby stream or river. This approach shows significant promise to the extent it could be applied to evaluating reductions in baseflow resulting from urban and agricultural land uses in Wisconsin.

More specifically, using existing fish population data across a gradient of hydrologic alteration (i.e., median August flow reduction – considered critical), Michigan scientists determined two flow/response relationships between populations of "thriving" (intolerant) fish species and "characteristic" (more tolerant) fish species for 11 stream types in Michigan (**Figure 53**). In developing the flow/response curves, fisheries ecologists examined the range of variation in the biological response across the flow alteration gradient and effectively smoothed the statistical scatter to create a trend line. Cut-points (vertical lines) were identified by consensus through a stakeholder process (**Figure 54**).

A diverse stakeholder committee proposed a ten percent decline in the thriving (sensitive) fish population as a socially acceptable or sustainable resource impact (Region A). A ten percent decline in the characteristic (tolerant) fish population was deemed to be an unacceptable adverse impact (Region D).[456] The Adverse Resource Impact (ARI) is defined as when a fish population can no longer succeed because of reduced "index flow" during critical summer months (August and September). Intermediate flow alterations (Regions B and C) trigger preventative or corrective environmental flow management actions depending on a stream's ecological condition. The Michigan "ten-percent rule" applies to each of the 11 stream types, but the shapes of the curves – and therefore the allowable or sustainable degree of hydrologic alteration – vary by stream type. Similar fish response curves are being developed by Michigan resource managers for high flow events.[457] CARPC is currently contracted with WDNR Division of Science Integrated Services to construct these flow alteration/ecological response curves based on USGS flow and WDNR fisheries data in Wisconsin and the Capital Region. Together, these two ecological response models (baseflow reduction and

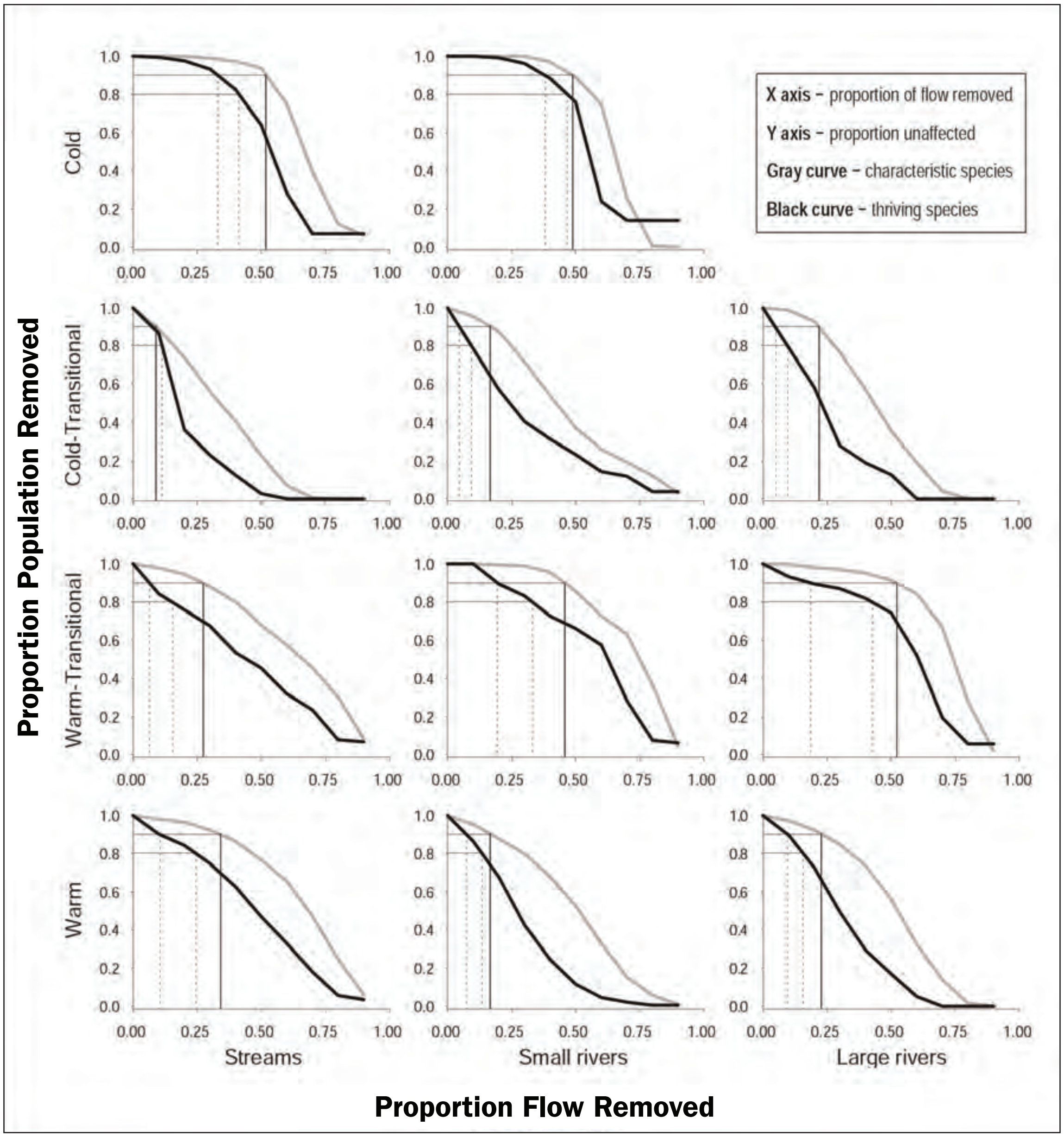
449 Power, 1995 and Poff, 2010a.
450 Walker, 1995.
451 Bunn, 2002 and Poff, 2010b.
452 Palmer, 2005.
453 http://www.conserveonline.org/workspaces/eloha
454 Michigan Groundwater Conservation Advisory Council, 2007.
455 http://www.miwwat.org/
456 Bartholic. Undated.
457 Troy Zorn, Ph.D., Michigan DNR; unpublished results August 2010.

increased stormflow) promise to be important tools for guiding and dealing more effectively with water resources management issues relating to the sustainability of urban development amid the backdrop of a historically agricultural landscape.

It is important to point out the goal of ELOHA is not to maintain or attempt to restore pristine conditions in all rivers or streams; rather, it is to understand the tradeoffs between human activity on water and resulting ecological degradation. Furthermore, in the absence of state rules, it does not have regulatory power or utility. As can be seen in the response curves in **Figures 53 and 54**, increasing levels of environmental stress reflect increased levels of ecological impact. The "acceptable" ecological condition for each river segment or river type is accomplished through a well-vetted stakeholder process of identifying and agreeing on the ecological and cultural values to be protected or restored through river management. ELOHA provides the necessary basis and understanding for facilitating those discussions. It is believed that applications of the ELOHA framework in the region will help to inform decision-makers and stakeholders about the ecological consequences of flow alteration, as well as promote regional environmental flow strategies for protecting and restoring water resource conditions. While ELOHA is a new advance in environmental flow analysis and biological health, it does not supplant more specific approaches for certain water bodies that require more in-depth analysis.

Overall there is much to be optimistic about in terms of the future water quality conditions in the region. The collective research, knowledge, and experience that has been gained over the last three decades has led to significant advancements in the science, tools, and programs needed to protect and improve the condition of our surface water resources. While much has been accomplished more work is needed. Efforts directed to controlling both urban and agricultural nonpoint source runoff quantity and quality need to be promoted and expanded in the region. In addition, the associated management programs, strategies and practices being implemented by designated management agencies should be considered more pro-actively *before* a resource becomes significantly impaired, as well as *improving* the resource where opportunities and funding permit.

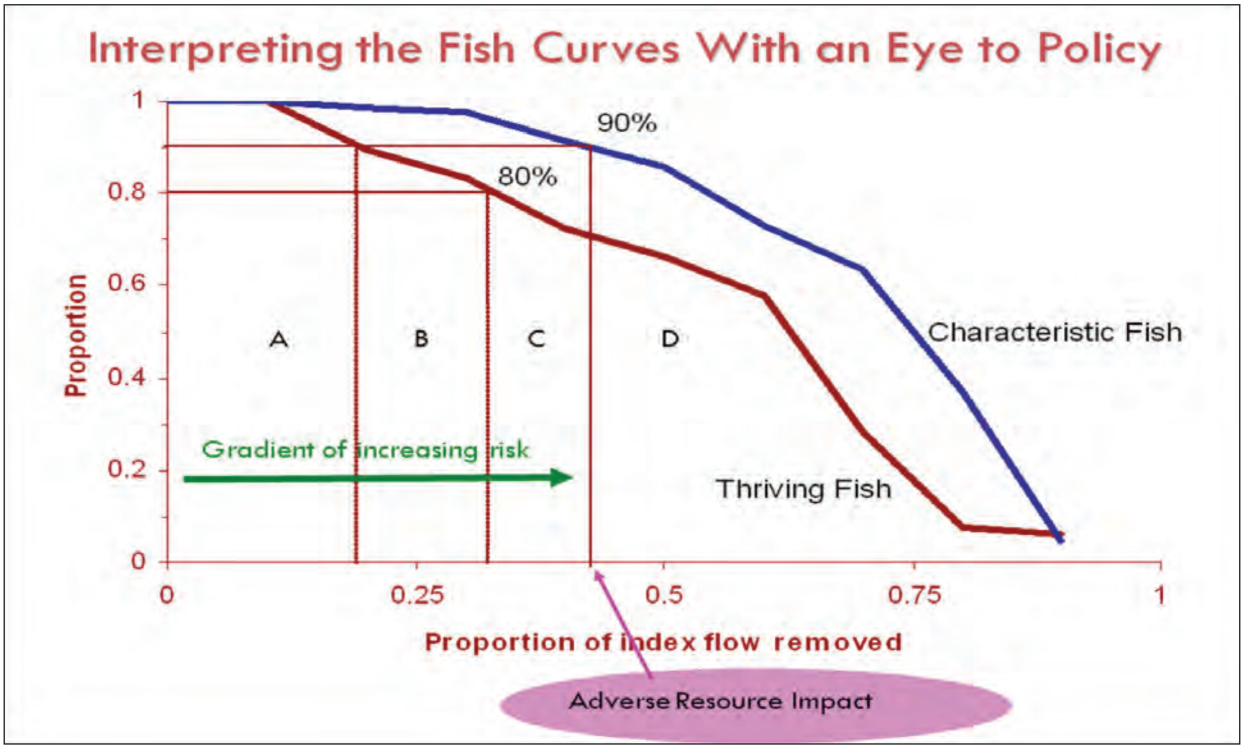
Figure 53. Actual Flow Alteration-Ecological Response Relationships



Source: Zorn et.al., 2008.

Curves describing fish community responses to water withdrawal for Michigan's 11 river types, as defined by size and July temperature characteristics. Axes are identical to those in Figure 54. The black curve describes the proportion of more sensitive "Thriving Species" at each increment of flow reduction. The gray curve quantifies the proportional change in more tolerant "Characteristic Species" at each level of water withdrawal. The right-most vertical line in each plot identifies the flow associated with an Adverse Resource Impact (Figure 52), while other vertical lines identify water withdrawal levels associated with undefined management actions to be taken in anticipation of the river baseflow yield (index flow) approaching the Adverse Resource Impact level.

Figure 54. Interpreting the Fish Response Curves with an Eye Toward Policy



The two function response curves were interpreted using horizontal lines representing preservation of 80 and 90 percent of the initial fish population metrics. At points where these lines intersected the two curves, a vertical line was dropped to indicate the proportion of Index Flow removed associated with that point on the curves. Selected points were chosen to reflect the Council's interpretation of degrees of impairment and restrictions set by legislation. Region D indicates the range of Adverse Resource Impact, defined as when a fish population can no longer succeed because of a reduced amount of water available.

Source: Michigan Groundwater Conservation Advisory Council, 2007.

List of Environmental Indicators and Terms Mentioned in this Report

Antidegradation: The Antidegradation rule is implemented in Chapter NR 207 of the Wisconsin Administrative Code. For some higher quality waters, such as ORW or ERW, new or increased discharges are either prohibited or allowed only in extreme and unique situations.

Baseflow: Baseflow consists of groundwater discharge to streams as well as regular or controlled surface discharges, where they exist, such as wastewater treatment plants, mining operations, or dams. Baseflow does not include streamflow resulting from stormwater runoff and can be determined by examining a stream's hydrograph (see below).

Best Management Practices (BMPs): BMPs refer to a rather large and diverse assortment of effective and practical, structural or nonstructural methods which prevent or reduce the movement of sediment, nutrients, pesticides, and other pollutants from the land to ground or surface waters. Collectively, they are used to protect water quality from potential adverse affects of agricultural or urban land use activities depending on the specific situation and circumstances.

Connected Impervious Area: Connected impervious area generally includes paved surfaces such as streets, driveways, parking lots, or short (<20 feet) lawn area which discharge directly to a storm sewer or water body, rather than a specially designed stormwater treatment facility or practice.

Designated use classifications for streams: Designated uses are those uses specified in water quality standards for each waterbody or segment, whether or not they are currently attained. Ideally, the designated use is based on the attainable use. (coldwater, warmwater sport fish, warmwater forage fish, limited forage, and limited aquatic life)

Dissolved oxygen criterion: Wisconsin Administrative Code NR 102.04(5) establishes minimum 5 mg/L for warmwater streams and 6 mg/L for coldwater streams or 7 mg/L for coldwater streams during spawning periods. NR 104.02(3) established minimum dissolved oxygen criterion for variance streams including 3 mg/L for limited forage streams and 1 mg/L for limited aquatic life streams.

Eutrophic: A eutrophic lake is one that has high primary production due to excessive nutrients. Algal blooms and poor water quality are frequent problems in these lakes. The TSI range for eutrophic lakes is 50 – 70.

Exceptional Resource Waters (ERW): ERW streams and lakes are high quality waters listed in Wisconsin Administrative Code NR 102.11. New or increased discharges are allowed only if they maintain the existing water quality; or if the new or increased discharge results in any lowering of water quality, the discharger must demonstrate to DNR that the discharge accommodates important social or economic development.

Hilsenhoff Biotic Index (HBI): The HBI reflect varying tolerances of stream aquatic invertebrates to organic pollution. The water quality scale for the HBI ranges from 10 (very poor) to 0 (excellent). While there is a wide variety of aquatic invertebrate biotic indices available to assess the environmental condition of streams, historically the WDNR used the HBI extensively as an indicator of low dissolved oxygen concentrations resulting from organic pollution. More recently, WDNR switched to primarily using a Macroinvertebrate IBI.

Hydrologic Regime: The water that flows in a river is more abundant at some times of the year than others because of the seasonality of the rains. The history of the flow patterns in the river during any year is known as the hydrological regime. This is usually measured by taking water height at a series of set gauges down the river at set intervals, usually daily. The water levels at any one gauge can then be connected to form a continuous curve on a graph (called a hydrograph) to represent to hydrological regime of the river at that gauge. Hydrologic regimes can also be established for wetlands and lakes.

Hydrograph: See Hydrologic Regime.

Hypereutrophic: Hypereutrophic are nutrient-rich lakes characterized by frequent and severe nuisance blue-green algae blooms, periodic fish kills, and very low transparency. The TSI range for hypereutrophic lakes is 71 – 110.

303(d) Impaired Waters List: A waterbody is "impaired" if it does not support its designated use by humans, fish, and other aquatic life and it is shown that one or more of the pollutant criteria are not met.

Index of Biotic Integrity (IBI): The IBI assesses the attributes of aquatic communities that are linked to environmental conditions based on fish species. Intolerant or environmentally sensitive species, and often species richness, are important metrics used to evaluate the environmental health of aquatic ecosystems. Warmwater IBIs and coldwater IBIs are typical versions of this methodology used to assess the environmental condition of streams and scores range from 0 (very poor) to 100 (excellent).

Macroinvertebrate Index of Biotic Integrity (M-IBI): The M-IBI metric is considered by many to be a better measure of general biotic condition than other aquatic invertebrate indices (e.g., HBI) because it responds to watershed-scale impacts of agricultural and urban land uses, riparian habitat degradation, sedimentation problems, and scouring. Benthic (bottom-dwelling) organisms comprise all the major trophic levels including decomposers, photosynthetic organisms, herbivores, and carnivorous animals. Since they have a limited degree of mobility, the sedentary nature of most benthic species makes them ideal chronic, long-term pollution indicators.

Macrophytes: Macrophytes are macroscopic plant species living in or near bodies of water (as opposed to microscopic algae). Macrophytes are typically rooted aquatic plants.

Mesotrophic: Mesotrophic lakes display an intermediate level of fertility or productivity, greater than oligotrophic lakes, but less than eutrophic lakes. These lakes are commonly clear water lakes and ponds with beds of submerged aquatic plants and medium levels of nutrients. Fish Lake was an example of a mesotrophic lake until the water quality decline that occurred since the late 1970s. The TSI range for mesotrophic lakes is 40 – 50.

Nonpoint Source Pollution: Nonpoint sources of pollution represent more diffuse sources of pollution washing off the land's surface and running into surface waters (as opposed to "point source pollution" discharging through a single point or pipe). Nonpoint source pollution is typically more difficult to regulate and control than point source pollution.

Oligotrophic: An oligotrophic lake has very low primary production, low nutrient concentrations and display very good water quality and clarity. Oligotrophic lakes typically occur in northern Wisconsin, particularly where watershed areas are relatively small compared to lake surface areas and land uses have not been significantly altered by agriculture or development. The TSI range for oligotrophic lakes is less than 40.

Outstanding Resource Waters (ORW): ORW lakes and streams are high quality waters that typically do not have any point sources discharging pollutants directly to the water (for instance, no industrial sources or municipal sewage treatment plants), although they may receive runoff from nonpoint sources. New point source discharges may be permitted only if their effluent quality is equal to or better than the background water quality of that waterway at all times—no increases of pollutant levels are allowed.

Phytoplankton: Phytoplankton, also known as microalgae, are similar to terrestrial plants in that they contain chlorophyll and require sunlight in order to live and grow. Most phytoplankton are buoyant and float in the upper part of the water column where sunlight penetrates the water.

Point Source Pollution: Point sources of pollution are those originating from a single point or pipe, such as a municipal or industrial wastewater discharge (as opposed to more diffuse "nonpoint source pollution" washing off the land's surface). Point source pollution is typically easier to regulate and control than nonpoint source pollution.

Secchi Disk: A secchi disk is an instrument used for measuring the clarity of water. It consists of a circular plate divided into alternating black and white quadrants and attached to a long measuring tape. The plate is lowered into the water, and the depth at which it is no longer visible from the surface is recorded.

Total Maximum Daily Load (TMDL): A TMDL is an analysis that determines how much of a pollutant a water body can assimilate before it excess water quality standards. A TMDL is the sum of waste loads from point sources, nonpoint sources, as well as a margin of safety.

Trophic State Index (TSI): The TSI uses a log transformation of secchi disk values as a measure of algal biomass on a scale from 0 - 110. Each increase of ten units on the scale represents a doubling of algal biomass. Because chlorophyll and total phosphorus are usually closely correlated to secchi disk measurements, these parameters also have trophic state index values. However, these values can vary based on complex chemical, physical, and biological interactions, such as examples in the following table.

TSI(Chl) = TSI(TP) = TSI(Sec)	It is likely that algae dominate light attenuation.
TSI(Chl) > TSI(Sec)	Large particulates, such as Aphanizomenom flakes dominate
TSI(TP) = TSI(Sec) > TSI(Chl)	Non-algal particulate or color dominate light attenuation
TSI(Sec) = TSI(Chl) χ TSI(TP)	The algae biomass in your lake is limited by phosphorus
TSI(TP) > TSI(Chl) = TSI(Sec)	Zooplankton grazing, nitrogen, or some factor other than phosphorus is limiting algae biomass

Watershed: A watershed includes all the land area contributing water to a specific body of water. It has been compared to a topographic bowl or basin separated from neighboring watersheds by ridgelines.

Zooplankton: Zooplankton are small animals that drift in aquatic environments. Individual zooplankton are usually too small to be seen with the naked eye.

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Attachment A

Fish and Aquatic Life Designations for Named Water Bodies in Dane County

This information is provided for general reference purposes and is subject to change. For more current updates please contact the WDNR Southern Region Fisheries Manager or consult the WDNR Water Data Viewer http://dnr.wi.gov/water/basin/.

Stream Name	Watershed	Water Size*	303(d) Status**	Current Use	Attainable Use	Designated Use	ORW / ERW	General Condition ***	Page #
Badfish Cr.	LR07	12.0 mi.	Y	WWSF	WWSF	DEF		Fair	pg.140
	LR07	0.9 mi.	Y	LFF	LFF	LFF		Poor[†]	
Badger Mill Cr.	SP15	2.0 mi.	D	Class II Trout	Class II Trout	LFF		Poor	pg. 77
	SP15	3.0 mi.	D	Class II Trout	Class II Trout	FAL Cold		Poor	
Barbian Pond (T8N R8E S2)	LR10	11 ac.	N	Small	FAL	DEF		Unknown[‡]	nr
Lake Barney (T6N R9E S34)	LR07	27 ac.	N	Shallow Seepage	FAL	DEF		Good	pg.143
Bass Lake (T5N R10E S24)	LR07	69 ac.	N	Shallow Seepage	FAL	DEF		Poor	pg. 142
Lake Belle View	SP15	88 ac.	N	Shallow Lowland	FAL	DEF		Fair	pg. 86
Black Earth Cr.	LW17	11.1 mi	N	FAL	WWSF	DEF		Fair	pg. 55
	LW17	5.8 mi	N	Class II Trout	Class II Trout	Cold		Good	
	LW17	2.5 mi	PA	Class I Trout	Class I Trout	Cold	ERW	Fair	
	LW17	4.6 mi	N	Class I Trout	Class I Trout	Cold	ORW	Fair	
	LW17	3.1 mi	PA	WWFF	FAL	DEF	ORW	Poor	
Blue Mounds Cr. (E. Br.)	LW15	4.0 mi.	N	Class III Trout#	Class II Trout	Cold		Unknown	pg. 64
Bohn Cr.	LW15	2.0 mi.	N	Class II Trout	Class II Trout	Cold		Excellent	pg. 63
	LW15	1.5 mi.	N	Class II Trout	Class II Trout	Cold		Unknown	
Brandenburg Lake (T8N R8E S62)	LR10	38 ac.	N	Shallow Seepage	FAL	DEF		Unknown	pg. 126
Brazee Lake (Patrick Marsh)	LR12	148 ac.	N	-	FAL	DEF		Unknown	nr
Brewery Cr.	LW17	0.7 mi.	PA	FAL	FAL Cold	DEF		Fair	pg. 58
	LW17	2.0 mi.	PA	FAL	FAL Cold	DEF		Good	
Carl Buechner Pond (T8N R8E S19)	LW17	12 ac.	N	-	FAL	DEF		Unknown	nr
Cherokee Lake (T8N R9E S24)	LR09	57 ac.	N	-	FAL	DEF		Unknown	pg. 119
Crystal Lake (T9N R7E S1)	LW18	526 ac.	N	Shallow Seepage	FAL	DEF		Fair	pg. 71
Dahmen Pond (T8N R8E S16)	LR10	6 ac.	N	-	FAL	DEF		Unknown	nr
Deer Cr.	SP16	4.7 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 92
	SP16	1.1 mi.	N	FAL	FAL	DEF	ERW	Good	

Stream Name	Watershed	Water Size*	303(d) Status**	Current Use	Attainable Use	Designated Use	ORW / ERW	General Condition ***	Page #
Diedrich Pond (T8N R8E S4)	LR10	19 ac.	N	-	FAL	DEF		Unknown	nr
Door Cr.	LR06	14 mi.	PA	WWFF	WWSF	LFF		Fair	pg. 136
Dorn Cr.	LR10	1.0 mi.	N	WWSF	WWSF	WWSF		Unknown	pg. 123
	LR10	5.5 mi.	Y	LFF	WWSF	DEF		Poor†	
Dunlap Cr.	LW18	6.1 mi.	N	FAL	FAL	DEF	ERW	Fair	pg. 67
	LW18	4.0	N	Class II Trout	Class II Trout	Cold	ERW	Fair	
Elvers Cr.	LW15	10.1 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 63
Fish Lake (T9N R7E S3)	LW18	216 ac.	N	Deep Seepage	FAL	DEF		Fair	pg. 68
Fishers Lake (T9N R6E S32)	LW18	4 ac.	N	Small	FAL	DEF		Unknown‡	nr
Flynn Cr.	SP16	4.6 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 94
Frog Pond Cr.	LR07	7.0 mi.	N	WWFF	WWFF	WWSF		Good	pg. 142
Fryes Feeder	SP16	2.0 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 93
	SP16	3.3 mi.	N	FAL	FAL	DEF	ERW	Good	
Garfoot Cr.	LW17	4.3 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 59
German Valley Branch	SP05	7.6 mi.	PD	Class II Trout	Class II Trout	FAL Cold		Good	pg. 103
Goose Lake (T7N R12E S2)	LR12	61 ac.	N	-	FAL	DEF		Unknown	pg. 149
Goose Lake (T6N R8E S13)	SP15	12 ac.	N	Deep Seepage	FAL	DEF		Poor	pg. 149
Gordon Cr.	SP05	8.2 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 103
Graber Pond (T7N R8E S2)	LR10	10 ac.	N	-	FAL	DEF		Poor†	126
Grass Lake (T6N R10E S30)	LR07	48 ac.	N	Shallow Seepage	FAL	DEF		Poor†	pg. 142
"Grass Lake (T5N R11E S18)"	LR07	10 ac.	N	Small	FAL	DEF		Poor†	pg. 142
Halfway Prairie Cr.	LW17	8.0 mi.	Y	WWFF	Class III Trout	DEF		Fair	pg. 60
	LW17	3.6 mi.	N	WWFF	WWFF	DEF		Fair	
Lake Harriett (T5N R9E S9)	SP13	35 ac.	N	Shallow Lowland	FAL	DEF		Fair	nr
Henry Cr.	SP15	1.0 mi.	D	Class II Trout	Class II Trout	FAL Cold		Good	pg. 80
Hook Lake (T6N R10E S29)	LR07	9 ac.	N	Small	FAL	DEF		Poor†	pg. 142
Indian Lake (T8N R7E S11)	LW17	66 ac.	N	Shallow Seepage	FAL	DEF		Good	pg. 60
Island Lake (T5N R10E S3)	LR07	10 ac.	N	Small	FAL	DEF		Poor†	pg. 143
Jeglum Valley Cr.	SP05	1.5 mi.	N	Class III Trout#	Class III Trout#	DEF		Good	pg. 105
Kalscheur Pond (T8N R8E S8)	LR10	11 ac.	N	Small	FAL	DEF		Unknown‡	nr
Keenans Cr.	LR06	2.0 mi	N	WWFF	WWSF	WWSF		Unknown	pg. 136

Stream Name	Watershed	Water Size*	303(d) Status**	Current Use	Attainable Use	Designated Use	ORW / ERW	General Condition ***	Page #
Lake Kegonsa	LR06	3,209 ac.	N	Shallow Lowland	FAL	DEF		Fair	pg. 168
Kittleson Valley Cr.	SP05	3.9 mi.	N	Class III Trout#	Class III Trout#	Cold		Fair	pg. 104
	SP05	6.1 mi.	N	Class II Trout	Class II Trout	Cold		Good	
Koshkonong Cr.	LR11	24.0 mi.	PA	WWSF	WWSF	DEF		Fair	pg. 145
	LR12	25.0 mi.	PA	WWSF	WWSF	DEF		Fair	
	LR12	6.0 mi.	N	LAL	LAL	LAL		Poor	
Lee (York Valley) Cr.	SP05	2.0 mi.	N	Class II Trout	Class II Trout	Cold		Excellent	pg. 105
	SP05	1.0 mi.	N	FAL	WWSF	DEF		Good	
Leutens Cr.	LR06	3.0 mi.	N	LFF	LFF	WWSF		Unknown	nr
Little Door Cr.	LR06	5.0 mi.	N	LFF	LFF	WWSF		Fair	pg. 137
Little Norway Cr.	LW15	1.3 mi.	N	FAL	Cold	DEF		Good	pg. 64
Little Sugar River	SP14	3.9 mi.	N	FAL	WWSF	DEF	ERW	Good	pg. 100
Louis Buechner Pond (T8N R8E S8)	LR10	9 ac.	N	-	FAL	DEF		Unknown	nr
Maher Pond (T5N R9E S9)	SP13	6 ac.	N	Small	FAL	DEF		Unknown‡	nr
Marsh Cr.	LW18	1.0 mi.	N	FAL	WWSF	DEF		Unknown	pg 67
	LW18	3.0 mi.	N	FAL	WWSF	DEF		Poor	
Marshall Millpond (T5N R12E S9)	UR05	185 ac.	N	Shallow Lowland	FAL	DEF		Poor	pg. 109
Maunesha River	UR05	7.7 mi.	Y	FAL	FAL	DEF		Fair	pg. 107
	UR05	18.6 mi.	Y	FAL	FAL	DEF		Fair	
Meier Pond (T8N R8E S18)	LW17	9 ac.	N	Small	FAL	DEF		Unknown‡	nr
Lake Mendota	LR10	9,781 ac	Y	Deep Lowland	WWSF	FAL Warm		Good	pg. 153
Milum Cr.	SP16	2.0 mi.	N	WWFF	WWFF	DEF	ERW	Fair	pg. 95
Moen Cr.	LW15	2.0 mi.	N	Class II Trout	Class I Trout	DEF		Good	pg. 63
Lake Monona	LR08	3,358 ac.	Y	Deep Lowland	WWSF	FAL Warm		Fair	pg. 162
MMSD Ditch to Oregon Br.	LR07	3.6 mi.	N	FAL	FAL	LAL		Unknown	nr
Morse Pond (T6N R8E S3)	SP15	13 ac.	N	Shallow Seepage	FAL	DEF		Unknown	pg. 87
Mortenson Pond (T5N R9E S26)	SP13	11 ac.	N	Shallow Seepage	FAL	DEF		Unknown	nr
Mount Vernon Cr.	SP16	3.5 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 91
	SP16	2.4 mi.	N	Class I Trout	Class I Trout	Cold	ORW	Good	
Mud Lake (T9N R7E S4)	LW18	54 ac.	N	Shallow Seepage	FAL	DEF		Fair	pg. 134
Mud Lake (T7N R12E S2)	LR12	34 ac.	N	Shallow Seepage	FAL	DEF		Good	pg. 135
Mud Cr. (T6N R11E S13)	LR12	9 mi.	N	WWFF	WWFF	DEF		Fair	pg. 148

Stream Name	Watershed	Water Size*	303(d) Status**	Current Use	Attainable Use	Designated Use	ORW / ERW	General Condition ***	Page #
Mud Cr. (T9N R12E S26)	UR02	10.8 mi.	Y	WWFF	WWSF	DEF		Poor†	pg. 111
Lower Mud Lake	LR06	195 ac.	N	Shallow Lowland	FAL	DEF		Poor†	pg. 135
Upper Mud Lake	LR08	223 ac.	N	Shallow Lowland	FAL	DEF		Poor	pg. 134
Murphys Cr.	LR08	4.7 mi.	N	WWFF	WWFF	DEF		Fair	pg. 130
Nine Springs Cr.	LR08	6.2 mi.	Y	WWFF	WWSF	DEF		Poor†	pg. 130
Nolan Cr.	UR02	10.0 mi.	N	LFF	WWSF	DEF		Unknown	pg. 111
Oregon Br.	LR07	4.7 mi.	PA	LFF	LFF	LFF		Poor-	pg. 141
	LR07	1.4 mi.	N	LAL	LAL	LAL		Unknown	
Pheasant Branch Cr.	LR10	1.0 mi.	Y	WWSF	WWSF	DEF		Fair	pg. 123
	LR10	8.1 mi.	Y	LFF	LFF	DEF		Fair	
Pleasant Valley Br.	SP05	5.9 mi.	Y	WWFF	Cold	DEF		Good	pg. 105
Primrose Br.	SP16	6.3 mi.	N	Class II Trout	Class II Trout	Cold		Fair	pg. 95
Rice Lake (T5N R12E S14)	LR11	170 ac.	N	Shallow Seepage	FAL	DEF		Fair	nr
Roxbury Cr.	LW18	4.0 mi.	N	FAL	WWSF	DEF		Unknown	pg. 68
	LW18	4.0 mi.	N	FAL	FAL	DEF		Unknown	
Rutland Br.	LR07	2.6 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Fair	pg. 141
Ryan Cr.	LW15	6.4 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Excellent	pg. 64
Saunders Cr.	LR11	11.8 mi.	N	WWFF	WWFF	WWSF		Fair	pg. 148
Schlapbach Cr.	SP15	3.0 mi.	N	FAL	FAL	DEF	ERW	Good	pg. 81
	SP15	1.0 mi.	N	FAL	FAL	DEF	ERW	Unknown	
Schumacher Cr.	UR05	3.0 mi.	N	FAL	FAL	DEF		Unknown	pg. 108
Sixmile Cr.	LR10	8.5 mi.	N	WWSF	WWSF	DEF	ERW	Fair	pg. 121
	LR10	3.6 mi.	N	LFF	LFF	WWSF	ERW	Poor	
Spring Cr.	UR05	4.0 mi.	N	FAL	WWSF	DEF		Unknown	pg. 108
Spring (Lodi) Cr.	LW19	3.6 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Fair	pg. 74
Springfield Pond	LR10	3 ac.	N	Small	FAL	DEF		Unknown‡	nr
Starkweather Cr. (East Br.)	LR08	3.7 mi.	Y	LFF	WWSF	DEF		Fair	pg. 128
Starkweather Cr. (West Br.)	LR08	2.6 mi.	N	FAL	FAL	DEF		Unknown	pg. 129
Stewart Lake	LW15	7 ac.	N	Small	FAL	DEF		Unknown‡	pg. 64
Stoney Brook Cr.	UR05	15.0 mi.	Y	LFF	WWSF	DEF		Poor†	nr
Stoughton Millpond	LR06	82 ac.	N	Shallow Lowland	FAL	DEF		Poor†	pg. 138
Story (Tipperary) Cr.	SP13	6.8 mi.	N	Class II Trout	Class II Trout	Cold	ERW	Good	pg. 98
Stransky Cr.	UR05	2.0 mil	N	FAL	FAL	DEF		Unknown	pg. 108
Strickers Pond (T7N R8E S14)	LR10	15 ac.	N	Shallow Seepage	FAL	DEF		Unknown	nr
Sugar River	SP15	4.2 mi.	N	WWSF	WWSF	DEF	ERW	Fair	pg. 82
	SP15	20.1 mi.	N	Class II Trout	Class II Trout	FAL Cold	ERW	Fair	
	SP15	4.6 mi.	N	Class II Trout	Class II Trout	FAL Cold	ERW	Fair	

Stream Name	Watershed	Water Size*	303(d) Status**	Current Use	Attainable Use	Designated Use	ORW / ERW	General Condition ***	Page #
Swan Cr.	LR08	4.4 mi.	N	WWFF	FAL	DEF		Good	131
Sweet Lake (T5N R12E S23)	LR11	27 ac.	N	-	FAL	DEF		Unknown	nr
Syftestad Cr.	SP05	5.2 mi.	D	Cold	Cold	DEF		Fair	pg. 104
Tiedemans Pond (T7N R8E S13)	LR10	15 ac.	N	Shallow Seepage	FAL	DEF		Unknown	nr
Token Cr.	LR09	2.9 mi.	N	WWSF	Class III Trout#	DEF		Fair	pg. 117
	LR09	3.5 mi.	Y	Class III Trout#	Class II Trout	Cold		Fair	
	LR09	3.3 mi.	Y	WWSF	Cold	DEF		Fair	
Vermont Cr.	LW17	3.5 mi.	Y	Class III Trout#	Class II Trout	DEF		Poor†	pg. 59
	LW17	6.1 mi.	N	Class II Trout	Class II Trout	Cold		Good	
Verona Gravel Pit	SP15	9 ac.	N	Small	FAL	DEF		Unknown‡	nr
Lake Waubesa	LR08	2,075 ac.	N	Shallow Lowland	FAL	DEF		Fair	pg. 166
Wendt Cr.	LW17	3.6 mi.	Y	LFF	WWFF	DEF		Fair	pg. 60
	LW17	4.6 mi.	Y	LFF	Class III Trout#	DEF		Good	
West Branch Sugar River"	SP16	7.6 mi.	PA	Class II Trout	Class II Trout	LFF		Fair	pg. 89
	SP16	11.2 mi.	D	Class II Trout	Class II Trout	FAL Cold		Good	
	SP16	3.5 mi.	D	Class II Trout	Class II Trout	FAL Cold		Good	
Lake Windsor (T9N R10E S31)	LR09	9 ac	N	Small	FAL	DEF		Poor†	pg. 119
Lake Wingra	LR08	345 ac.	PA	Shallow Lowland	FAL	DEF		Good	pg.164
Wingra (Murphy) Cr.	LR08	1.2 mi.	Y	WWSF	WWSF	DEF		Poor†	pg. 129
Yahara River	LR06	9.0 mi.	Y	WWSF	WWSF	DEF		Poor†	pg. 131
	LR06	5.7 mi.	Y	WWSF	WWSF	DEF		Poor†	
	LR06	2.0 mi.	N	WWSF	WWSF	WWSF		Unknown	
	LR08	2.0 mi.	N	WWSF	WWSF	DEF		Unknown	
	LR09	20.0 mi.	N	WWSF	WWSF	DEF		Fair	

* Segments for streams begin at the mouth (mile zero or county boundary) and transition sequentially upstream.

** 303(d) status:

D – Delisted

PD – Proposed to be de-listed

PA – Proposed to be added

nr – Not reported. Typically small water bodies or pothole wetlands where the condition is not known or lacking

*** General condition may be more heavily based on Macroinvertebrate IBI results where there is inconsistent information (see individual water body descriptions and WDNR's Water Data Viewer for more detailed information)

† WDNR considers poor or suspected poor

‡ Methodology does not currently exist for evaluating the condition of "Small" lakes or ponds. WDNR is looking to emerging wetland assessment tools for guidance

The WDNR considers a Class III Trout stream as being a Warmwater Sport Fishery

Attachment B-1

Stream Baseflow Water Quality Monitoring Results

Period of Record	Station		Flow cfs	Temperature Deg. C	pH s.u.	Dissolved Oxygen mg/L	NO3 + NO2 Nitrogen mg/L	Ammonia Nitrogen mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Dissolved Phosphorus mg/L	Total Phosphorus mg/L	Specific Conductivity (us/cm)	Chloride mg/L	Alkalinity as CaCO3 mg/L	Turbidity NTU	COD mg/L	Suspended Sediment mg/L	E. Coli col/100 ml
Attachment B-1. Stream Baseflow Water Quality Monitoring Results																			
	WISCONSIN RIVER BASIN																		
2006 (May-Oct)	Black Earth Cr. @ Black Earth	mean	28.0	13.7	7.8	9.0	2.5	0.02	0.18	2.7	0.04	0.05	643	28	292	3.0	<10	10	488
		min.	27.0	10.5	7.5	6.3	2.1	0.01	0.14	2.3	0.03	0.04	636	26	277	2.6	<10	4	370
		max.	31.0	16.4	8.2	12.5	2.7	0.03	0.21	2.9	0.05	0.06	653	29	300	4.1	<10	18	770
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6
2007 (May-Oct)	Black Earth Ck at Stagecoach Rd Nr Cross Plains	mean	1.3	17.1	7.8	9.0	2.1	0.05	0.42	2.6	0.15	0.19	670	29	314	4.3	15	28	437
		min.	0.6	14.1	7.3	7.3	1.5	0.02	0.12	1.9	0.05	0.07	621	27	300	2.0	<10	7	110
		max.	2.4	20.0	8.3	12.4	2.9	0.13	0.73	3.4	0.20	0.24	695	33	327	7.3	20	82	970
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6
	SUGAR-PECATONICA RIVER BASIN																		
2007-2010	Sugar River Valley Rd.	mean	--	8.5	7.9	9.1	5.1	0.09	0.45	5.6	0.09	0.14	592	28	233	--	2	20	858
		min.		0.2	7.3	3.5	1.1	0.01	0.03	2.4	0.02	0.02	249	17	42		2	5	5
		max.		19.8	8.2	12.4	7.1	0.73	1.31	7.4	0.47	0.51	860	35	292		8	86	5,730
		# samples															24 (BOD)		
2007-2010	Badger Mill Creek @ STH 69	mean	--	10.1	8.0	10.2	7.1	0.08	0.65	7.8	0.11	0.19	976	148	253	--	2	31	1,400
		min.		0.4	7.6	6.7	2.9	0.01	0.21	4.2	0.02	0.07	526	68	96		2	4	290
		max.		20.2	8.5	13.4	10.5	0.45	1.44	12.0	0.31	0.41	1,493	251	319		5	147	4,900
		# samples															24 (BOD)		
2007-2010	Sugar River STH 69	mean	--	9.1	8.0	9.4	5.8	0.09	0.54	6.4	0.09	0.15	688	65	241	--	3	24	1,014
		min.		(0.1)	7.5	5.4	1.8	0.01	0.06	3.0	0.02	0.04	343	33	53		2	3	120
		max.		19.8	8.4	12.5	8.4	0.68	1.36	8.8	0.40	0.49	950	108	316		8	66	5,670
		# samples															24 (BOD)		
2007 (May-Oct)	West Br. Sugar River @ STH 92 near Mt. Vernon	mean	23.7	14.5	7.6	8.3	6.7	0.02	0.25	7.0	0.06	0.10	707	41	283	8.7	12	36	925
		min.	12.0	11.0	7.1	6.3	6.3	0.01	0.20	6.6	0.04	0.06	688	32	278	2.0	10	5	1
		max.	38.0	17.7	7.9	10.9	7.0	0.03	0.29	7.3	0.07	0.15	757	56	288	28.0	20	70	2,300
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6
2008 (May - Oct)	Mount Vernon Creek near Mount Vernon	mean	29.0	11.5	7.9	9.9	4.9	0.02	0.16	5.1	0.03	0.05	587	16	274	7.7	<10	36	1,045
		min.	24.0	9.5	7.8	8.5	4.6	0.01	0.13	4.8	0.02	0.03	576	15	267	3.0	<10	13	180
		max.	42.0	13.5	8.1	11.3	5.2	0.02	0.24	5.4	0.04	0.07	594	18	278	12.0	<10	54	3,800
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2007-2010	West Br. Sugar River CTH PB	mean	--	9.9	8.1	9.6	5.3	0.09	0.57	5.9	0.11	0.17	526	24	224	--	2	19	2,008
		min.		(0.1)	7.5	4.7	2.4	0.01	0.10	3.8	0.02	0.05	315	19	83		2	3	2
		max.		19.7	8.6	13.7	6.6	0.71	1.53	8.1	0.41	0.54	621	28	305		7	48	18,600
		# samples															24 (BOD)		

Attachment B-1. Stream Baseflow Water Quality Monitoring Results

Period of Record	Station		Flow cfs	Temperature Deg. C	pH s.u.	Dissolved Oxygen mg/L	NO3 + NO2 Nitrogen mg/L	Ammonia Nitrogen mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Dissolved Phosphorus mg/L	Total Phosphorus mg/L	Specific Conductivity (us/cm)	Chloride mg/L	Alkalinity as CaCO3 mg/L	Turbidity NTU	COD mg/L	Suspended Sediment mg/L	E. Coli col/100 ml
	YAHARA RIVER BASIN																		
2010 (Apr-Aug)	Yahara River at Windsor	mean	39.3	16.2	8.1	9.5	8.2	0.02	0.38	8.6	0.05	0.08	750	40	311	4.6	<10	16	298
		min.	26.0	11.0	8.1	8.8	7.4	0.01	0.14	8.1	0.02	0.05	712	37	290	<2.0	<10	9	83
		max.	65.0	19.8	8.2	10.0	8.7	0.04	0.68	9.1	0.07	0.10	775	43	317	7.0	10	21	450
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	6 (2006)	6 (2006)	6 (2006)	3	3
2009 (May-Aug)	Token Creek near Madison	mean	28.7	14.9	8.0	10.1	8.9	0.03	0.45	9.4	0.02	0.05	779	41	264	3.0	<10	39	287
		min.	26.0	11.6	7.9	9.2	8.7	0.01	0.05	9.0	0.02	0.03	778	40	239	2.2	<10	9	190
		max.	34.0	16.7	8.1	11.8	9.0	0.05	0.83	9.6	0.03	0.08	780	43	289	4.0	10	95	410
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2006)	6 (2005)	6 (2005)	3	3
2008 (May-Oct)	Sixmile Creek near Waunakee	mean	28.7	16.2	8.0	8.8	3.4	0.02	0.50	3.9	0.12	0.15	782	39	348	4.7	15	28	556
		min.	25.0	13.4	7.8	8.2	2.1	0.01	0.46	2.7	0.07	0.10	748	39	326	3.0	<10	14	66
		max.	33.0	19.9	8.1	9.4	5.3	0.02	0.57	5.8	0.19	0.22	807	40	370	7.8	20	54	2,500
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2009 (May-Aug)	Pheasant Branch at Middleton	mean	2.9	18.8	7.7	8.3	2.8	0.13	0.47	3.4	0.01	0.05	939	90	237	5.5	18	29	188
		min.	1.9	17.3	7.7	7.6	2.3	0.07	0.38	2.8	0.01	0.04	888	79	213	3.5	10	19	83
		max.	4.2	19.8	7.7	9.4	3.5	0.22	0.61	4.3	0.01	0.07	974	104	262	8.8	30	44	270
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2006)	6 (2005)	6 (2005)	3	3
2009 (Jun-Aug)	East Branch Starkweather Creek at Madison	mean	5.8	18.5	7.4	3.2	3.0	0.10	0.37	3.4	0.04	0.04	1,093	148	265	2.6	17	19	477
		min.	4.3	16.5	7.4	1.1	2.8	0.03	0.27	3.2	0.04	0.01	1,060	137	242	<2.0	10	5	150
		max.	7.1	20.0	7.5	6.7	3.3	0.22	0.49	3.6	0.06	0.10	1,150	166	305	4.5	20	35	650
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2005)	6 (2005)	6 (2005)	3	3
2009 (Jun-Aug)	West Branch Starkweather Creek at Madison	mean	6.0	19.2	7.7	4.6	1.5	0.13	0.46	2.1	0.04	0.08	847	66	287	3.1	10	33	963
		min.	4.4	17.1	7.6	3.8	1.0	0.09	0.29	1.6	0.02	0.07	806	60	258	<2.0	<10	11	620
		max.	8.6	20.5	7.7	5.2	2.0	0.21	0.62	2.8	0.05	0.09	912	77	318	5.6	20	45	1,600
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2005)	6 (2005)	6 (2005)	3	3
2008 (May-Oct)	Door Creek near Cottage Grove	mean	10.2	16.2	7.9	8.1	4.1	0.08	0.48	4.6	0.06	0.10	817	49	337	7.3	13	20	790
		min.	7.6	12.3	7.5	3.8	2.1	0.05	0.34	2.9	0.03	0.08	769	46	315	4.4	<10	7	130
		max.	15.0	20.0	8.0	12.3	4.7	0.16	0.67	5.1	0.11	0.16	838	52	348	12.0	20	33	3,000
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
2010 (Apr-Aug)	Nine Springs Creek near Madison at Moorland Rd	mean	13.0	16.6	7.5	5.0	3.6	0.12	0.58	4.3	0.04	0.11	801	60	280	6.0	18	26	243
		min.	12.0	9.6	7.3	2.7	1.7	0.09	0.46	2.4	0.02	0.08	742	55	248	<2.0	<10	6	170
		max.	14.0	20.5	7.7	8.5	5.4	0.17	0.70	5.9	0.06	0.14	836	65	316	13.0	30	38	390
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2006)	6 (2006)	6 (2006)	3	3
2010 (Apr-Aug)	Spring (Dorn) Creek near Waunakee	mean	5.8	17.2	7.9	5.1	2.1	0.03	0.60	2.7	0.16	0.22	761	35	--	--	--	13	68
		min.	5.1	9.9	7.4	0.9	0.7	0.01	0.37	1.2	0.05	0.18	730	34				2	50
		max.	7.2	21.4	8.8	12.0	4.4	0.06	1.03	5.4	0.24	0.28	780	36				35	83
		# samples	3	3	3	3	3	3	3		3	3	3	3				3	3
2008 (May-Oct)	Yahara River near Stoughton	mean	524.3	19.6	8.7	9.4	0.4	0.06	0.58	1.0	0.02	0.10	565	49	185	16.1	27	14	49
		min.	348.0	14.9	8.2	6.8	0.2	0.01	0.54	0.8	0.00	0.06	487	49	165	7.3	10	7	20
		max.	757.0	25.7	8.9	10.3	0.6	0.18	0.63	1.4	0.07	0.15	748	50	205	34.0	40	17	75
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Attachment B-1. Stream Baseflow Water Quality Monitoring Results

Period of Record	Station		Flow cfs	Temperature Deg. C	pH s.u.	Dissolved Oxygen mg/L	NO3 + NO2 Nitrogen mg/L	Ammonia Nitrogen mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Dissolved Phosphorus mg/L	Total Phosphorus mg/L	Specific Conductivity (us/cm)	Chloride mg/L	Alkalinity as CaCO3 mg/L	Turbidity NTU	COD mg/L	Suspended Sediment mg/L	E. Coli col/100 ml
2007-2010	Badfish Creek CTH A	mean	--	12.3	7.9	9.6	12.4	0.03	0.81	13.2	0.17	0.25	1,446	259	291	--	2	6	913
		min.		9.1	7.6	7.2	10.9	0.02	0.67	11.6	0.04	0.13	1,351	242	272		2	11	186
		max.		15.6	8.1	11.3	13.8	0.05	0.95	14.6	0.41	0.51	1,566	280	310		2	3	2,130
		# samples		7	7	7	7	7	7	7	7	7	7	7	7		7 (BOD)	7	7
	MAUNESHA RIVER BASIN																		
2010 (Apr-Aug)	Maunesha River near Sun Prarie	mean	17.7	15.8	8.1	8.4	6.1	0.02	0.54	6.7	0.08	0.14	752	40	335	8.8	17	29	183
		min.	14.0	9.8	8.0	7.2	5.6	0.02	0.25	5.8	0.01	0.04	744	39	283	4.5	10	6	170
		max.	20.0	19.2	8.2	10.2	6.4	0.02	0.69	7.1	0.12	0.22	759	41	356	17.0	20	49	210
		# samples	3	3	3	3	3	3	3	3	3	3	3	3	5 (2006)	6 (2006)	6 (2006)	3	3
	KOSHKONONG CREEK BASIN																		
2007 (May-Oct)	Koshkonong Creek near Sun Prarie	mean	7.6	17.5	7.7	7.9	9.6	0.10	0.76	10.4	0.35	0.40	1,553	274	322	2.4	20	6	372
		min.	3.1	11.5	7.2	6.6	5.1	0.05	0.68	5.9	0.10	0.13	1,350	209	295	2.0	20	2	110
		max.	11.0	21.3	8.0	9.2	13.8	0.17	0.82	14.8	1.30	1.35	1,770	336	337	3.2	20	15	1,100
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	6
2007 (May-Oct)	Koshkonong Creek near Rockdale	mean	72.5	18.3	7.9	7.6	3.8	0.08	0.84	4.8	0.32	0.31	858	58	333	22.5	32	61	444
		min.	28.0	13.6	7.4	6.8	3.4	0.05	0.54	4.3	0.14	0.25	835	44	319	11.0	20	24	290
		max.	130.0	21.6	8.1	8.3	4.6	0.19	1.31	5.3	0.96	0.44	888	69	351	33.0	50	88	650
		# samples	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6	6	5

Attachment B-2

Stream Baseflow Metal and Miscellaneious Parameter Monitoring Results

Attachment B-2. Stream Baseflow Metal and Miscellaneious Parameter Monitoring Results*

Period of Record	Station	Arsenic (ug/L)	Boron (ug/L)	Cadmium (ug/L)	Chromium+3 (ug/L)	Cobalt (ug/L)	Copper (ug/L)	Iron (ug/L)	Lead (ug/L)	Manganese (ug/L)	Mercury (ug/L)	Nickel (ug/L)	Silica (mg/L)	Sulfate (mg/L)	Zinc (ug/L)
	Acute Toxicity Criteria for Aquatic Life**	339.8	--	9.65	16.02	--	30.45	--	208.9	--	0.83	2219	--	--	220.7
	Chronic Toxicity Criteria for Aquatic Life**	148	--	3.82	10.98	--	18.73	--	54.71	--	0.44	93.8	--	--	220.7
	WISCONSIN RIVER BASIN														
2006 (Aug)	Black Earth Cr. @ Black Earth	0.4	15	<0.04	0.6	0.3	1.4	111	0.1	28	<0.01	2	14	14	8
2007 (Aug)	Black Earth Ck at Stagecoach Rd Nr Cross Plains	1.1	8.4	0.01	0.4	0.2	<1.2	257	0.2	85	0.01	0	19	15	3
	SUGAR-PECATONICA RIVER BASIN														
2010 (n=6)	Sugar River Valley Rd.	--	--	0.08	1.4	--	2.6	--	0.9	--	--	1	--	20	9
2010 (n=6)	Badger Mill Creek @ STH 69	--	--	0.09	2.4	--	4.0	--	1.5	--	--	1	--	31	24
2010 (n=6)	Sugar River STH 69	--	--	0.08	1.4	--	6.9	--	1.1	--	--	1	--	16	18
2007 (Aug)	West Br. Sugar River @ STH 92 near Mt. Vernon	0.7	27.0	0.02	0.4	0.2	0.7	124	0.2	24.7	<0.01	1	7.1	18	<6
2008 (Aug)	Mount Vernon Creek near Nount Vernon	0.5	6.3	0.01	0.5	0.2	<1.2	282	0.4	40.1	<0.01	1	9.6	14	<6
2010 (n=6)	West Br. Sugar River @ CTH PB	--	--	0.08	1.6	--	6.2	--	1.5	--	--	1	--	19	16
	YAHARA RIVER BASIN														
2006 (Aug)	Yahara River at Windsor	1.1	12	<.04	0.9	0.4	1.3	225	0.3	54	<.01	2	17	27	<6
2005 (July)	Token Creek near Madison	2.0	12.0	<.04	0.7	0.5	0.8	90	0.1	13.7	<.01	3	11.5	24	<6
2008 (Aug)	Sixmile Creek near Waunakee	1.1	12.0	<0.01	0.4	0.2	0.8	111	0.1	39.5	<0.01	1	13.0	20	<6
2005 (July)	Pheasant Branch at Middleton	4.0	18.0	0.04	<.8	0.6	2.1	680	0.2	169.0	<.01	4	9.9	88	<6
2005 (July)	East Branch Starkweather Creek at Madison	0.2	37.0	<.04	<.8	0.5	1.2	120	0.4	47.6	0.0	3	4.3	32	4
200 (July)	West Branch Starkweather Creek at Madison	4.0	15.0	<.04	<.8	0.6	1.0	310	0.6	57.1	<.01	4	7.1	56	<6
2008 (Aug)	Door Creek near Cottage Grove	1.6	15.0	<0.01	0.4	0.2	0.7	214	0.2	63.8	<0.01	1	13.8	26	<6
2006 (Aug)	Nine Springs Creek near Madison at Moorland Rd	0.7	13.0	<.04	1.1	0.3	0.8	175	0.1	37.4	0.0	2	11.5	23	<6
2008 (Aug)	Yahara River near Stoughton	1.8	22.0	0.01	0.3	0.1	5.1	101	0.5	33.1	<0.01	1	11.1	18	<6
2010 (n=2)	Badfish Creek CTH A	--	--	0.10	0.8	--	10.6	--	0.7	--	--	1	--	33	46
	MAUNESHA RIVER BASIN														
2006 (Aug)	Maunesha River near Sun Prarie	1.8	14	<.04	0.9	0.6	1.6	356	0.3	154	<.01	2	18	39	<6
	KOSHKONONG CREEK BASIN														
2007 (Aug)	Koshkonong Creek near Sun Prarie	1.1	147	0.04	0.3	0.3	4.7	118	0.3	31	0.01	1	15	33	35
2007 (July)	Koshkonong Creek near Rockdale	3.0	34	0.04	1.2	1.0	2.1	1,240	1.3	174	0.01	2	11	45	7

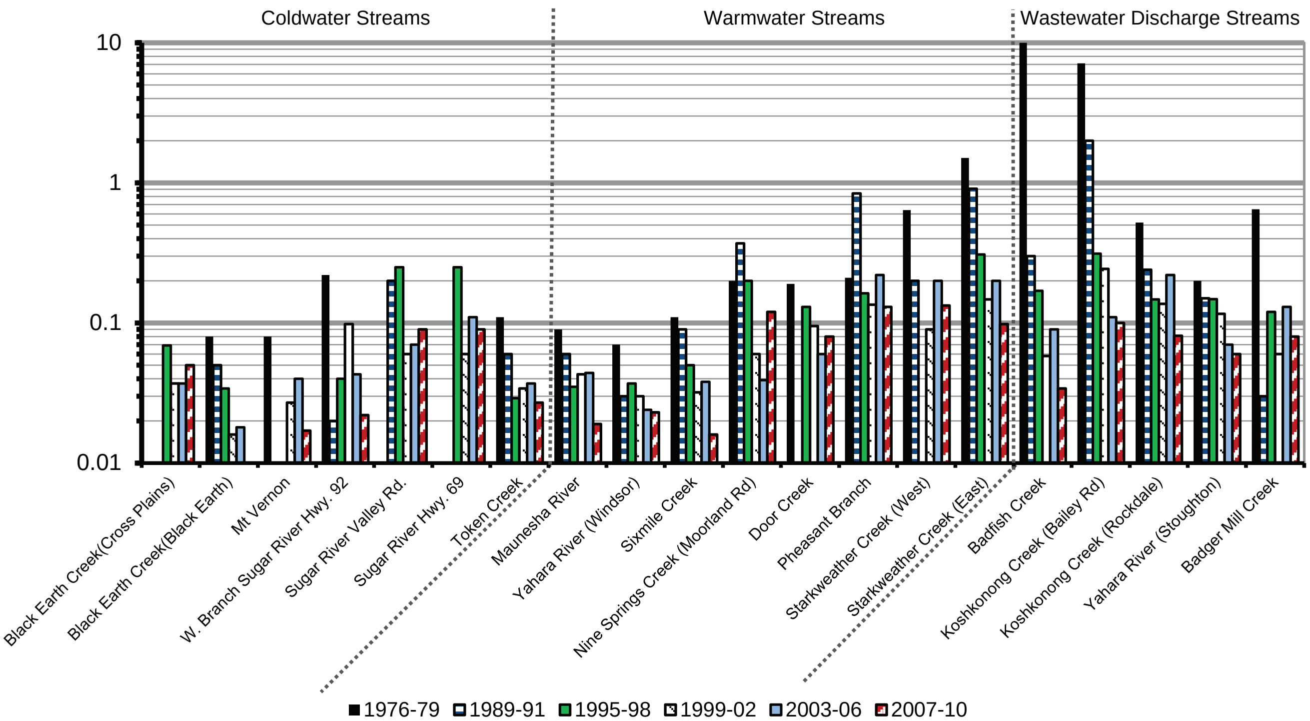
* Metal results are from a single sample collection unless otherwise noted/ Concentrations of metals are reported as total recoverable.

** As listed in State Administrative Code Chapter NR 105.

Attachment C

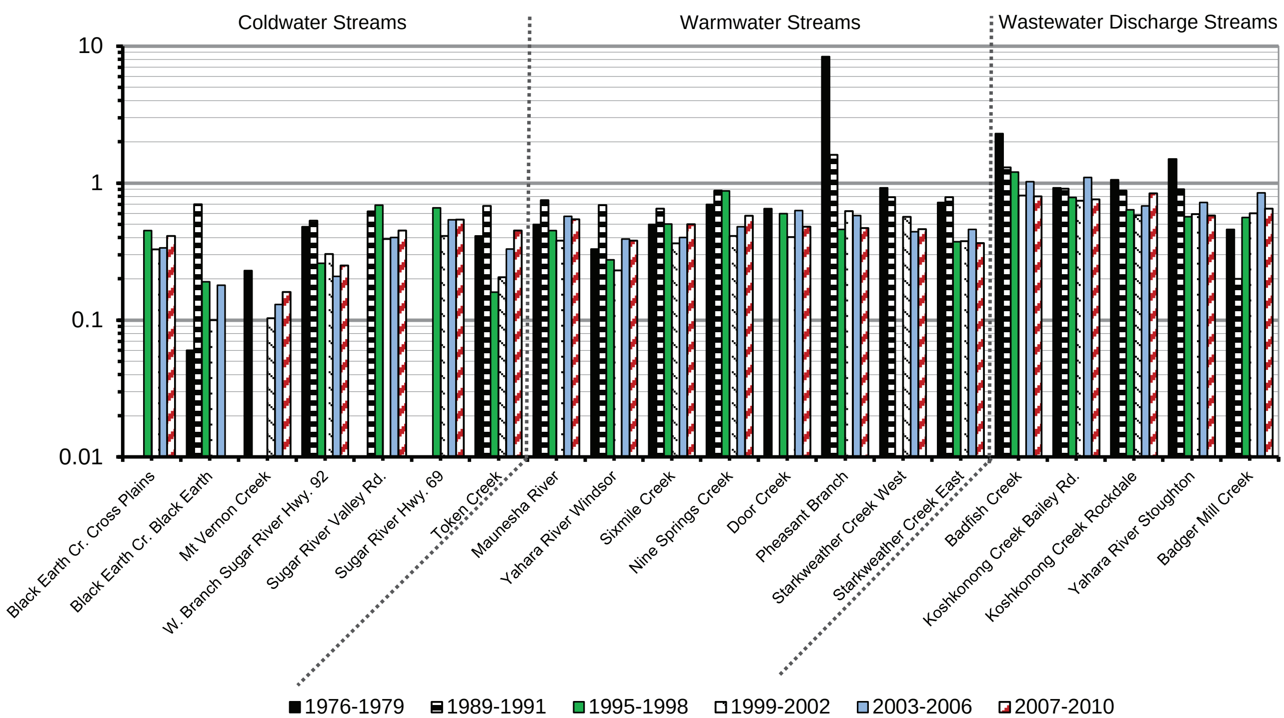
Historical Water Quality Charts

C – 1 Historical Comparison of Mean Baseflow Concentrations: Ammonia Nitrogen (mg/L)



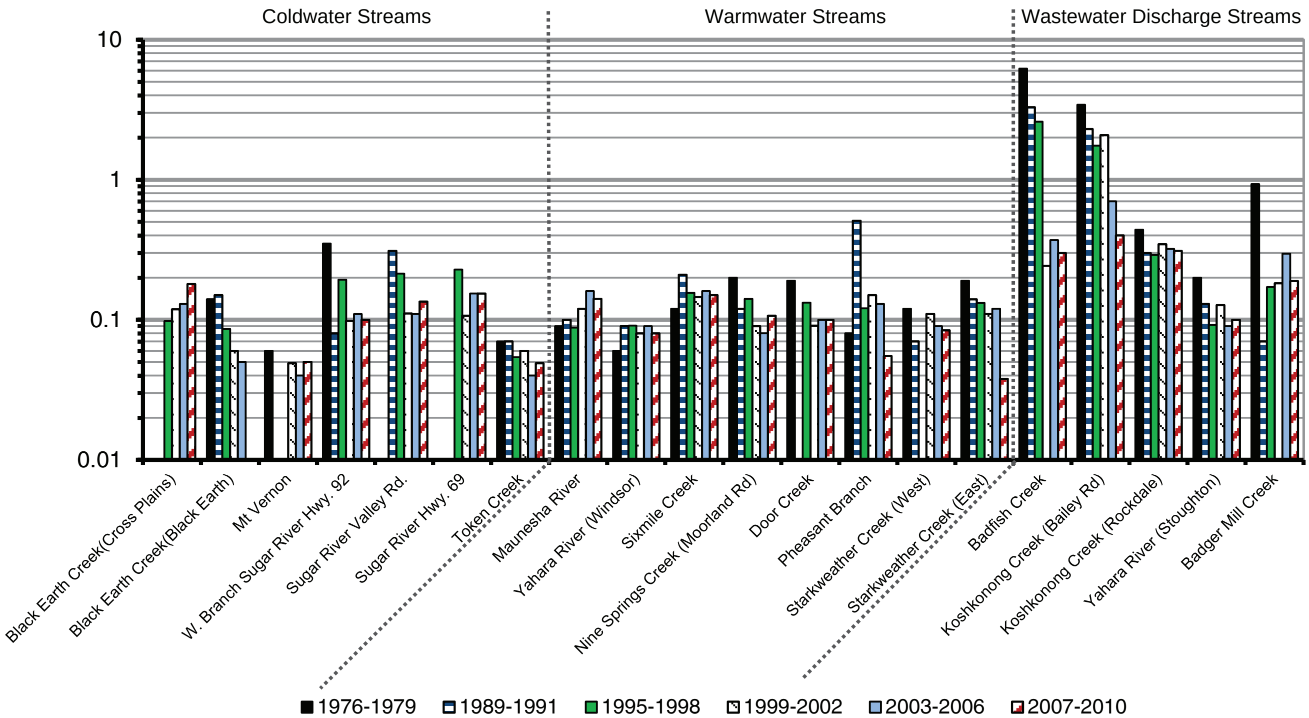
Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

C – 2 Historical Comparison of Mean Baseflow Concentrations: Organic Nitrogen (mg/L)



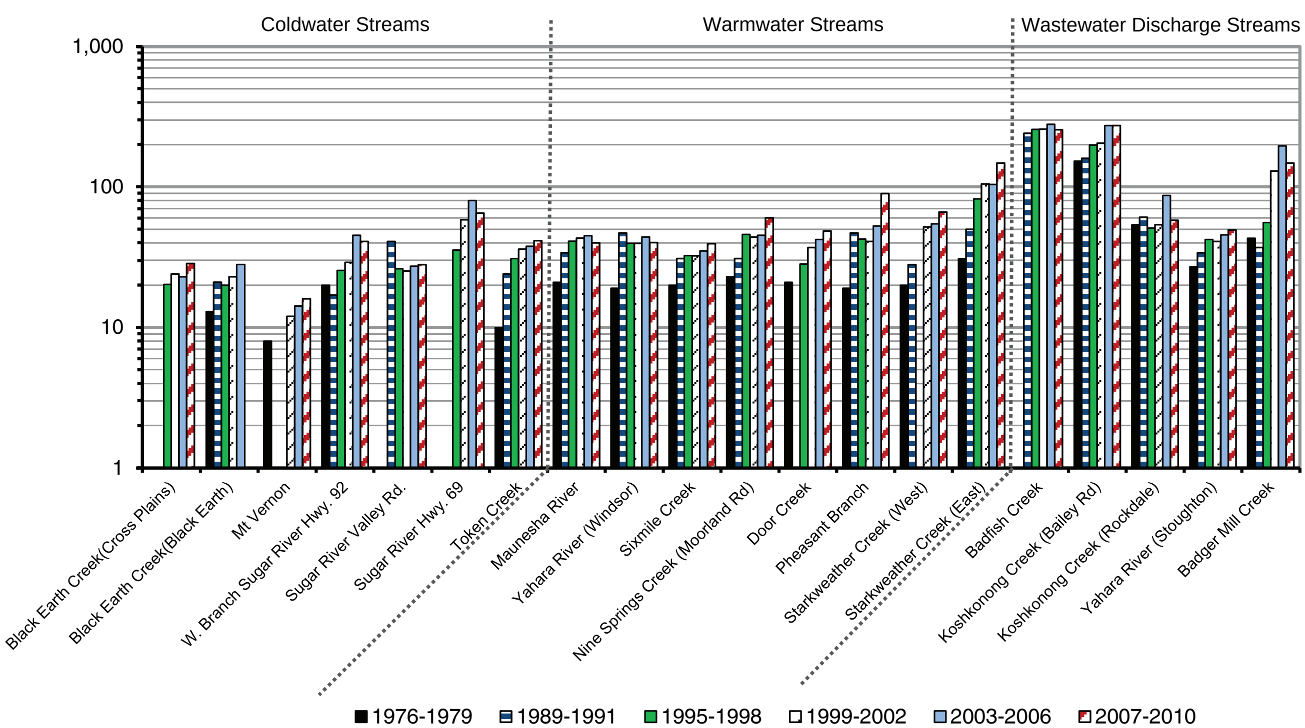
Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

C – 3 Historical Comparison of Mean Baseflow Concentrations: Total Phosphorus (mg/L)



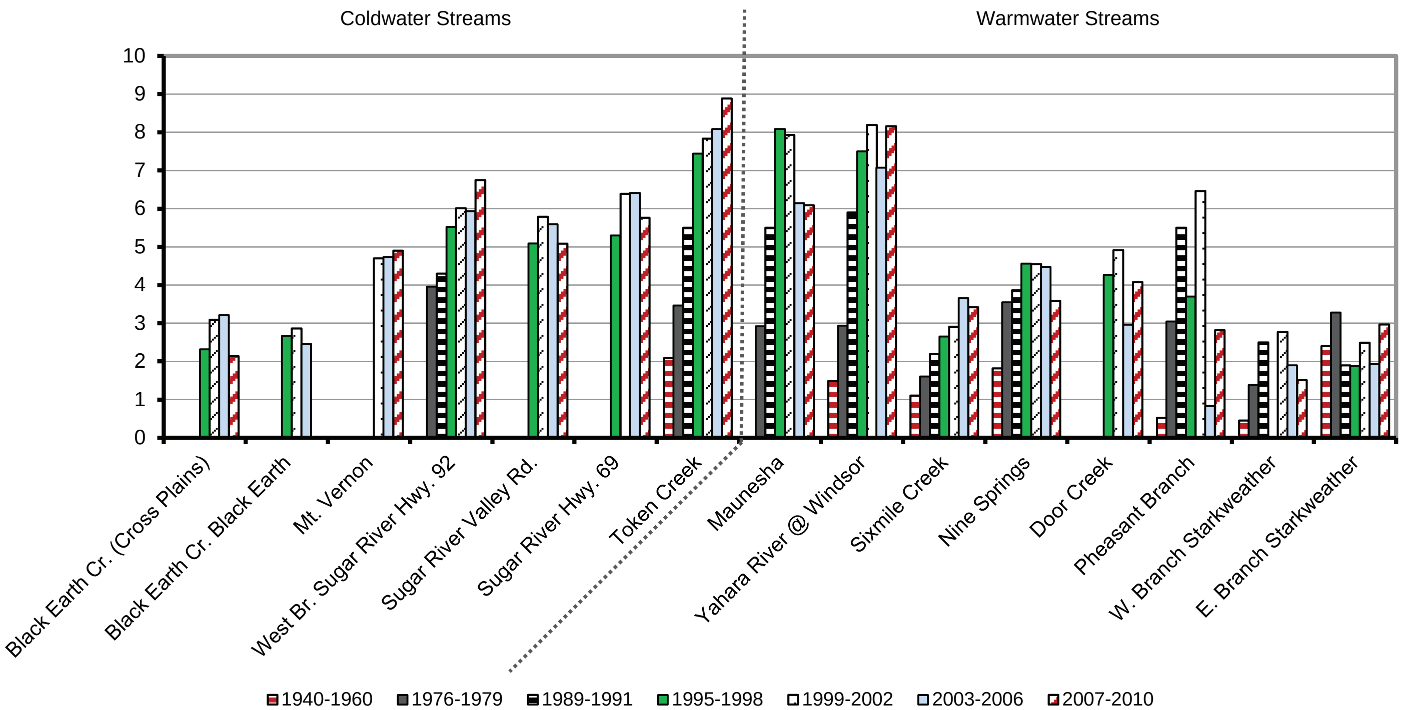
Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

C – 4 Historical Comparison of Mean Baseflow Concentrations: Chloride (mg/LI)



Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

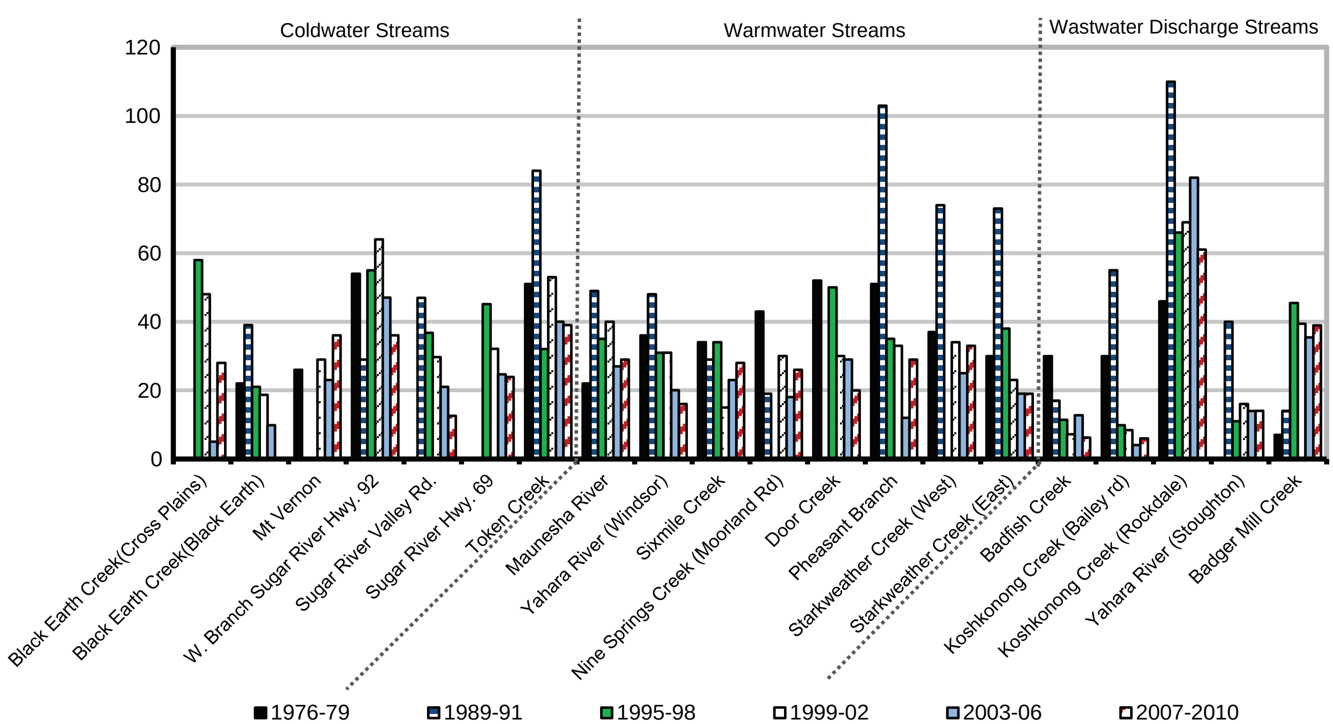
C – 7 Historical Comparison of Mean Baseflow Concentrations: Nitrate + Nitrite Nitrogen (mg/L)



Note: Groundwater contributions. Does not include wastewater discharge streams having greater than 15% effluent volume

Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

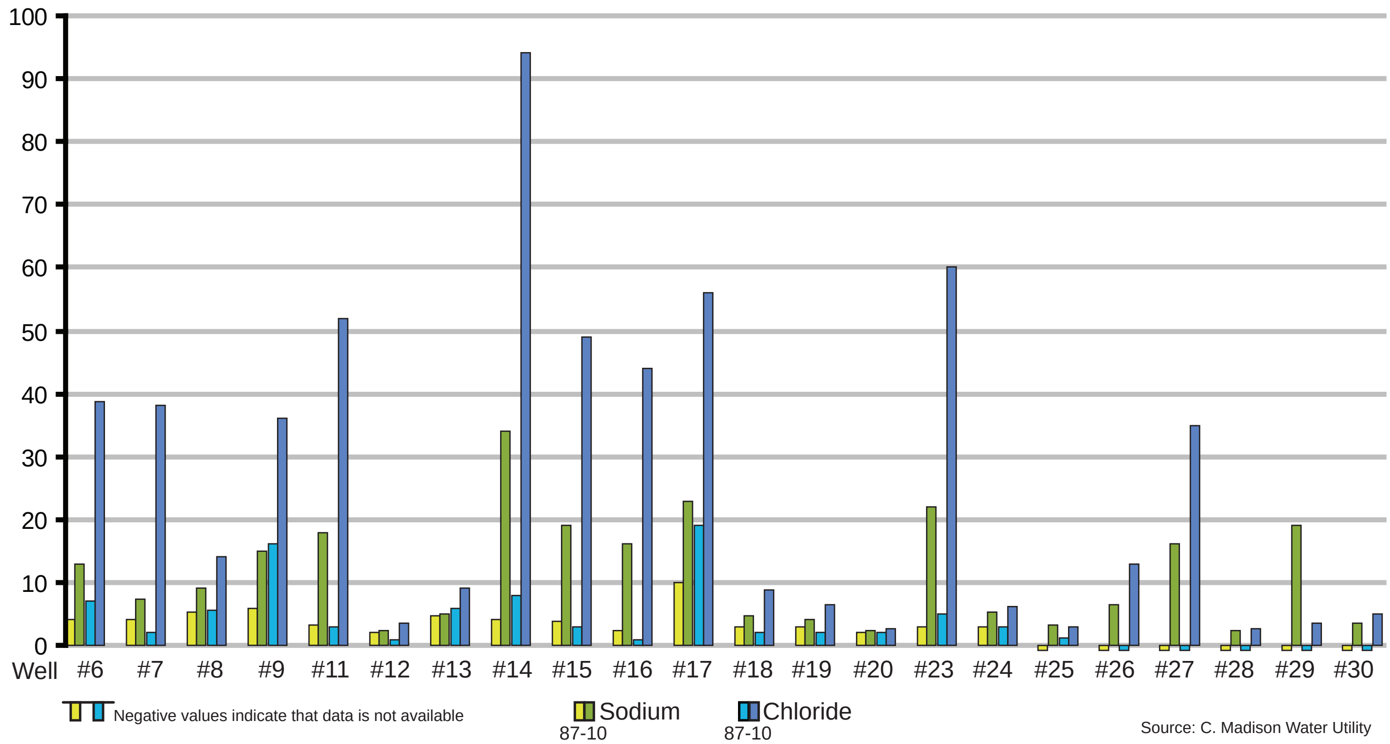
C – 8 Historical Comparison of Mean Baseflow Concentrations: Suspended Sediment (mg/L)



WDNR water quality criteria for Chloride is 395 mg/L (Chrmic) and 757 mg/L (acute), NR 105.06.

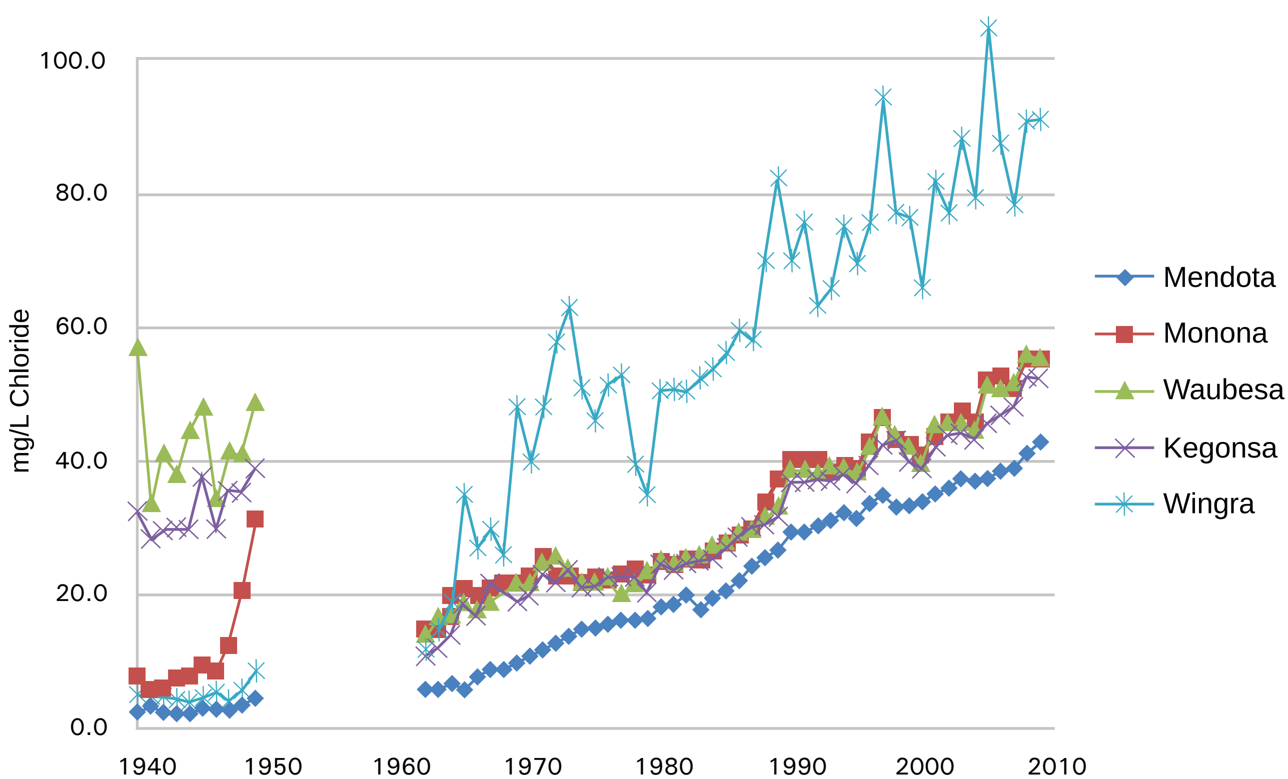
Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

C – 9 Sodium and Chloride Concentrations in Madison Wells Collected in 1987 and 2010 (mg/L)



Source: C. Madison Water Utility

C – 10 Historical Comparison of Lake Chloride Levels (mg/L)



Environment Canada: 1999 Canadian Environmental Protection Act, 1999. Priority Substances List Assessment Report. Road Salts.