APPENDIX B

SURFACE WATER QUALITY CONDITIONS

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INTRODUCTION

General Sources of Data

The sources of data and information used for this summary of surface water quality in Dane County are too numerous to list here, but some of the more comprehensive sources are noted to illustrate the scope of available information on Dane County's water resources.

The United States Geologic Survey (USGS) and the Wisconsin Department of Natural Resources (WDNR) have carried out substantial surface water quality monitoring in Dane County. The USGS has conducted baseflow water chemistry monitoring of several Dane County streams over the last several 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 authored several professional reports and papers pertaining to water resources in Dane County and statewide.

The WDNR conducts several 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; the Lower Wisconsin, Sugar-Pecatonica, and Upper and Lower Rock basins. However, these basin plans have not been updated recently. Nonpoint source (NPS) pollution abatement priority projects and reports also provided 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) for several has been conducting water chemistry, fish and macroinvertebrate monitoring of streams that receive its highly treated effluent. The Dane County Land Conservation Division of the Land and Water Resources Department also provided information on agricultural land use and stormwater management in Dane County.

Several changes in state administrative codes and county and municipal ordinances have occurred since 1992 that have greatly aided in the management efforts to protect Dane County water resources. Some of the more important ones are the creation of administration code NR 151 in 2002 and its subsequent revision in 2010 that dealt with agricultural and urban runoff statewide, and Chapter 14 of the Dane County Code of Ordinances that regulated manure management, erosion control and stormwater management in the county.

Mike, I think you were going to handle the remainder of the intro

Water Resources of the Koshkonong Creek and Maunesha River Basin

Watershed Descriptions

Map of the two watersheds needed

The Koshkonong Creek-Maunesha River watersheds are in eastern Dane County. It is in the drumlin and wetland 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[1] 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[2]. 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.

Base flow in streams in the watersheds is generally low and water temperatures are warm because groundwater recruitment is minimal[3]. 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 two primary soil associations are the Dodge-St. Charles-McHenry association and the Bavaria-Houghton-Dresden association. 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 of the watershed are 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[4]. This affects the quality of the biotic communities of the streams and of downstream receiving waters such as the Marshall Millpond, Lake Koshkonong and the Crawfish River.

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.

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[1] Schultz, 1986.
[2] WDNR, 2006. http://www.dnr.state.wi.us/landscapes/
[3] Dane County Regional Planning Commission, 1992.
[4] Robertson, et.al., 2006.

Incorporated areas totally or partially in the watersheds are the City of Sun Prairie, and the villages of Cottage Grove, Marshall, Cambridge and Rock Springs.

Table _____ Maunesha River Watershed Land Cover

Resource Characteristics	in acres
Agricultural	43,046
Hydric Soils	15,773
Other*	6,038
Wetlands	5,767
Woodland	2,673
Transitional**	2,270
Residential	1,442
Open water	249
Institutional/Governmental	137
Industrial	125
Outdoor recreation	69
Commercial	56
Size of watershed	**77,635**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

Maunesha River Watershed

Maunesha watershed map

Maunesha River. 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 empting 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 Stansky 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% of its land in agriculture[5]. Corn and soybeans are the primary crops. Soils in the watershed range from well-drained to very well-drained soils on the drumlin hills to poorly-drained to very poorly drained wet mineral and organic soils in low areas between drumlins. Each of the three towns through which the Maunesha flows have shown reductions in erosion and soil loss since 1988[6]. However, 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 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 it provides some additional base flow to the river. There are other small springs in the watershed that provide additional limited baseflow[7]. 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[8]. The Maunesha is also listed as a water or"paddling" trail by Dane County[9].

Maunesha River at Twin Lane Road

[5] Jones, 2008.
[6] Dane County Land &Water Resources Department, 2008
[7] Dane County Regional Plaaning Commission, 1988.
[8] WDNR, 2009.
[9] For more information about Dane County water trails, go to the Capitol Water Trails webpage http://www.capitolwatertrails.org/index.php

The 1992 Appendix B considered water quality of the Maunesha River to be generally good. It expressed a concern regarding the possibility of nighttime DO sags and low-flow conditions that could affect instream habitat and water quality[10].

The Department of Natural Resources (DNR) has classified the Maunesha as Warm Water Sport Fishery (WWSF) stream that is not supporting its existing or potential use[11]. Dane County Regional Planning Commission has classified the Maunesha as a class I stream[12] with protection as its general management objective[13]. The DNR placed the Maunesha River on the state state's list of impaired waters[14] in 1998. 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)[15] to address the water quality impairments of the Maunesha and other streams in the Rock River Basin. A target instream phosphorus level of 0.125 mg/l is being proposed[16] for the Maunesha River is and for other larger, low gradient streams in the Rock River basin. This level is significantly above the reference[17], background or potential, P value for streams recommended by Robertson et.al. of 0.03-0.04 mg/l for wadeable streams, but it reflects the realities of such low gradient streams in agricultural areas.

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[10] See the DCRPC's 1992 Water Quality Plan Appendix B for a more detailed description of pre-1992 conditions.
[11] Johnson, 2002.
[12] Go to http://danedocs.countyofdane.com/webdocs/PDF/capd/WBC_web.pdf to find more information.
[13] Dane County Regional Planning Commission, 2007.
[14] Section303 d of the Clean Water Act.
[15] For an explanation of Wisconsin's TMDL program, to http://dnr.wi.gov/org/water/wm/wqs/303d/pdf/TMDLOverviewFactSheet.pdf
[16] WDNR, 2006.
[17] 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.

The USGS conducted water chemistry monitoring at one Maunesha River station downstream of USH 151 in 2002 and 2006. The results did not indicate a DO impairment at this location. Twelve DO measurements were taken in the two years with the DO ranging between 6.2 to 12.7 mg/l, with an average DO of 7.75 mg/l. Monitoring for total P showed a range of 0.07-0.23 mg/l with a Total P average of 0.17 mg/l. Organic nitrogen levels have declined between 1992 and 2006 while total phosphorus levels have increased somewhat based on USGS data. Suspended sediment levels in the stream have also declined significantly between 1992-2006[18].

The DNR has done 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 of the Deansville Marsh, and at CTH TT downstream of the marsh. The Hilsenhoff biotic index[19] (HBI) scores were 4.69 (good water quality) and 6.83 (fairly poor water quality with significant organic pollution) respectively[20]. Macroinvertebrate Index of Biotic Integrity was also done at these two sites in 1998. Those IBI scores were 4.27 and 3.98 respectively. These scores indicate better water quality about 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. IBI Monitoring was done in 2007 at an unnamed tributary at Greenway Road north of Deansville Marsh. Intermittent IBI monitoring at the Greenway Road Site indicated good water quality and habitat conditions[21].

Schumaker Creek is a small stream that rises in the Town of Medina and flows about three miles northeast to the Maunesha River at the Marshall Millpond. Much of its length is channelized to facilitate agricultural drainage. The creek flows through a wetlands complex downstream of Dane CTH TT before entering the millpond. Nothing is known of conditions in the creek. It is suspected of having poor instream habitat conditions due to the agricultural nature of its small sub-watershed.

Spring Creek rises in the Town of Deerfield and flows north to join the Maunesha River below the Marshall Millpond. It has been channelized for most of its length to facilitate agricultural drainage. Monitoring done in 1988 indicated "fair" water quality. No recent monitoring or assessment has been done. The DNR has classified it as a warm water forge fishery (WWFF) stream.

Stransky Creek. Stransky Creek is a small ditched creek that joins the Maunesha just upstream of the Marshall Millpond. Much of its length has been channelized to facilitate agricultural drainage. It is classified as limited forage fishery (LFF) stream by the DNR. The stream has a

[18] From CARPC summary of USGS monitoring station data.
[19] Hilsenhoff, 1987.
[20] Data from WDNR SWIMS Data Base, 2010.
[21] WDNR South Central Region Water Resources files, 2010.

low base flow. IBI Monitoring 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.

Stony Brook. Stony Brook is a small stream that rises on the Dane-Jefferson flowing south then east into Jefferson County where it empties into the Maunesha River in the Waterloo State Wildlife Area in Dodge County. 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.

Marshall Millpond. The Marshal Millpond is a 185 acre impoundment of the Maunesha River in Marshall, Wisconsin. 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[22]. WDNR fish survey done in 2005 found the lake's fishery was dominated by common carp[23]. Some panfish and largemouth bass have also been noted.

Watershed Summary. 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[24], natural vegetation or a combination of natural vegetation and forage or biomass crops[25], can improve water quality and instream aquatic communities. Buffers may also increase stormwater infiltration, especially if planted to deep-rooting native prairie vegetation. Planting native trees on drumlin slopes may also encourage more infiltration needed to maintain stream baseflow.

If the number and intensity of warm weather storm events increases as predicted by some, water quality improvements already gained may be lost due to increased and more intense runoff events. No evaluation of what impacts removal of the Waterloo Millpond dam had on instream habitat, water quality and fisheries downstream of the Marshall Millpond dam have been done.

Crawfish River Watersheds

[22] WDNR. Upper Rock River Basin webpage, http://dnr.wi.gov/org/gmu/uprock/surfacewaterfiles/watersheds.html 2010.
[23] WDNR, Fishery Management Data Base, accessed in 2010.
[24] Weigel, et.al, 2005.
[25] Weigel, 2003.

Small portions of two Crawfish River watersheds are in the Koshkonong Creek – Maunesha River Basin, The Upper Crawfish River Watershed and the Lower Crawfish River Watershed. These two partial watersheds are lumped together 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. Dominant land use of both is agriculture.

Table _____ Crawfish River Watersheds Land Cover

Resource Characteristics	in acres
Agricultural	8,538
Hydric Soils	2,193
Other*	800
Wetlands	682
Woodland	461
Transitional**	276
Residential	83
Open water	12
Institutional/Governmental	3
Industrial	6
Outdoor recreation	0
Commercial	1
Size of watershed in Dane County	**10,205**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

Mud Creek originates in Dane County, flows northeast into Dodge County, and enters the Crawfish River. Three of Mud Creek's ten miles are in Dane County. The stream is classified as a warm-water forage fishery, but agricultural nonpoint pollution and associated habitat and sedimentation impairments keep it from being classified as a warm-water sport fishery. The DNR considers conditions in the creek to be poor and has placed it on the state's list of impaired waters (303d).

Nolan Creek is a 5 mile long stream in Dane County supporting a 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. Its current biological use is as a limited forage fishery (LFF) but the DNR believes it can be a warm water sport fishery.

Koshkonong Creek Watershed

Watershed map here

The Koshkonong Creek watershed is in the drumlin and marsh physiographic region of Dane County. The creek and its tributaries drain approximately 138 square miles in the drumlin-marsh area of eastern Dane County. Base flow in streams is generally low with warm water temperature due to low groundwater base flow 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.

Table _____ Koshkonong Creek Watershed Land Cover

Resource Characteristics	**in acres**
Agricultural	76,509
Hydric Soils	30,189
Other*	12,774
Wetlands	10,475
Woodland	7,776
Transitional**	5,771
Residential	4,922
Open water	1,046
Institutional/Governmental	512
Industrial	885
Outdoor recreation	1,019
Commercial	424
Size of watershed in Dane County	**111,712**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

The DNR breaks the Koshkonong Creek watershed into two separate watersheds; the Upper Koshkonong and the Lower Koshkonong Creek watersheds. We have combined them for this report. Land use is primarily agricultural and 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 and there have been small improvements for some water quality parameters[26]. Even so, water quality and instream habitat are still severely affected by agricultural sediment and nutrient loading.

Soil Loss map from LCD's Land and Water Management Plan (?)

Increasing stormwater flow and pollutant loading from urbanizing parts of the watershed may is becoming a problem. The Sun Prairie and Cottage Grove areas have seen rapid urbanization in the past twenty years. (See Table ___.___). The increase in impervious surfaces has resulted in increased runoff to receiving waters. New development in Dane County must meet the erosion and stormwater management requirements of the county's Erosion Control and Stormwater Management Ordinance. The ordinance[27], enacted in 2006, was developed to protect the county's surface and groundwater and wetlands. Stormwater management practices at new developments must be designed to meet pre-development runoff rates and trap 5 micron and larger particles and prevent them from getting into surface waters[28]. Infiltration of runoff is encouraged in order to try to maintain stream base flow and temperature. New developments are required to have stormwater detention and retention ponds to reduce runoff reaching surface waters. No comprehensive review of the performance of these measures to determine their actual effectiveness.

Koshkonong Creek

Koshkonong Creek rises on the south and east edge of the City of Sun Prairie. It flows southerly about 42 miles, draining about 138 square miles in eastern Dane County before joining the Rock River at Lake Koshkonong in Rock County[29]**.** 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.

Land use is predominately agriculture except near Sun Prairie and Cottage Grove, both experiencing rapid urban development. A 2004 report by the Dane County Regional Planning Commission modeled the potential impact of groundwater withdrawal on Koshkonong Creek

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[26] Data from CARPC files.
[27] Chapter 14, Dane County Code of Ordinances
[28] Dane County Land and Water Resources Department, 2007.
[29] Information from the Dane County DCiMap, an online geographic information system (GIS) http://dcimap.co.dane.wi.us/dcimap/index.htm

baseflow[30]. The 2030 simulated baseflow near Bailey Road would be 0 cubic feet per second (cfs) compared with an estimated 2004 baseflow of 0.24 cfs. This shows a need for new developments above Ridge Road in the Town of Cottage Grove to have stormwater practices that maximize stormwater infiltration in order to maintain existing stream base flow.

Koshkonong Creek is classified as a "limited aquatic life" (LAL) stream from its headwaters to CTH T where the classification changes to WWSF. Flow is intermittent in its headwaters reach with industrial cooling water 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 natural limiting conditions such as a flat gradient, low base flow 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 surface water. Dane County Land Conservation Department information shows significant soil loss reduction in the towns[31] through which the creek flows. This is an indication of improved farming practices taking place in the watershed.

The Sun Prairie wastewater treatment plant (WWTP) discharge treated effluent to Koshkonong Creek, making it an effluent dominated stream in its headwater reach. The stream also receives urban stormwater runoff from Sun Prairie and 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.

Instream ammonia levels measured by USGS have declined significantly since 1992 at both Bailey Road near Sun Prairie and at Rockdale. Total phosphorus and suspended sediment have also declined between 1992 and 2006. DNR rotational monitoring done in late 2009 and early 2010 at Jefferson CTH O just east of the Dane-Jefferson line, showed an average total P to be 0.115 mg/l. The total P values ranged from 0.073 mg/l to 0.214 mg/l. The average total P is slightly below the target in the Rock River TMDL.

The headwaters reach of Koshkonong Creek does not exhibit good water quality. Fish-IBI and HBI monitoring[32] done in 2000 at Bailey Road downstream of the Sun Prairie WWTP, a channelized headwaters reach, indicated poor water quality conditions (HBI=7.9; IBI=1.19), due to very significant organic pollution. USGS did water chemistry monitoring downstream of the Sun Prairie facility in 1999, 2003 and 2007. The data shows an improvement in total P loading to Koshkonong Creek. The average total P in 1999 was 2.08 mg/l, while in 2007 it had dropped to 0.39 mg/l. The 2007 total P levels are significantly above the proposed TMDL total P goal for

[30] Dane County Regional Planning Commission, 2004.
[31] See the Dane County Land and Resource Management Plan, 2008.
[32] All IBI monitoring data are from the DNR's SWIMS data base.

low gradient streams in the Rock River basin. One aquatic invasive species has been found in the creek, the rusty crayfish[33].

Koshkonong Creek at CTH

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Macroinvertebrate monitoring at CTH TT (WWSF reach) in 1997 and 2003 showed HBI values 5.39 and 6.08 respectively indicating "fair" water quality but with fairly significant organic pollution. Fish IBI scores at the same sites and dates (2.99 in 1997 and 4.11 in 2003) also indicated "fair" water quality conditions. Other biotic index monitoring on Koshkonong Creek in Dane County indicate similar water quality conditions. (See Table ___.___, BI Monitoring data). 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.

Dane County has proposed to establish a Koshkonong Creek Natural Resources Area stretching from the south edge of the City of Sun Prairie south to Interstate 94. The purpose would be flood mitigation, wetland restoration potential and future recreational opportunities (Dane County, 2009). Dane County's park and recreation plan and the DNR's Glacial Heritage Area plan suggest

[33] Go to http://dnr.wi.gov/invasives/aquatic/ for more information on invasive species in Wisconsin.

establishing a "paddling" trail on Koshkonong Creek if access were improved. The plan also proposes to provide more shore fishing opportunities along the creek[34].

Koshkonong Creek and Rockdale Millpond

The Rockdale Dam on Koshkonong Creek formed an impoundment of about 72 acres[35] with a maximum depth of 5 feet and an average depth of about one foot. 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[36]. 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[37]. The creek has been re-establishing a channel in the impoundment bed since dam breaching and 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[38]. Removal of the dam led to high mortality for mussels both within the former impoundment and in downstream reaches due to silt smothering them (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. Water Action Volunteers have been monitoring three locations on Koshkonong Creek looking at DO, temperature, a simplified biotic index and simplified habitat rating. DO monitoring by WAV members showed one instance where DO was below full aquatic life (FAL) standards at 4.5 mg/l over a four year period between 2005-2009. Limited WAV biotic index monitoring indicated generally "fair" water quality at the sites[39].

One of the goals of the Rockdale dam removal was to restore the exposed impoundment bed to prairie and 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

[34] WDNR, 2009.
[35] Another estimate of the impoundment area is 104 acres. See Orr and Koenig, 2006.
[36] Doyle, et.al., 2003.
[37] WDNR, 2002.
[38] Suresh et.al., 2004.
[39] See the Water Action Volunteer website http://www.uwex.edu/erc/wavdb/ .

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[40].

Koshkonong Creek Upstream of Rockdale Dam Site

Koshkonong Creek Summary. 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. USGS water chemistry indicate a small 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 2010[41] Additional improvements could occur with more aggressive stormwater management measures in and around Sun Prairie, Cottage Grove and Deerfield, 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

[40] Orr and Koenig, 2006.
[41] Steve Fix personal observation, 2010.

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 improve water quality conditions of Koshkonong above CTH T. However, if the number and intensity of warm weather storm events increases as predicted by some, improvements already gained may be lost.

Increasing urban stormwater runoff from developing areas will also affect instream conditions. Sun Prairie, Cottage Grove, and the towns abutting them need to require stormwater control measures that limit runoff and promote infiltration. A broad study is needed to assess current conditions in Koshkonong Creek upstream and downstream of the former Rockdale millpond to develop an evaluation report documenting 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 northeast to join Koshkonong Creek northeast of the Village of Deerfield. The Deerfield WWTP discharges treated effluent to Mud creek via an effluent channel. Mud Creek's watershed is about 22 square miles and is predominately agricultural. The stream has a low gradient of about six feet/mile. Much of the stream has been ditched and wetlands drained for agriculture. Polluted agricultural runoff is considered the primary threat to existing water quality[42]. There is no measured flow data for Mud Creek. A large stand of Angelica (*Angelica atropurpurea*) was observed near Hillcrest Road[43] indicating a groundwater seep or fen helping to maintain the stream's limited baseflow. Extreme fluctuations in flow have been observed after major runoff events indicating the effectiveness of the agricultural drainage systems.

The DNR re-classified Mud Creek to warm water forage fishery (WWFF) stream in 1988 indicating some water quality improvement. Intermittent stream fish IBI scores calculated from 1998 and 2004 monitoring at Hillcrest Road indicate excellent water quality conditions at that location.

Saunders Creek

Saunders Creek rises in southeast Dane County and flows 10 miles south to join the Rock River south of Edgerton. 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

[42] Johnson, 2002.
[43] Steve Fix, Personal Observation, 2010.

ditching, carry sediments to the stream, affecting water quality. Some remnant wet meadows between Edgerton and Albion and above Albion still exist, providing limited Northern pike spawning habitat wetlands. The DNR has classified the lower 5 miles of the stream as warm water sport fishery stream (WWSF), although sedimentation has probably has a significant impact on instream habitat and water quality. Fish monitoring done in 2003 at USH 51 in Rock County showed a fish assemblage dominated forage fish with few game fish. Three intermittent IBI samples at three locations between 1998 and 2003 indicated very good fish biotic integrity. HBI monitoring done near Edgerton in 1998 and 2003 indicated "fair" water quality.

Unnamed Tributary to Koshkonong Creek (Goose Lake Trib)

The Goose Lake Trib 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. Monitoring done in 1998 at CTH BB on the downstream end of the wildlife area showed intermittent IBI showed "excellent" water quality conditions. Two pollution intolerant species and one species on the state's Special Concern list[44], the banded killifish, were found. Populations of the banded killifish has been documented to be in decline in southern Wisconsin[45]

[44] "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 http://dnr.wi.gov/org/land/er/biodiversity/ .

[45] Marshall et al., 2004.

Table ____. Streams of the Maunesha River Watershed (Upper Rock River Basin)

This table includes streams in the Lower Crawfish Watershed

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish and Aquatic Life Conditions	303(d) Status	Impairment Impact	Impairment Source	F-IBI(No)*/HBI (No.)*
Maunesha River	31.8 mi.	WWSF	WWSF	No	Poor	Y	Degraded habitat	Total P, Hydr.Mod, Tot.Sus.Solids,Sediment	60#(1)/5.80(3)
Mud Creek (York)	10.8	WWFF	WWSF	No	Poor	Y	Degraded habitat	HydroMod, Sediment, Tot.Sus.Solids	--/--
Nolan Creek	10	LFF	WWSF	No	Poor	N	Degraded habitat	AgNPS	--/--
Schumacher Creek	3	Unknown	Unknown	---	Unknown	N	Degraded habitat?	??	--/--
Spring Creek	4	Unknown	WWSF	---	Unknown	N	Degraded habitat?	??	--/--
Stony Brook	15	LFF	WWSF	No	FAL(default)	Y	Degraded habitat	Sediment, Tot.Sus. Solids	/6.54(2)
Stransky Creek	2	LFF	Unknown	---	FAL(default)	N	Degraded habitat algae	Sediment, nutrients	25(2)#/6.96(2)

- =Average score

= Intermittent IBI score

Table ____. Streams of the Koshkonong Creek Watershed

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish and Aquatic Life Conditions	303(d) Status	Impairment Source	Pollutant	F-IBI/HBI (No.)
Koshkonong Creek	0-23	WWSF	WWSF	Partially	Poor	N	UrbStormwater,WWTP Channelization	Tot-P, Tot.Sus Solids, Habitat	/7.98(1)
	23-29	LAL	LAL	Fully	Poor		Degraded habitat, algae	Habitat, TotSus.Solids,	48(5)*/5.92(8)
Mud Creek (Deerfield)	9	WWFF	WWFF	Partially	Poor	N	Degraded habitat	Tot.P, Sediment	97(3)#/4.65(1)
Saunders Creek	0-5	WWSF	WWSF	Partially	Poor	N	Degraded habitat	Tot.P, Sediment	86(3)#/5.74(2)
	5-15	WWFF	WWFF						

*= 4 intermittent IBI, 1 warmwater IBI

#= intermittent IBIs

Water Resources of the Yahara River Basin

The Yahara River basin occupies the central one-third of Dane County. It is in the drumlin and wetland 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. 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[46]. 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. 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 along the western edge of the basin, separating it from the mostly non-glaciated Sugar River Basin. There were large wetland areas adjacent streams and lakes. Many wetlands have been ditched and drained for agriculture and development.

The soils of the Yahara basin are highly productive. The two primary soil associations are the Dodge-St. Charles-McHenry association and the Bavaria-Houghton-Dresden association. The Dodge-St. Charles-McHenry association is characterized by well drained and moderately well drained silt loams. These soils formed in the varied landscape of drumlins and ground, end and recessional moraines. The Dodge and St. Charles soils are highly fertile and very productive. Sable silty-clayey-loam soil is a poorly drained hydric soil often found in depressions and low-lying areas. The Bavaria-Houghton-Dresden association formed mainly in glacial outwash

[46] WDNR, 2006. http://www.dnr.state.wi.us/landscapes/

material near streams and moraines. Soils of this association vary from the well drained Bavaria and Dresden soils to the very poorly drained Houghton muck soil.

MAP OF YAHARA BASIN HERE; Mike , one of your aerial photos too??

Land Use

The northern third of the Yahara River basin is primarily agricultural. Dairying, corn and soybean production are the primary agricultural activities. These agricultural nonpoint sources include cropland erosion and livestock operations. There are several rapidly growing communities in the northern part of the basin. The primary source of pollution is erosion from agricultural lands from agricultural lands, contributing sediment and nutrients to streams and downstream lakes[47]. Urban communities in the northern third are the City of DeForest, and the Villages of Waunakee and Dane. The growing northwest third of the City of Sun Prairie and the unincorporated communities of Windsor, Westport and Morrisonville are also in this northern portion. Waunakee is one of the fastest growing communities in Dane County. Most wastewater from this portion of the basin is sent to the Madison Metropolitan Sewerage District's (MMSD) Nine Springs treatment plant. Urban stormwater runoff and runoff from construction sites may cause local problems.

(a table showing population growth of cities, villages and towns in Yahara basin)

The central part of the basin, the area surrounding Lakes Mendota, Monona, Waubesa, Upper and Lower Mud and Wingra, is predominantly urban. It includes much of the cities of Madison, Middleton, Monona and Sun Prairie, and the Village of McFarland. Urban nonpoint sources of pollution, runoff from impervious surfaces and erosion from construction and urban development activities affect water quality and instream habitat of the urban streams in this part. 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. Almost all municipal wastewater at MMSD's Nine Springs facility and diverted around the Yahara chain of lakes.

[47] DCRPC, 1992.

The southern portion of the Yahara River 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, cropland erosion and from livestock operations. Two incorporated communities, the City of Stoughton and the Village of Oregon, are in this portion. While both communities are growing, they are not showing the very rapid development seen in the Waunakee-Sun Prairie-Cottage Grove area. Both Stoughton and Oregon discharge treated municipal effluent to surface waters. MMSD also discharges its highly treated effluent to Badfish Creek.

The surface water resources of the Yahara River Basin represent the most heavily used and arguably, highly valued in Dane County. The Yahara lakes are the most heavily used recreational resources in the region, and their scenic beauty is one of the prized assets of Dane County.

Upper Yahara River Watersheds

Map showing both watersheds here

There are two watersheds in the upper third of the Yahara River Basin. They are the Yahara River-Lake Mendota Watershed (hereafter referred to as the Upper Yahara River Watershed) that includes all land that ultimately drains to the Yahara River above Lake Mendota, and the Six Mile and Pheasant Branch Creeks Watershed. The Upper Yahara River Watershed covers about 85 square miles, while the Six Mile and Pheasant Branch Creek watershed is also about 85 square miles in size. Communities wholly or partially in these watersheds are the villages of Waunakee. DeForest, and Dane, parts of the cities of Middleton and Sun Prairie, the unincorporated community of Morrisonville, and the towns of Windsor, Westport, Burke, Vienna, Springfield and Middleton. Streams in the watersheds are the Yahara River, Token Creek, Harbison Tributary, Sixmile Creek, Dorn Creek and Pheasant Branch Creek. There are several unnamed tributaries, many having been ditched or straightened for agricultural purposes.

Land use. Land use in the Upper Yahara River and the Six Mile and Pheasant Branch Creek watersheds is predominately agricultural. The soils of the two watersheds are generally highly productive. They are high in phosphorus content. Corn and soybeans are the principle crops grown in the watersheds. Animal livestock operations, dairying and beef, are a major agricultural activity. There are several large dairy and beef operations in the watersheds including six facilities that require a concentrated animal feeding operation (CAFO)[48] discharge permit from the DNR. Additional large operations requiring a CAFO discharge permit are expected in Dane County.

A CAFO facility can cause significant adverse impacts on receiving waters. The DNR CAFO permit specifies requirements for proper runoff control, manure storage and manure management to ensure there are no discharges of pollutants to surface water and to protect groundwater. Once the permit is issued, the owner or operator is required to submit a finalized Manure Management Plan based on the conditions of the issued permit, a monitoring and inspection program, and annual reports summarizing the land spreading of manure to ensure compliance with the permit. Operators must also submit an application for permit renewal every five years, and must notify the DNR of any proposed construction or management changes.

There has been rapid residential and commercial urban development in a belt running from Middleton to Waunakee to DeForest to Sun Prairie. There are no significant impacts on surface waters from wastewater discharges in this part of the basin[49]. Most wastewater is transmitted to the Madison Metropolitan Sewerage District's Nine Springs wastewater treatment facility Rapid urban development can lead to water resources problems due construction site erosion and runoff from impervious surfaces. Runoff conveys sediment and nutrients to surface water potentially adversely affecting instream habitat morphology and biotic communities. Each of the large communities has stormwater management plans or plan components and ordinances. Unincorporated areas are covered by Dane County's stormwater ordinances[50]. In addition, several of the municipalities jointly hold a Group Municipal Storm Water Discharge permit from the DNR. The combination of these regulatory requirements is aimed at reducing the pollutant loading and volume of stormwater runoff reaching surface waters. No comprehensive analysis of the DNR group permit stormwater implementation efforts and requirements, or of individual municipal stormwater management goals, has been done.

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[48] A CAFO is a livestock operation with 1,000 or more animal units. Seven hundred dairy cows or 1,000 beef cattle equal 1,000 animal units. See http://dnr.wi.gov/runoff/ag/faq_cafo.htm for a complete list.
[49] Dane County Regional Planning Commission, 2005.
[50] See Chapter 14, Dane County Code of Ordinances http://www.countyofdane.com/unified/information/ordinances.aspx

Lake Mendota Priority Watershed Project

The Yahara River-Lake Mendota watershed and the Pheasant Branch and Six Mile Creek watersheds were selected as a DNR nonpoint source pollution abatement priority watershed project in 1993, called the Lake Mendota Priority Watershed Project. The goal of the project was to reduce phosphorus and sediment loading to Lake Mendota, the largest and furthest upstream of the Yahara chain of lakes. The watershed encompassed a 230 square mile drainage basin, 88% of which is in Dane County. Approximately 77% of the watershed is agricultural or otherwise undeveloped.

An estimated about 72,000 pounds of phosphorus and 9,600 tons of sediment were entering Lake Mendota annually[51]. The five sub-watersheds with the highest estimated phosphorus delivery rates were Pheasant Branch Creek (6,686 pounds per year), Sixmile Creek (6,374 pounds per year), Dorn Creek (6,299 pounds per year), Token Creek (4,699 pounds per year) and the Yahara River (4,437 pounds per year) sub-watersheds. This pollutant loading resulted in excess sedimentation nutrient loading affecting instream habitat and water quality. The excessive phosphorus loading to the lake resulted in an increase in noxious blue-green algae blooms, excessive aquatic weed growth and decreased water clarity in the lake. Modeling indicated that an estimated 50% reduction in phosphorus loading to the lake (about 37,000 pounds annually) would reduce the number of days algae blooms could potentially occur in the lake. A significant decrease in phosphorus loading to Lake Mendota would also reduce phosphorus levels in downstream lakes[52]. Reduction of sediment loading to tributary streams and to the lake was also a goal of the priority watershed project. An estimated 9,600 tons of sediment was delivered to the lake annually. The projects goal was to reduce that annual delivery rate by about 50% or 4,800 tons. The water quality goal for Lake Mendota is to reduce the concentration of spring total phosphorus in the lake to less than 0.074 mg/L. Modeling results indicate that this concentration will result in a decrease in the concentration of blue-green algae to less than 2 mg/L during the summer months.

Approximately 75% of the phosphorus loading to Lake Mendota came from agricultural parts of the watershed. The priority watershed project would provide farm owners cost sharing for the

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[51] Betz,(Ed). 1997.
[52] Lathrop and Carpenter, 2010.

installation of best management practices (BMPs) designed to reduce the amount of sediment and phosphorus leaving farm fields and barn yards. Implementation phase of the project began in 1998 and ended at the end of 2009. The following BMPs were installed[53]:

- 46 barnyard runoff systems,
- 10 water diversion,
- 58.1 acres of grassed waterways installed,
- 3,105 feet of streambank protection measures,
- 2 field terrace systems,
- 8 agricultural sediment basins or grade stabilization structures,
- 148.9 acres of grassed buffers along surface waters, and
- 18.8 acres of restored wetlands.

In addition, all 10 of identified critical site animal lots and 80 critical site crop fields were addressed during the project. Nutrient management plans, plans limiting the amount of phosphorus and nitrogen that could be applied to farm fields, were also completed for several farms in the watershed. A Farm Practices Inventory (FPI) survey was conducted early in the project to establish baseline data. The same participating producers will be surveyed again in 2010 to identify changes that have occurred as a result of the priority watershed project.

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 include the funding of municipal storm water plans, additional street sweeping, and Dane County's enactment of an erosion control and storm water management ordinance. Main goals of these measures is to assure adequate erosion control and storm water management actions and facilities are utilized in developing areas, reduce direct discharges to surface waters by 80%, and reduce or control peak storm water flows from developing areas.

[53] Dane County Land and Water Resources Department, 2010.

No comprehensive Lake Mendota watershed analysis of estimated phosphorus and sediment loading reduction had been published as of October 2010. However, Dane County Land Conservation Division has estimated that implementation of watershed project best management practices on animal lots has reduced phosphorus loading to surface water by about 8,300 pounds annually, approximately 74% of the project goal for phosphorus from this source category[54] 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). That report is expected in early 2011. Some 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 trend toward larger animal feeding operations in the watershed poses a potential threat to the lake in terms of nutrient loading. These operations will need additional cropland acreage on which to spread manure generated by their operation. This land need for manure spreading is in competition with residential and commercial development also occurring in the watershed. One answer is the Dane County Community Manure Digester. Located near Waunakee, the digester will take liquid manure from three local dairy operations. 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 farmers 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 material, 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[55].

[54] Dane County Land & Water Resources Department, 2009.
[55] WDNR, Environmental Impact Statement, 2010.

Sediment and nutrient loading reductions to surface water and the Yahara lakes may 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 average annual precipitation increasing between 4.5 To 7 inches in Dane County between 1950 and 2006[56]. The frequency of 3-inch rainfall events has increased significantly over the last 10 years[57]. Current runoff models, and management assumptions based on those models, may have to be altered if this trend continues. Additional and more intense rural and 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.

No estimate of the total amounts of phosphorus and sediment loading reductions to streams and Lake Mendota measures has been made since completion of the project. Lathrop noted that:

> "no discernible effect of nonpoint P 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[58]."

Upper Yahara River Watershed

The Upper Yahara River Watershed[59] is in north central Dane County. About 25% 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 over 2,000 acres, is the last large wetland complex in the watershed, and there are several smaller wetlands complexes also remaining. Most, if not all, of these wetlands have been altered or degraded.

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[56] WICCI, (no date). http://www.wicci.wisc.edu/resources/wicci_climate_change_maps.pdf
[57] Lathrop and Carpenter, 2010.
[58] Lathrop and Carpenter, 2010.
[59] The DNR refers to this watershed as the Lake Mendota and Yahara River Watershed.

Table _____ Upper Yahara River Watershed Land Cover

Resource Characteristics	in acres
Agricultural	35,066
Hydric Soils	8,012
Other*	6,533
Wetlands	4,884
Residential	4,260
Transitional**	3,456
Woodland	1,457
Outdoor recreation	1,306
Industrial	979
Open water	688
Commercial	388
Institutional/Governmental312	56
Size of watershed in Dane County	**54,415**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

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 Warm Water Sport Fishery (WWSF) stream[60].

The river has a relatively low gradient of about 4.4 feet per mile 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 priority watershed plan lists this reach of the Yahara River as a priority[61]. There was significant wooded and open buffer in this reach, but development in DeForest and the Town of Windsor has reduced the buffer and replaced it with impervious surfaces and turf grass in some areas. Residential development on

[60] Johnson, 2002.
[61] Betz, et.al. 1997.

the ABS property has resulted in removal of trees and understory on the formerly wooded hillsides adjacent the stream. This could increase stormwater runoff and decrease infiltration adversely affecting water quality, habitat and morphology of the Yahara River in this reach.

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 in Dane County, Wisconsin. Covering over 3,200 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. The less accessible central areas probably retain the condition and appearance of many of the Yahara basin marshes a century ago. Islands of upland support oak forest or open fields, while small depressions have high quality ponds or springs[62].

[62] Bedford, et.al., 1974.

Yahara River at Windsor Road

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.

The Village of DeForest, the community of Morrisonville, and the towns of Vienna, Windsor and Westport are all within its drainage area. DeForest, Windsor and Westport are all rapidly growing communities. Data from the Wisconsin Department of Administration's Demographic Services Center shows the population of DeForest has grown about 15.8% since 2000, while the populations of Windsor and Westport have grown 12.4% and 6.0% respectively over the same time frame[63]. The 2010 preliminary combined population estimate for the three communities is 18,272, or about 12.5% increase over the 2000 population.

Yahara River Water Quality. 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 good warm water sport fishery[64]. 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 and channelization of it and feeder tributaries. This has led to poor aquatic habitat while 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 warm water sport fishery[65], it is more accurately a warm water forage fishery due to low flows, elevated temperatures, lack of diverse habitat, and low DO levels[66]. The 1997 WDNR priority watershed plan estimated that the Yahara River sub-watershed delivered approximately 12.7% of the annual total sediment and

[63] Wisconsin Department of Administration, Demographic Services Center; http://www.doa.state.wi.us/subcategory.asp?linksubcatid=96&linkcatid=11&linkid=64&locid=9
[64] DCRPC, 1992, and Johnson, 2002.
[65] See the watershed table for the Yahara River and Lake Mendota Watershed (LR-09), http://www.dnr.wisconsin.gov/org/gmu/lowerrock/surfacewaterfiles/watersheds/lr09.pdf
[66] Betz, et.al, 1997.

phosphorus loading to Lake Mendota[67]. Analysis of USGS data shows a general downward trend in suspended sediment concentrations in the river. Total phosphorus concentrations over the same period have remained steady[68].

Insert USGS data bar charts for P and sediment here

The section of the river from DeForest downstream to Windsor Road is the nicest stretch of stream in the sub-watershed. It has riffles, pools, diverse substrate and good velocity and support warmwater game and forage fish[69]. It is affected by urban development resulting in stormwater runoff, construction site erosion, and loss of infiltration areas and wetlands. Its biological use is as a warmwater sport fishery. The priority watershed plan considered this reach as having the greatest potential for supporting valuable sport fishery.

The third reach from Windsor Road to Lake Mendota including Cherokee Marsh has 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 one 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 0.04 mg/l, respectively. Suspended sediment has declined significantly from about 50 mg/l to 20 mg/l over the same period at Windsor Road[70]. 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

[67] Betz, et.al., 1997.
[68] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[69] Sorge, 1996.
[70] CARPC Files, from USGS data, 2010.

(range 2.95-429.3 lbs), and June with a mean 94.6 pounds per day (range 5.81-737.1 lbs)[71]. This differs slightly from the mean monthly suspended sediment discharge over the same period. 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% of the total phosphorus loading occurs between January and March based on data from this station[72]. Lathrop also suggested that summer algal growth in Lake Mendota may be limited by both phosphorus and nitrogen loading to the lake.

Watershed appraisal HBI monitoring of the Yahara River monitoring done in 1994-95 indicated ranged from "very good" water quality conditions at the upper River Road crossing (HBI score=4.44) to "fair" (HBI score=5.90) at CTH V[73]. The average HBI score for the five locations monitored was 4.91 indicating "good" water quality.

The DNR did 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 DNR 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 goes upstream[74]. 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.

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 fish-IBI, HBI, flow and temperature monitoring. The Village of DeForest and Town of Windsor should require no increase in stormwater runoff and maximum infiltration of runoff in new developments while

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[71] USGS data, http://waterdata.usgs.gov/wi/nwis/monthly?referred_module=qw&search_criteria=county_cd&submitted_form=introduction
[72] Lathrop, 2007.
[73] Sorge, 1996.
[74] Wisconsin Department of Natural Resources, South Central Region Water Resources Files, 2010.

promoting distributed infiltration measures such as rain gardens and bio-filters in already developed areas to protect the water resources of the Yahara River.

The WDNR conducted fish IBI and HBI surveys at eight locations on the Yahara River in the fall of 2010. Results and analysis were not available at the time of this summary. USGS is also doing extensive water chemistry monitoring of the Yahara River in the Town of Windsor in 2010 to support a report on nutrient loading in the watershed.

The USGS 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)[75]. This differs slightly from the mean monthly suspended sediment discharge over the same period. Three months, April, May and June had the same mean of 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. Farmers, municipalities, Dane County, the DNR and the NRCS need to continue to install and maintain practices to minimize runoff and sediment and nutrient loading to the river.

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 a large amount of the baseflow for the Yahara River and Lake Mendota[76].

Token Creek has a diverse fishery containing warmwater, coldwater, forage fish and rough fish species. The DNR has classified the first two miles upstream of the Yahara River as WWSF.

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

[76] DCRPC, 1992.

Miles 2 to 4 of Token is classified as a cold water fishery while the remaining upstream 6 miles has a default WWSF classification[77]. It is a class III trout stream, one of the few trout streams east of USH 51[78]. Token Creek was placed on the state's 303d list of impaired waters[79] in 1998. It was listed because of water quality impairments due 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% of the annual total sediment and phosphorus loading to Lake Mendota[80]. 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[81]. ***Insert USGS data bar charts for P and sediment here***

Token Creek has substantial groundwater inflow and has been designated a thermally sensitive stream[82]. Springs that feed Token Creek are estimated to supply 50% of the baseflow to Lake Mendota[83]. 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 springs flow. The main recharge area for the Culver Springs is to the north. Water flows out of Culver Springs at 50^0 F has a cooling effect on Token Creek, maintain a stream water temperature within the optimum temperature range for trout[84]

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[77] Johnson, 2002.
[78] Wisconsin Department of Natural Resources. 2008. *Trout Management in Dane County*, Fisheries Management Program-South Central Region, Fitchburg, WI. http://dnr.wi.gov/fish/reports/final/2008StreamAssessment.pdf
[79] See http://dnr.wi.gov/org/water/wm/wqs/303d/index.htm for a discussion of the DNR's impaired waters program.
[80] Betz, et.al., 1997.
[81] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[82] Dane County Land and Water Resources Department, http://www.countyofdane.com/lwrd/landconservation/cws/index3.html
[83] Betz (Ed), 1997.
[84] Roa—Espinosa, et.al. 2003.

Token Creek at Dam Site Off Portage Road

Token Creek is subject to a high level of development pressure from the City of Sun Prairie and development pressure in adjacent unincorporated areas of the Town of Windsor. 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

In 1993 the dam on Token Creek that formed the 44 acre Token Creek Millpond partially failed. The resulting partial drawdown of the millpond exposing several spring 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 303d list in 1998. In 2002 the EPA approved a Total Maximum Daily Load (TMDL)[85] plan for Token Creek. Project goals included:

- restoration of stream morphology and habitat,

[85] See http://dnr.wi.gov/org/water/wm/wqs/303d/index.htm for a more detailed TMDL discussion.

- managing and reducing sediment and other pollutant loading from agricultural land through Lake Mendota Priority Watershed Plan, and
- managing storm water discharges through the Lake Mendota Priority Watershed Plan and the DNRs storm water discharge permit program.[86]

The DNR has added the goal of restoring a native brook trout fishery in the reach downstream of the Culver Springs.

Restoration work on Token Creek to improve habitat and hydrologic functions include:

- removing the berm around the Culver Springs allowing them to flow freely,
- bank stabilization, and
- removal of pond sediment above the dam location[87].

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” (HBI score=4.30) to “fairly poor” (HBI score=7.44) depending on location. The monitoring was done prior to complete dam removal[88]. 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 was 7.49 (very poor water quality conditions), while the HBI score at the same site in 2008 was 4.92 indicating “good” water quality conditions.

The DNR has done cold water 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. Results of coldwater IBI done in 2000 and 2001done upstream of 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[89]. 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

[86] WDNR, *Token Creek TMDL for Sediment and Habitat*, 2002.
[87] WDNR, Expenditures of Inland Water Trout Stamp Revenues, 2009.
[88] Sorge, 1996.
[89] Data from DNR Fisheries Management files.

"good"[90]. These data coupled with the ongoing channel and habitat improvement indicates that Token Creek can sustain a viable cold water fishery. The DNR is attempting to establish a native brook trout fishery in the Culver Springs area.

The primary threat to Token Creek water quality is from urban stormwater and runoff from major roadways. The City of Sun Prairie has installed several stormwater measures in developing areas near the creek to minimize pollutants reaching the stream and minimize adverse thermal impacts to the stream from urban runoff. The Friends of Token Creek, Dane County and the WDNR have also acquired land adjacent the creek to further protect it.

Continued urban development increasing the amount of impervious cover is a threat to Token Creek and the Culver Springs. 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 Token Creek, protecting the coldwater fishery of the creek.

Harbison (Pederson) Tributary

The Harbison Tributary is a cold water tributary to Token Creek south of STH 19. A large collection of springs provides its baseflow. It provides a stable supply of cold water to Token Creek. Harbison Tributary experiences 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[91]. Four cold water IBIs done in 2000 and 2001 all indicated "good" biotic integrity. The DNR has been doing habitat improvement projects including removal of a rough fish holding pen and streambank work. This is consistent with the washed HBI assessment monitoring done in 1994 and 1995.

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 has the potential to significantly increase stormwater volume altering instream habitat, thermal and pollutant loading affecting the coldwater fishery of the stream.

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[90] WDNR, 2008.
[91] Betz, 1997.

Continued urban development in DeForest and the towns of Windsor and Burke that increases the amount of 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.

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 publically owned by the state, Dane County and the City of Madison. It supports a sport fishery including large-mouth bass, walleye and northern pike.

Agricultural and urban nonpoint 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 10-acre impoundment of an unnamed tributary to the Yahara River. It has a maximum depth of six feet. Little is known about its fishery or water quality conditions.

Cherokee Marsh

Cherokee Marsh is an extensive wetland complex of over 2,000 acres north of Lake Mendota. There are several wetland types including a fen, low prairie, bogs, shrub-carr and sedge meadows. Attempts were made to ditch and drain portions of the wetlands in its southern portion resulting 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. The Wisconsin Wetlands Association has designated Cherokee Marsh as a state "wetlands gem[92]" and it is used for outdoor environmental education by several schools.

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. Little is known about the water quality of the ponds. The ephemeral ponds are threatened by attempts to ditch or drain them to increase agriculturally productive land.

Sixmile and Pheasant Branch Creeks Watershed

The Sixmile Creek and Pheasant Branch watershed is in the northwest part of Dane County. It is 85-square 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 north and south forks), Sixmile Creek and Dorn Creek, a tributary to Sixmile. 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 adjacent waterways.

Soil associations in the watershed vary from the Dodge-St. Charles-McHenry silt loam association to the Batavia-Houghton-Dresden silt loam and muck soil association. These soils 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 the greatest sediment and phosphorus losses are located in this watershed[93].

Table _____ Sixmile and Pheasant Branch Watershed Land Cover

[92] Wisconsin Wetlands Association (WWA), Wisconsin's Wetland Gems, http://www.wisconsinwetlands.org/gemsbook.htm 2009.
[93] Jones, et.al. 2010.

Resource Characteristics	in acres
Agricultural	38,635
Open water	10,128
Residential	8,414
Hydric Soils	6,613
Other*	6,252
Transitional**	5,030
Wetlands	2,936
Outdoor recreation	2,422
Commercial	1,784
Woodland	1,680
Institutional/Governmental	1,248
Industrial	916
Size of watershed in Dane County	**76,513**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

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 BMPs 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 feet per mile. 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 good[94]. It supports a limited forage fishery west of STH 113, and a diverse forage and warm water sport fishery from STH 113 to Lake Mendota[95]. The WDNR has classified Sixmile Creek as an Exceptional Resource Water (ERW) from Waunakee Marsh downstream to Lake Mendota. The fishery above STH 113 is a limited warm water forage fishery. Downstream of Highway 113 the fishery changes to a warmwater sport fishery stream. The reach between STH 19 in Waunakee to just downstream of Mill Road has the best instream habitat. Macroinvertebrate samples at Highway 19 and Mill Road indicated "good" water quality[96]. Further downstream the gradient decreases, water turbidity increases and the stream bottom is fine, often deep, silt. Warmwater fish IBIs indicate "poor" to "fair" biotic integrity while intermittent IBIs indicate good biotic integrity.

The 1997 WDNR priority watershed plan estimated that the Sixmile Creek sub-watershed delivered approximately 18.2% of the annual total sediment and phosphorus loading to Lake Mendota[97]. Total phosphorus concentrations in water samples from Sixmile Creek have shown a slight downward trend based since 1990 on analysis of USGS data. Suspended sediment concentrations appear more erratic over the same period[98]. ***Insert USGS data bar charts for P and sediment here***

There has been significant soil loss reduction in the Town of Westport part of the watershed since 1988, but soil loss in the other townships have remained stable over the same period[99]. There have been fish kills on Sixmile in past years, including one in 2001 thought to be caused by high chlorine levels from flushing of a new water main[100].

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[101].

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[94] DCRPC, 1992.
[95] Johnson, 2002.
[96] Betz, et.al. 1997.
[97] Betz, et.al., 1997.
[98] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[99] Dane County Land &Water Resources Dept, 2008.
[100] Jones, Ed., 2008.
[101] Sorge, 1996.

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 et.al. in 2004 regarding the decline of forage fish species in the Rock River basin[102].

Fish IBI monitoring done by the DNR at two locations on Sixmile in 2007 indicate "fair" to "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. Macroinvertebrate (HBI) monitoring done by the DNR in 2007 also indicated "fair" water quality. Family Biotic Index monitoring done in 2002, 2006 and 2009 by Water Action Volunteer citizen monitors 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.

Two small unnamed streams are tributary to Sixmile Creek. One rises to the 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[103]. The second tributary originates in section 10 of the Town of Westport and flows south to Sixmile Creek. This small narrow coldwater stream is well buffered from Hogan Road downstream[104].

The primary threats to water quality in Sixmile Creek continue to be from urban nonpoint sources, runoff from impervious surfaces and construction sites, in the Village of Waunakee and the Town of Westport. Waunakee Marsh captures much of the sediment and nutrients from

[102] Marshall, et.al, 2004.
[103] Fix. Personal Observations, 2010.
[104] Betz, et.al. 2000.

agricultural areas tributary to Sixmile Creek west of Waunakee adversely affecting the marsh ecology[105]. Some of these pollutants may leave the marsh during periods of high water and flows.

[105] Johnson, 2002.

Sixmile Creek at STH 113 in Waunakee

Dorn Creek

Dorn Creek is 6 miles long. It rises in the Town of Springfield and flows southeasterly through agricultural and Governor Nelson State Park before meeting Sixmile Creek. The stream supports mainly tolerant warmwater forage fishery. Two intolerant forage species are also known to inhabit the creek, the northern redbelly dace and pearl dace[106]. Land use is predominately agricultural upstream of CTH Q. Downstream of Highway Q, the stream passes through wetlands. These wetlands provide spawning for northern pike and wildlife habitat.

Dorn Creek's sub-watershed is slightly more than one-third the size of Sixmile's sub-watershed and was estimated to contribute 18% of the sediment and phosphorus loading to Lake Mendota compared with Sixmile's 18.2%. This indicates the intense agricultural activities occurring in its sub-watershed. Dorn Creek has been listed as 303d stream because of habitat impairment due to sediment loading impairing aquatic habitat and has been included in the Rock River Basin Total Maximum Daily Load (TMDL) development project as a second level priority stream[107].

The 1997 priority watershed plan macroinvertebrate 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 was 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[108].

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.

Pheasant Branch

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[106] Johnson, 2002.
[107] WDNR, 2006.
[108] WDNR, South Central Region Water Resources Files, accessed in 2010.

Pheasant Branch is a 9-mile long stream that drains 22.7 square miles of west-central Dane County. It enters western Lake Mendota after flowing through the Pheasant Branch marsh complex that includes a large springs. 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 feet per mile. That is misleading in that it reflects the steep gradient of the and below Century Avenue creek between US Highway 12 and Century Avenue (CTH M) and of the South Fork. A significant length of the North Fork above Highway 12 is relatively flat. The lower end of Pheasant Branch flows through the Pheasant Branch wetlands complex that includes the Frederick Springs, a major water source for Lake Mendota. The wetlands are important providing fish spawning habitat and habitat for a number of aquatic species.

There are two forks of Pheasant Branch. 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. 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 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.

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 Parmanter. Middleton has installed a large detention pond is just upstream of USH 12, designed to try 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. Middleton has done different types of bank stabilization efforts to reduce the erosion. The channelization and straightening of the stream channel, coupled with the rapid urbanization have increased peak flows carrying sediment and nutrients to Pheasant Branch Marsh and ultimately to Lake Mendota.

Failing Bank Stabilization Along Pheasant Branch in 2010

The existing biological use of the first mile of Pheasant Branch between Lake Mendota and the Pheasant Branch marsh is a warm water sport fishery. The WDNR considers the remaining nine miles to support a tolerant limited forage fishery[109]. Pheasant Branch Creek is also on the state's 303d impaired waters list due to degraded aquatic habitat and low DO levels. It is a "high" priority candidate for TMDL development[110]. Dissolved oxygen reading below water quality criteria[111] have been recorded during USGS and WDNR monitoring done in 2005 and 2009 with the lowest reading being 3.5 mg/l.

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

[109] Johnson, 2002.
[110] See http://www.wnrmag.com/Water/ImpairedWater_AdvSearch.aspx for a list of Dane County impaired waters.
[111] Dissolved oxygen levels below 5 mg/l do not meet state water quality criteria. See Wisconsin Administrative Code NR 102.04(4)(a) http://legis.wisconsin.gov/rsb/code/nr/nr102.pdf

reach which was surprising given what was considered good habitat conditions[112]. WDNR baseline fish IBI monitoring done in 2009 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 of macroinvertebrates also indicate "poor" water quality conditions[113].

The 1997 Lake Mendota priority watershed report estimated that Pheasant Branch sub-watershed of the Lake Mendota watershed contributed 19% of the sediment and phosphorus loading to the lake. Suspended sediment concentrations, measured in milligrams per liter (mg/l), have declined since 1995 based on a summary of USGS data[114]. Total phosphorus concentrations have also declined but not at the same rate as sediment concentrations. ***Insert USGS data bar charts for P and sediment here*** Phosphorus loading to Pheasant Branch shows a fluctuating downward trend between 1992 and 2008 based on USGS monitoring station data. The annual fluctuations are due to the number and intensity of annual storms and runoff events. Pheasant Branch is also on the state's 303d list of impaired waters and has been included in the Rock River Basin Total Maximum Daily Load (TMDL) development project as a top 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 Pheasant Branch is 0.08 mg/l[115].

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 (increase in impervious surfaces) of the undeveloped parts of the sub-watershed would increase overland flow 84%, increase mean annual streamflow 53%, but decrease baseflow by 15%. This scenario would also decrease regional groundwater recharge by 10%[116]. The increase overland flow and mean annual baseflow coupled with an overall decrease in baseflow indicates a system with more "flashy" stormflow events and greater erosive 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. Much of the groundwater recharge area for Frederick Springs lies within the Pheasant Branch drainage area. The surface water drainage

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[112] Sorge, 1996.
[113] WDNR, South Central Region Water Resources Management Files, Accessed in 2010.
[114] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[115] WDNR, 2006.
[116] Steuer and Hunt, *Use of a Watershed-Modeling Approach to assess Hydrologic Effects of Urbanization, North Fork Pheasant Branch Basin Near Middleton, Wisconsin,* 2001.

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[117]. 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 and provide a first step in efforts to protect both surface water baseflow, groundwater recharge and flow from springs.

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 takes stormwater from the near westside of Madison, parts of Shorewood Hills and the University of Wisconsin campus, discharging to Lake Mendota at University Bay. Willow Creek's drainage basin contributes the normal urban pollutants such as toxic elements from streets and parking lots, nutrients from lawns, construction site 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[118]. The USGS no longer supports a monitoring station on Willow Creek.

117 Hunt and Steuer, *Simulation of the Recharge Area for Frederick Springs, Dane County, Wisconsin*, 2000.

118 Corsi, et.al. *Unit-Area Loads of Suspended Sediment, Suspended Solids, and Total Phosphorus From Small Watersheds in Wisconsin*, 1997.

Willow Creek at Observatory Drive

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 drainage area is in agriculture. Runoff from surrounding farm fields has impaired water quality.

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

These four ponds are all 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. Water level in Tiedeman's Pond had risen to the point of threatening adjacent homes.

Middleton solved this problem by pumping water from the pond to Lake Mendota. The ponds do provide some limited wildlife habitat to some migratory waterfowl and to some amphibians.

Yahara River – Lake Monona Watershed

The Yahara River – Lake Monona watershed covers about 85 square miles with over 70% being considered urban. It includes all streams draining to Lake Monona, Lake Waubesa and Lake Wingra ***(See Lakes Section***). 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 go into the streams and lakes. Streams in the watershed include the Yahara River, Starkweather Creek, Wingra Creek, Murphy's Creek, Swan Creek and Nine Springs Creek. Other water features include Lake Monona, Lake Wingra, Lake Waubesa (all three discussed in a separate section), Upper Mud Lake, the Nine Springs wetlands, the South Waubesa wetlands.

Table _____ Yahara River and Lake Monona Watershed Land Cover

Resource Characteristics	**in acres**
Hydric Soils	11,507
Residential	11,049
Other*	10,662
Transitional**	10,522
Agricultural	10,240
Open water	6,261
Wetlands	5,636
Outdoor recreation	3,179
Commercial	3,106
Woodland	2,479
Industrial	2,456
Institutional/Governmental	1,687
Size of watershed in Dane County	**61,643**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

Starkweather Creek

Starkweather Creek is tributary to Lake Monona at the lake's north end at Olbrick Park. 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 main stem flowing to Lake Monona.

East Branch Starkweather Creek

The East Branch begins just west of I39/90/94 near East Towne Mall. The stream drains much of the east side of Madison south of East Washington Avenue (USH 151). It is about 2.8 miles long and has a low stream gradient of about five feet per mile[119].

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. This area is threatened by continued urban development that decreases infiltration of water into groundwater that supports the springs flow. There s 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 fluctuations are common during low flow periods in summer. Fish populations vary during the year reflecting seasonal migrations and low summer dissolved oxygen (DO) readings[120]. Runoff from a recycling facility has caused water quality problems in the past. Warm Water IBI monitoring done at two location on the East Branch at STH 30 and 300 meters upstream of Highway 30 in 2007 showed biotic integrity ratings of "fair" (decreased fish species richness) and "poor" (relatively few fish species) respectively[121]. Mean

[119] DCRPC, 1992.
[120] Johnson, 2001.
[121] WDNR South Central Region Water Resources Files and SWMS data base 2010.

baseflow concentrations of phosphorus and sediment have decline over the past 18 years while mean concentrations of chlorides have increased[122].

The East Branch is on the state's 303d list of impaired waters due to metals concentrations in sediment, low DO, sedimentation and total suspended solids.

West Branch Starkweather Creek

The West Branch originates near Cherokee Marsh. It is about seven miles long with a stream gradient of 3.7 feet per mile. 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 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[123]. The airport in 1993 constructed a $1 million collection system to protect the West Branch from ethylene glycol spills. Madison has done streambank work to reduce bank erosion and make the area adjacent the stream more aesthetically pleasing. Mean baseflow concentrations of sediment and phosphorus have shown a small downward trend since 1992, while mean concentrations of chloride have increased[124].

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 feet per mile. The stream often acts as a backwater to Lake Monona due to low flows and flat gradient. Urban nonpoint sources of pollution are major

[122] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey
[123] Johnson, 2001.
[124] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey

water quality problems in the mainstem. The pollutants from the nonpoint sources include sediment, oil and grease and trash contributed by the upstream branches of Starkweather. Heavy metals, PCBs and other toxic constituents were found in the stream bottom sediments. Portions of the stream were dredged, spoils disposed at an approved site, and streambanks were re-vegetated[125].

The East Branch is on the state's 303d list of impaired waters due to metals concentrations in sediment, low DO, sedimentation and total suspended solids.

Wingra (Murphy) Creek

Wingra Creek is a channelized stream flowing 2 miles 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 a warm water sport fishery (WWSF). It has a very shallow stream gradient of 2.0 feet per mile. 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 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[126]. The City of Madison has done streambank stabilization projects on sections of Wingra to reduce streambank erosion and improve the riparian aesthetics.

[125] Johnson, 2002.
[126] Johnson, 2002.

Wingra Creek at Beld Street

Nine Springs Creek

Nine Springs Creek begins as a ditched intermittent stream at the out let 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 feet per mile. 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 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[127]. The Madison Metropolitan Sewerage district (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[128].

Nine Springs Creek at Syene Road

Nine Springs Creek is on the state's 303d list of impaired waters and has been included in the Rock River Basin Total Maximum Daily Load (TMDL) development 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 is

[127] Swanson, et.al. *Two-way cluster analysis of geochemical data to constrain spring source waters*, 2001.
[128] Johnson, 2002.

0.08 mg/l[129]. 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[130]

Unnamed Tributary (Penitto Creek)

This small tributary rises east of I-39/90 and flows southwest to Upper Mud Lake. It drains agricultural land east of the Intestate. It is channelized west of the Interstate and flows through cropland and a developing commercial area on either side of Femrite Road. It has poor habitat due to low flows channelization and sedimentation from agricultural activities, construction site runoff and urban stormwater runoff. Despite the poor habitat, a Family Biotic Index (FBI) done in the 1990's indicated "very good" water quality. The FBI score, coupled with other indicators, indicated groundwater discharge and cool water temperatures[131].

Murphy's Creek

Murphy's Creek, a small 3-mile long spring-fed creek, begins in a wetland complex adjacent USH 14, south of Byrne Road. It flows northeast to Lake Waubesa at the Lake Waubesa Wetlands State Natural Area in the South Waubesa wetlands complex. The creek's sub-watershed has a large proportion of wetlands to total surface area. It has a stream gradient of 8 feet per mile. Flow in the creek is generally low. The stream is considered to have good water quality[132] and groundwater seepage and large wetland buffers contribute to good water quality and habitat in the lower reaches. Water quality, fishery and habitat are limited in the upper reaches of Murphy's by low flows. The WDNR considers the stream as Warm Water Forage Fishery (WWFF) stream[133]. Primary threats to water quality are from agricultural runoff and runoff from roads.

Swan Creek

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[129] WDNR, 2006.
[130] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[131] Johnson, 2002.
[132] Johnson, 2002.
[133] Source: WDNR Lower Rock River Basin website; http://dnr.wi.gov/water/WatershedDetailTabs.aspx?ID=LR08&Name=Yahara River and Lake Monona

Swan Creek is a small cool water stream that begins in the eastern part of the City of Fitchburg and flows east to Lake Waubesa and the South Waubesa wetlands in the Town of Dunn. A survey of non-game fish species in the Rock River basin found more forage fish species in 1998 than found in the stream in the 1970's indicating an increase in species diversity[134]. 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 form a stormwater pond discharge[135]. Primary water quality threads are for urban development. The WDNR has done two intermittent fish IBI monitoring at Lalor Road. Both IBIs indicated "fair" water quality conditions[136].

[134] Marshall,et.al, 2004.
[135] Fitchburg Planning Department, *City of Fitchburg Comprehensive Plan*, 2010.
[136] WDNR, 2010b.

Swan Creek at Lalor Road

Yahara River

The Yahara River between Lake Mendota and Monona is essentially a boat channel connecting the two lakes. It receives very heavy boating pressure during 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.

Nine Springs Wetlands Complex

The large Nine Springs wetland complex extends from Dunn's Marsh on the west to Lake Waubesa. It has several springs that provide significant baseflow to Nine Springs Creek. The wetlands are part of the Nine Springs E-way, a large environmental corridor that provides wildlife habitat, some water quality functions and recreational opportunities. The wetlands have a history of disturbance including the straightening of Nine Springs Creek and placing the Beltline Highway through the wetlands. There are still pockets of higher quality wetlands with good native plant diversity within the wetlands complex.

South Waubesa Wetlands

The South Waubesa wetlands are on the southwest corner of Lake Waubesa. The South Waubesa Wetlands is considered one of the highest quality and most diverse wetlands in Dane County. It is recognized by the Wisconsin Wetlands Association as a Wisconsin wetlands gem[137]. The wetland complex is more than 500 acres in size containing higher quality sedge meadows, shrub-carr, fen and marsh areas. There are several springs in the wetlands. The diversity of wetland types and plant species diversity provides habitat for nesting and migratory birds, amphibians, and spawning areas for fish. The DNR has designated a part of the wetlands as a State Natural Area.

Badfish Creek Watershed

The Badfish Creek watershed is in south central Dane County and extends into the northwest corner of Rock County. The watershed has an area of 85.5 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 watershed. 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.

[137] WWA, 2009.

There are 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.

Table _____ Badfish Creek Watershed Land Cover

Resource Characteristics	in acres
Agricultural	29,716
Hydric Soils	7,351
Other*	4,279
Wetlands	3,327
Residential	2,424
Woodland	2,096
Transitional**	1,817
Open water	767
Outdoor recreation	271
Institutional/Governmental	170
Industrial	167
Commercial	118
Size of watershed in Dane County	**41,849**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

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 feet per mile. 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 (see discussion on MMSD). The Village of Oregon also contributes to the total effluent 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 warm water sport fishery (WWSF). Badfish Creek is on the state's 303d list of impaired waters due to PCBs found in sediments. It is a "low" priority stream for TMDL development.

Water quality was quite bad in the 1970's due to the large amount of effluent from MMSD and Oregon. MMSD has 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 have increased showing improved water quality. MMSD has also conducted IBI monitoring at two locations on Badfish, at CTH A downstream of Rutland Branch and Old Stage Road. Wisconsin warm water IBI biotic integrity ratings at both sites has ranged between "poor" to "very poor", while Wisconsin coldwater IBI integrity rating of "poor" was calculated at both sites[138]. MMSD reports have shown that water quality and fish species richness has improved since MMSD began monitoring Badfish in the early 1980s based on their monitoring. Assessment of MMSD's collected data suggests that MMSD's effluent quality is not inhibiting aquatic species from living in Badfish Creek[139]. Northern hog suckers, considered an intolerant fish species, have been found at the two MMSD monitoring sites on Badfish[140]. MMSD regularly find 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 are the controlling water quality factors[141]. MMSD has found some dense eurasian water milfoil, a highly aggressive invasive aquatic plant, in Badfish over the last six surveys[142].

Badfish Creek at Old Stage Road

[138] Steven, Jeffrey C. *Badfish Creek Fish Survey*, 2010.
[139] MMSD, *Eightieth Annual Report of the Commissioners of the Madison Metropolitan Sewerage District*, 2010.
[140] MMSD, Seventy-*Ninth Annual Report of the Commissioners of the Madison Metropolitan Sewerage District*, 2010.
[141] Johnson, 2002. http://www.rockrivercoalition.org/badfish/docs/BadfishDNRdoc.lr107.pdf

[142] Steven, 2010.

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[143]. Hilsenhoff 2003 HBI monitoring done at CTH A in 2003 showed "fair" water quality (HBI=5.7) indicating fairly significant organic pollution[144].

Oregon Branch

Oregon Branch begins in the Village of Oregon and flows 10 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

[143] Source: CARPC cooperative water resources monitoring program and U.S. Geological Survey.
[144] WDNR, 2010b.

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.

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 dominate fish 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. Warm water IBIs done at this site indicated "poor" biotic integrity due to relatively few species[145].

Rutland Branch

Rutland Branch, also known as Anthony Branch, is a small spring-fed, cold water trout stream in south central Dane County. It joins the Oregon Branch to form Badfish Creek. It is listed as an Exceptional Resource Water (ERW) of the state. It has a stream gradient of 25.6 feet per mile. 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[146]. A 2001 coldwater IBI done by the DNR showed Rutland Branch to have "fair" biotic integrity indicating the stream has experienced some moderate environmental degradation[147].

145 Steven, 2010.
146 Johnson, 2002
147 WDNR, 2010b.

Rutland Branch at Dane CTH

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Frogpond Creek

Frogpond Creek is a small spring-fed stream that begins in a U.S. Fish and Wildlife Service's Waterfowl (USFWS) Production Area (WPA) east of the Village of Brooklyn. It flows east along the Dane-Rock county line. 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"[148] A 2004 Hilsenhoff HBI monitoring effort at Franklin Road indicated Frogpond had very good water quality (HBI 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 warm water IBI indicated "fair" biotic integrity[149].

Frogpond Creek at Franklin Road

[148] Johnson, 2002.
[149] WDNR, 2010b.

Bass Lake

Bass Lake is a 69-acre highly eutrophic 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.

Grass Lake (Town of Dunn)

Grass Lake is a 48-acre highly eutrophic 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[150].

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 the acidic northern bogs. Much of its surface is covered with a floating sedge bog mat that has several plant species unique to Dane County such as the insectivorous round-leaf sundew, bogbean, leatherleaf, bog birch, tamarack and cotton grass[151]. The bog area has been designated a State Natural Area by the DNR.

Island Lake

Island Lake is a 20-acre 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.

Lake Barney

Lake Barney is a 27-acre 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 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. The U.S. Fish and Wildlife Service own much of the wetlands west of Lake Barney.

Yahara River – Lake Kegonsa Watershed

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.

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[150] WDNR. Hook Lake Wildlife Area http://dnr.wi.gov/org/land/wildlife/wildlife_areas/hook.htm Accessed 2010.
[151] WDNR, Hook Lake Bog, http://dnr.wi.gov/org/land/er/sna/index.asp?SNA=242 Accessed 2010.

Municipalities in the Dane County portion of the watershed are 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 towns of Pleasant Springs, Dunn, Dunkirk, Rutland, Blooming Grove, Sun Prairie and Burke. Stoughton is the only municipal wastewater treatment plant that discharges to surface waters, the Yahara River.

Table _____ Yahara River and Lake Kegonsa Watershed Land Cover

Resource Characteristics	in acres
Agricultural	37,449
Hydric Soils	11,240
Other*	10,356
Wetlands	6,372
Residential	4,927
Open water	4,175
Transitional**	4,066
Woodland	3,620
Outdoor recreation	1,309
Industrial	422
Institutional/Governmental	329
Commercial	241
Size of watershed in Dane County	**66,894**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

The Yahara River is the principle and most important stream in the watershed. Other streams in the Dane County part of the watershed are Door Creek, Little Door Creek, Keenan Creek and Leuten Creek. There are several small unnamed tributaries to the names streams and lakes in the watershed. Most of these have been channelized to facilitate drainage and agricultural production. Other water resources are Lake Kegonsa (discussed in the Yahara Lakes section), Lower Mud Lake, Stoughton Millpond, Dunkirk Millpond, Lower Mud Lake wetlands, and Door Creek wetlands. Large areas of historic wetlands have been drained and converted to agriculture. This modification has increased sediment and nutrient loading to surface waters.

Yahara River

The Yahara River is 40 miles long with 23 miles being in Yahara-Kegonsa watershed. The Yahara River in this watershed begins at the Babcock Park dam on Lake Waubesa 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 classified as a warm water sport fishery (WWSF) stream and supports a diverse warm water fishery of approximately 48 species[152]. The Yahara River from Lake Kegonsa downstream to where Badfish Creek joins it in Rock County was added to the state's impaired waters (303d) list in 1998. Phosphorus, sediments and total suspended solids have led to impairment of acceptable dissolved oxygen levels and degraded habitat. The Rock River is a high priority for TMDL development. A phosphorus water quality target of 0.125 mg/l has been proposed[153]. Most wastewater has been directed to the MMSD Nine Springs treatment facility. Rural nonpoint sources of pollution are now the primary threat to water quality.

Baseflow in the Yahara River downstream of Lake Mendota has decreased about 35% since MMSD's sewage was diverted around the Yahara lakes in 1958[154]. The decrease in baseflow coupled 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[155] where the river drops only two feet. 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. The river falls about 30 feet from the Dunkirk Millpond to the county line. There are a series of riffles and runs in this reach. Warm water IBI monitoring done at Dane CTH N below the Dunkirk in 2007 showed a biotic integrity rating of "good" indicating somewhat less than

[152] Bardeen and Ripp, 2001.
[153] WDNR, 2006.
[154] DCRPC, 1992.
[155] Habecker, 2002.

optimal species richness[156]. A 2007 Hilsenhoff HBI indicated "good" water quality conditions (HBI score=5.09)[157].

Yahara River at CTH N

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. High development pressure for waterfront property also poses the threat of increased construction site erosion. The hydrologic modifications to the stream in the form of dams and decreased baseflow also are a continuing problem[158].

Door Creek

Door Creek is tributary to the Yahara River at Lake the north end of Lake Kegonsa. It begins in the southeast corner of the Town of Burke and flows south 12.7 to the lake. Door Creek and its tributaries drain 29.5 square miles of rolling agricultural land and the rapidly developing far east

[156] WDNR, 2010.
[157] WDNR South Central Region Water Resources Files, 2010.
[158] Bardeen and Ripp, 2001

side of Madison and the village and town of Cottage Grove. Much of Door Creek has been straightened and ditched to facilitate drainage. The stream ditching and straightening allows heavy loads of sediments and nutrients to reach Lake Kegonsa. Remeandering the creek through the marsh was considered but concern that the effort would result in even more sediment loading to the lake and harm higher quality wetland areas.

Door Creek is a sluggish stream with a flat gradient of 2.4 feet per mile. It is subject to high temperatures and low flows. Its potential has been limited by natural conditions such as low baseflow and slow velocity. Groundwater modeling done in 1999 predicted a 17% decrease in Door Creek baseflow between 1995 and 2020[159]. Municipal high capacity pumping of groundwater and the resulting drawdown of groundwater levels is the problem. Sediment and nutrient loads are significant due to the ditching and stream straightening, and by wetland drainage and agricultural runoff[160]. Wetlands, particularly the Door Creek wetlands at the mouth of the creek, provide important spawning areas for northern pike and other fish species. Door Creek is considered a limited forage fishery (LFF) stream. Water quality is generally poor due to heavy sedimentation reducing habitat. However, some improvement to water quality has been noted and may result in the stream being reclassified[161].

Intermittent IBI monitoring at two locations on Door Creek (Vilas Hope Road and Hope Road) indicated "fair" biotic integrity. Warm water 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 (HBI score=5.26) while the HBI at Hope Road was "poor" (HBI score=8.05). Heavy stream bottom silt was noted at Hope Road[162].

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, and urban sources such as construction sites and runoff from impervious surfaces. Continued and increased municipal water supply groundwater pumping will continue to affect stream baseflow, particularly in its headwaters area.

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[159] Water Resources Workshop, *Door Creek Watershed Assessment*, 2009.
[160] DCRPC, 1992.
[161] Bardeen and Ripp, 2001.
[162] WDNR, 2010.

Door Creek at Hope Road

Little Door Creek

Little Door Creek is a small ditched stream that joins Door Creek south of USH 12/18. It drains about 8.3 square miles and has an average stream gradient of 11.8 feet per mile. Several small wetlands are adjacent 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[163] . A 2001 IBI taken near Cottage Grove indicated “fair” biotic integrity, and HBI monitoring also indicated “fair” water quality[164]. An intermittent fish IBI at CTH N in 1998 indicated “poor” biotic integrity.

Leuten Creek

Leuten Creek is a small spring-fed stream beginning in the Town of Pleasant Springs and flowing south and west to the Yahara River below Lake Kegonsa. It is about five miles long and has an average stream gradient of 9.7 feet per mile. 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[165]. It currently supports a limited forage fishery (LFF).

Keenan Creek

Keenan Creek is a small tributary to Upper Mud Lake through a large wetlands complex on the southwest end of Lower Mud. Keenan is nearly 4.5 miles long and has an average stream gradient of 25 feet per mile It drains an drains an area of 3.6 square miles. Land use is agriculture and rural residential. It is considered a warm water forage fishery, although no recent monitoring has been done[166].

[163] Bardeen and Ripp, 2001.
[164] WDNR, 2010.
[165] Bardeen and Ripp, 2001.
[166] Bardeen and Ripp, 2001.

Table ____. Streams of the Yahara-Mendota and Sixmile Pheasant Branch Watersheds

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish and Aquatic Life Conditions	303(d) Status	Impairment Impact	Impairment Source	F-IBI/HBI Ave. (No.)
Dorn (Spring) Creek	0-1	WWSF	WWSF	Partially	Poor)	No	Habitat	Sediment, Tot.P., AgNPS	/6.26(4)
	1-6.5	LFF	WWSF	Not	Poor	Yes			
Harbison Tributary	1	COLDII	COLDII	Yes	Fair	No	?	?	64*(5)/4.70(4)
Pheasant Branch	0-1	WWSF	WWSF	Partially	Poor	Yes	Habitat, low DO	Tot.P., Sediment, Tot.Sus.Solids	7.5(2)/7.36(9)
	1-9	LFF	LFF	Partially	Poor				
Sixmile Creek	0-8.5	WWSF ERW	WWSF ERW	Partially	Poor	No	Habitat, Temperature	Tot.P, Urb-NPS, Ag-NPS	57.5(8)##/6.09(14)
	8.5-12	LFF	LFF	Partially	Poor				
Token Creek	0-2.9	WWSF	COLD III	No	Poor	No	Habitat	Tot.P, sediment	30*(2)/5.87(2)
	2.9-6.35	COLD II	COLD II	Partially	Fair	Yes	Habitat	Tot.P, sediment, urban NPS	36*(5)/4.96(4)
	6.35-9.6	COLD III	COLD II	Not	Poor	Yes	Habitat	Tot.P, sediment, urban NPS	0*(2)/5.78(7)
Willow Creek	<1	LAL	?	?	Poor	No	Habitat, DO(?)	Tot.Sus> Solids, Urb-NPS	---
Yahara River (Above Lake Mendota)	20	WWSF	WWSF	Partially	Poor-Fair	No	Habitat, Temperature	Tot.P, AgNPS, urban NPS, sediment	10.5#(10)/4.70(9)

*= Cold-IBI

#= 5 Cold-IBIs and 5 Warm-IBIs

##= 2 Warm-IBIs and 6 Intermittent IBIs

Table ____. Streams of the Yahara-Monona Watershed

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish and Aquatic Life Condition	303(d) Status	Impairment Source	Impairment Impact	F-IBI/HBI (No.)
Murphy's Creek	3	WWFF	WWFF	Partially	Poor	N	NPS	Habitat	40(1)*/6.75(1)
Nine Springs Creek	6	WWSF	WWSF	Partially	Poor	Y	Tot.P, Sediment, Tot.Sus.Solids, UrbNPS	LowDO, Water Temp	
Starkweather Creek	0.5	LFF	WWSF	Not	Poor	Y	Metals, Sediment, Tot.Sus.Solids, BOD, UrbNPS	Low DO, Habitat, Chronic Aquatic Toxicity	
Starkweather Creek (East Branch)	2.7	LFF	LFF	Not	Poor	Y	Metals, Sediment, Tot.Sus.Solids, BOD, UrbNPS	Low DO, Habitat, Chronic Aquatic Toxicity	75(2)*/7.27(2)
Starkweather Creek (West Branch)	6.7	LFF	LFF	Not	Poor	N	Metals, Sediment, Tot.Sus.Solids, BOD, UrbNPS	Low DO, Habitat, Chronic Aquatic Toxicity	
Swan Creek	2	WWFF	Unknown	Unknown	Unknown	N	UrbNPS	Temp., Habitat	45(2)*/4.72(1)
Yahara River	2	WWSF	WWSF	Partially	Poor	N	UrbNPS		
Wingra (Murphy) Creek	2	WWSF	WWSF	No	Poor	Y	Unknown	Chronic Aquatic Toxicity	

*= Intermittent-IBI

Table ____. Streams of the Badfish Creek, and Yahara-Kegonsa Watersheds

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish & Aquatic Life Condition	303(d) Status	Impairment Source	Impairment Impact	F-IBI/HBI (No.)
Badfish Creek	0-12	WWSF	WWSF	Partially	Poor	Y	PCBs	Contaminated sediement	/5.70(1)[*]
	12-13	LFF	LFF	Partially	Poor				
Door Creek	13	WWFF	WWSF	Not	Poor	N	AgNPS, UrbNPS,	Habitat, Turbidity, Temp., Sedimentation	66.6(3)[#]/5.94(3)
Frogpond Creek	7	WWFF	WWFF	Partially	Fair	N	AgNPS	Sedimentation, Habitat	70(2)[**]/4.49(1)
Keenans Creek	4.5	WWFF	WWSF(?)	Partially	Poor	N	AgNPS	Habitat, Sedimentation	-/-
Leutens Creek	3	LFF	LFF	Partially	Poor	N	AgNPS, Hydraulic Modification	Habitat, Sedimentation	-/-
Little Door Creek	5	LFF	LFF	Partially	Poor	N	AgNPS, Hydraulic Modification	Habitat, Sedimentation, Turbidity, Flow	30(1)[#]/5.66(1)
Oregon Branch	0-4	LFF	LFF	Partially	Poor	N	Muni.PointSource, UrbNPS, AgNPS	Habitat, Turb, DO, Sedimentation, Temp	-/-
	4-6	LAL	LAL(?)		Poor				
Rutland Branch	2.6	Cold II/ERW	Cold II/ERW	Partially	Fair	N	AgNPS	Habitat, Sedimentation	50(1)[***]/--
Yahara River	23	7.3-16.3	WWSF	WWSF	Poor-Fair	Y	AgNPS, Hydraulic Modification	DO,Habitat, Flow	67(1)[##]/5.08(1)
		16.3-22			Poor	Y	AgNPS, Hydraulic Modification	DO,Habitat, Flow, Sedimentation	--/--
		22-25			Poor	N	AgNPS, Hydraulic Modification	DO,Habitat, Flow, Sedimentation	--/--

*= Madison Metropolitan Sewerage District has long-term IBI and HBI data for Badfish Creek.

#= Intermittent-IBI

**= One Intermittent –IBI, one warmwater-IBI.

##= Warmwater-IBI

***= Coldwater IBI

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Yahara Chain of Lakes

The Yahara Chain of Lakes is the centerpiece of Dane County's natural resources and vital for the greater Madison economy. 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. And 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 (WDNR 2002). 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 Dane County an attractive destination for water based recreation and tourism.

The Yahara lakes sustain a productive fishery that is a regional attraction and economy 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 the mean length was 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 but 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 Columbia County. The watershed also lies within the greater Southeast Glacial Plains Ecological Landscape. There are many opportunities within this landscape to restore natural communities that also benefit water quality (WDNR Wildlife Action Plan 2005). 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 position within the watershed, history and sources of pollution and basin morphometry. The physical characteristics for Lake Mendota, Lake Monona, Lake Wingra, Lake Waubesa and Lake Kegonsa are summarized in Table 1.

Lake Mendota is the largest and deepest of the Yahara lakes (Table 1). 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% of the watershed is urban with development expanding rapidly. Urban areas lie along the west, east and southern parts of the lake but development is expanding to 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 and Villages of Arlington, Deforest, Waunakee, Dane and Windsor.

Table 1: Physical Characteristics of the Yahara Lakes

Characteristic	Mendota	Monona	Wingra	Waubesa	Kegonsa
Surface area (acres)	9,847 (3,985 ha)	3,277 (1,326 ha)	345 (140 ha)	2,083 (843 ha)	3,210 (1,299 ha)
Volume (gallons)	134 billion	29 billion	1.9 billion	10 billion	18 billion
Maximum depth (ft)	83 (25.3 m)	74 (22.6 m)	14 (4.3 m)	38 (11.6 m)	32 (9.8 m)
Mean depth (ft)	42 (12.7 m)	27 (8.3 m)	8.9 (2.7 m)	15 (4.7 m)	17 (5.1 m)
Surface July max. water temp. (F)	73.4 - 78.8 (23 - 26 C)	75.2 - 82.4 (24 - 28 C)		75.2 – 82.4 (24 – 28 C)	75.2 – 82.4 (24 – 28 C)
Bottom July min. water temp. (F)	50 – 53.6 (10 – 12 C)	51.8 – 57.2 (11 – 14 C)		59 – 69.8 (15 – 21 C)	62.6 – 77 (17 – 25 C)
Shoreline length (miles)	21.9 (35.2 km)	13.2 (21.2 km)	3.7 (5.9 km)	9.4 (15.1 km)	9.6 15.4 km)
Shoreline dev.	1.57	1.64		1.47	1.21

factor					
Flushing Rate (yr)	0.15	0.91	2	3.2	2.2
Dir. drainage (sq. mi.)	217 (562 sq. km)	40.5 (105 sq. km)	5.4 14 sq. km)	43.6 (113 sq. km)	54.4 (141 sq. km)
Drainage at outlet (sq. mi.)	232 (602 sq. km)	278 (720 sq. km)	5.4 (14 sq. km)	325 (842 sq. km)	385 (996 sq. km)

Lake Monona, Lake Wingra and Lake Waubesa are located within the 61,643 acre 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 385 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 (70%) 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 high propensity for internal nutrient recycling. Kegonsa is located within the 126 square miles Yahara Kegonsa Watershed (66,894 acres in Dane County). Upper watershed lake water quality and internal nutrient mixing are the principal factors that influence the water quality of this lake.

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 (Carpenter 2005). 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 governmental sponsored monitoring in response to declining water quality in the lakes.

Lathrop (2007) provided the most recent chronology and analysis of environmental problems in the lakes. 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 blooms in Lake Monona, Lake Waubesa and Lake Kegonsa. Dissolved reactive phosphorus was very high in these lakes but declined precipitously in Lake Monona after municipal wastewater was diverted downstream to Lake Waubesa. The very high nutrient levels Lake Waubesa and Lake Kegonsa were sustained until 1958 or shortly thereafter when all of Madison's municipal wastewater was diverted to Badfish Creek, and downstream of the Yahara lakes. Levels of inorganic 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 and 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.

The management of the Yahara lakes evolved as a response to eutrophication. Lakes management was initially reactive but eventually became science based. When

Cyanobacteria 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 essentially treated the symptoms of eutrophication rather than the causes. The legacy of extensive copper sulfate 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 (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. Until full implementation of the Clean Water Act during the 1980's, the successive wastewater diversions had largely transferred water quality problems to downstream waters.

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, completion of the first Lake Mendota watershed manure digester with capacity to generate $2 million worth of electricity per year and ban on phosphorus based lawn fertilizers. These and other conservation efforts have been endorsed by the Yahara Lakes Legacy Partnership.

Long-term nutrient analysis of the Yahara Chain of Lakes revealed that both phosphorus and nitrogen can be limiting to algal growth. Nitrogen can be limiting due to three factors: low iron concentrations for N_2 fixation, high denitrofixation rates and high phosphorus inputs (Lathrop 2007). 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. Consequently, the Yahara lakes have high capacities for internal phosphorus loading compared with lakes where sulfate levels are lower.

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 related to 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. During the Environmental Assessment of the NR 107 program in the late 1980s, the State Public Intervener's Office and various conservation and environmental groups questioned the authority of the state to allow riparian landowners to chemically treat public waters for private use.

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 (Martin 2009) to address existing and potential new invasions that can undermine the Yahara lakes. Zebra mussels had been found in isolated areas of Lake Monona while an invasive bluegreen alga (*Cylindrospermopsis*) has been identified in Lake Waubesa and Lake Kegonsa. The exotic Cyanobacteria species has potential to produce toxins at greater frequency than native bluegreens. 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.

<u>Lake Mendota</u>

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 2 provides a glimpse of the extensive research that had focused on Lake Mendota water quality and ecology. Numerous peer reviewed articles, dissertations and books had been published on Lake Mendota since 1992 when the last Dane County water quality plan 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 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 1. Lake eutrophication had been well documented and the lake is currently on the USEPA 303(d) due to a fish consumption advisory for polychlorinated biphenyls or PCBs. Summer Cyanobacteria 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 to 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. 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 (Kamarainen et al. 2009).

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 but landowner participation was low as well as project effectiveness as revealed by long term USGS monitoring data for Pheasant Branch Creek (Nowak et al. 2006). 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. 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.

The Lake Mendota Priority Watershed Project began in 1994 with a goal of reducing phosphorus loading to Lake Mendota by 50%. The 265 square mile watershed was inventoried as part of the plan. Seventy-four percent of the watershed was agriculture, 6% was wetland and 20% was urban. From 30 to 50% of the wetlands in the watershed had been previously drained. Four hundred-three barnyards were inventoried with 319 that drained directly into tributaries. An estimated 15,048 lbs/P generated from animal waste sources reach Lake Mendota each year. Nutrient management plans were prepared for over 36,000 acres of croplands or approximately 37% of the total cropland in the watershed. Annual soil loss in the watershed was estimated at 37,502 tons/acre/yr. The annual soil loss reaching Lake Mendota was estimated at 6,589 tons/yr with associated phosphorus loading of 35,030 lbs/P/yr. Streambank erosion accounted for an annual soil loss of 728 tons/yr and associated phosphorus loading of 4,608 lbs./yr. All total agriculture contributes about 75% and urban areas contribute about 25% of the annual 81,000 lbs of phosphorus reaching Lake Mendota each year.

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 et al. (1999) 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. As a result, there has been a steady increase in phosphorus fertility in watershed soils along with increased manure production. The long term watershed phosphorus increase may be a reason why the priority watershed goal of 50% phosphorus reduction was not achieved. More recently, 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. Controlling nutrient input to Lake Mendota is critical since it has become the primary source phosphorus for the lower Yahara lakes.

Table 2: Examples of research documents produced since the 1992 Appendix B report

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The University of Wisconsin Madison Limnology Department conducts intensive water quality monitoring on Lake Mendota as part of the Long Term Ecological Research (LTER). Figures 1a, 1b and 1c display secchi, total phosphorus and chlorophyll data along with associated Trophic State Indices (TSI). Lake Mendota remains moderately eutrophic with median TSI values for total phosphorus, chlorophyll and secchi at 62, 53 and 50 respectively. The lower TSI for secchi may reflect bio-interactions in the lake as mentioned earlier.

While a major focus of Lake Mendota research and management has been addressing long term water clarity declines and levels of nuisance Cyanobacteria blooms, significant changes had occurred to nearshore areas. Lyons (1989) 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. 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 are macrophytes obligates and aquatic plant losses linked to herbicides treatments and structures can destroy and fragment their habitat (Garrison et al. 2005).

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 supporting coarse woody debris, floating-leaf plants including American lotus (*Nelumbo lutea*) and 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 1a: Recent surface total phosphorus levels in Lake Mendota and associated TSI (≥ 50 – 70 = eutrophic). LTER database

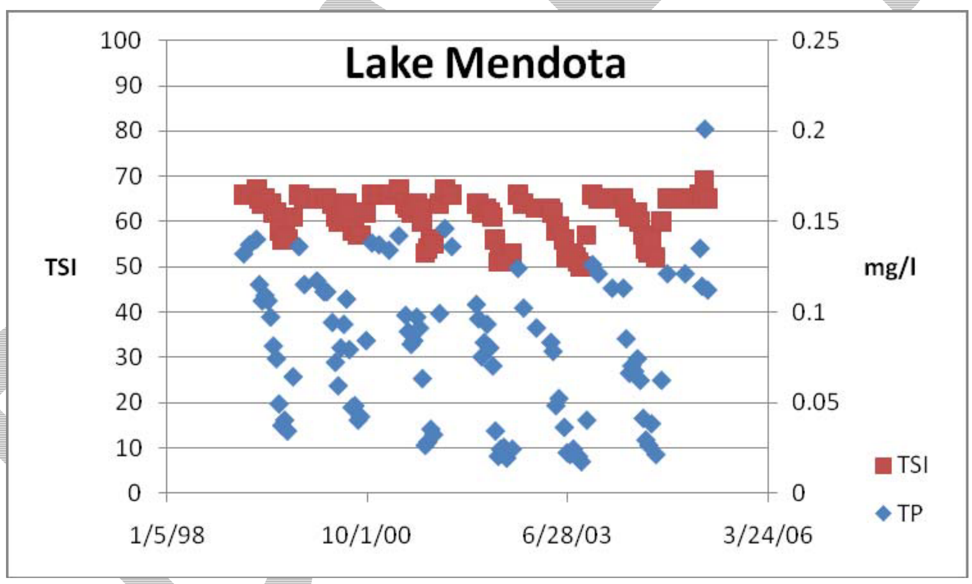


Figure 1b: Recent surface – 2 meters chlorophyll a levels in Lake Mendota and associated TSI (≥ 50 – 70 = eutrophic). LTER database

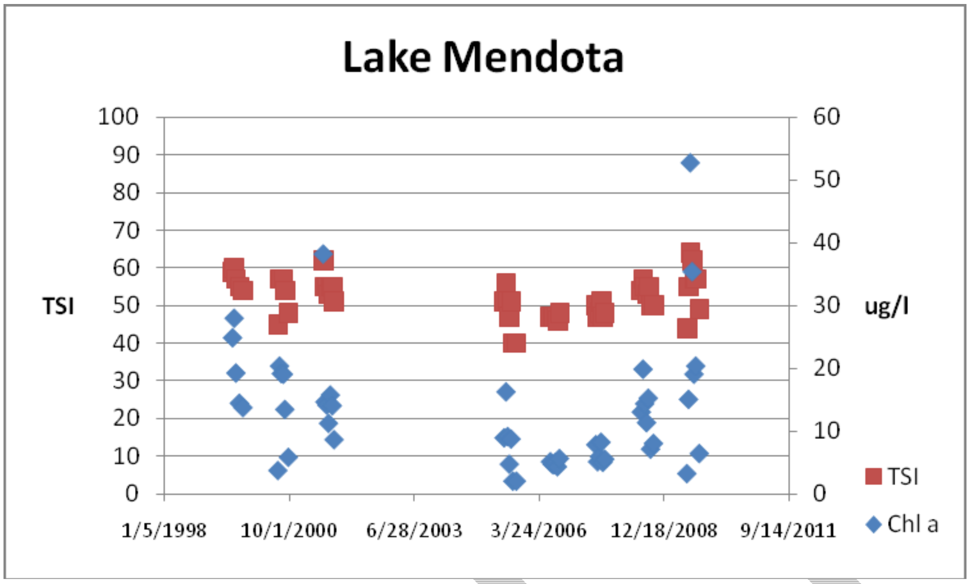
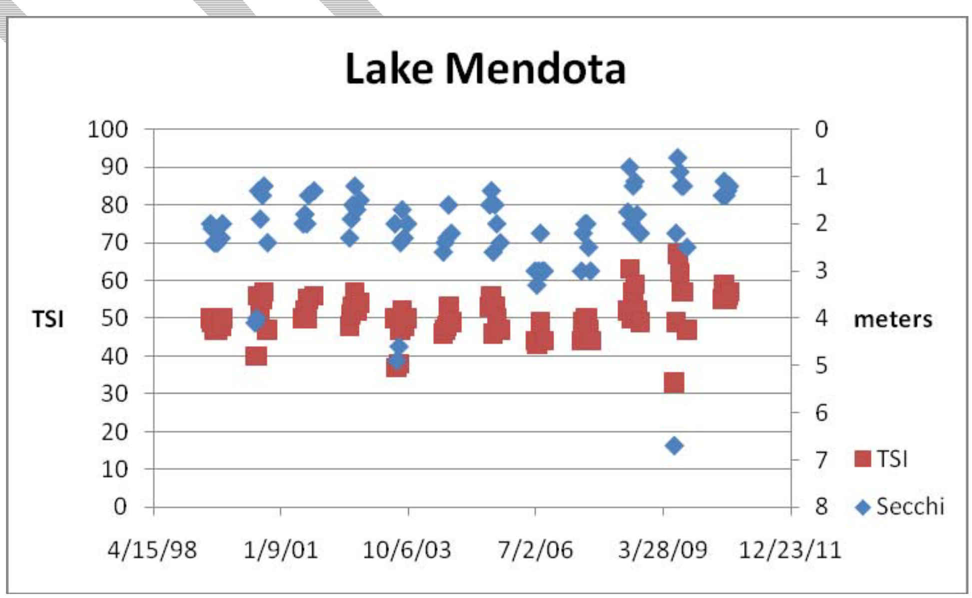


Figure 1c: Recent secchi measurements in Lake Mendota and associated TSI (≥ 50 – 70 = eutrophic). LTER database



Lake Monona

Lake Monona is the second largest lake in the county. Physical features of the lake and watershed appear in Table 1. 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 Cyanobacteria 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 (DCRPC 1979). 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 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 USEPA 303d list for mercury and PCB fish consumption advisories.

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 85 square mile watershed that is 70% urban. 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 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 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 domestic water use and associated wastewater diversion along with expansion of impervious surfaces that limit surface water infiltration. Both of these changes affect base flow 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 and impact of the high density urban landscape.

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 over 50% of the annual phosphorus load that is estimated at 36,800 lbs/yr. Lake Monona water clarity is typically only slightly lower than Lake Mendota in recent years and reflects more significant internal loading in Lake Monona (Lathrop 2007). Summer secchi readings typically fall between 1.5 to 2 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 Lake Monona TSI values for total phosphorus, chlorophyll and secchi were 60, 53 and 53 respectively compared with 62, 53 and 50 for Lake Mendota. The TSI parameters and values for Lake Monona appear in Figures 2a, 2b and 2c.

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 largescale mechanical harvesting and nearshore herbicides treatments. In 2008, Dane County Office of Lakes and Watersheds 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 two hundred-eighty of the sites were located within 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 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*) and 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 2a: Recent surface concentrations of total phosphorus in Lake Monona and associated TSI values (≥ 50 – 70 = eutrophic). LTER database.

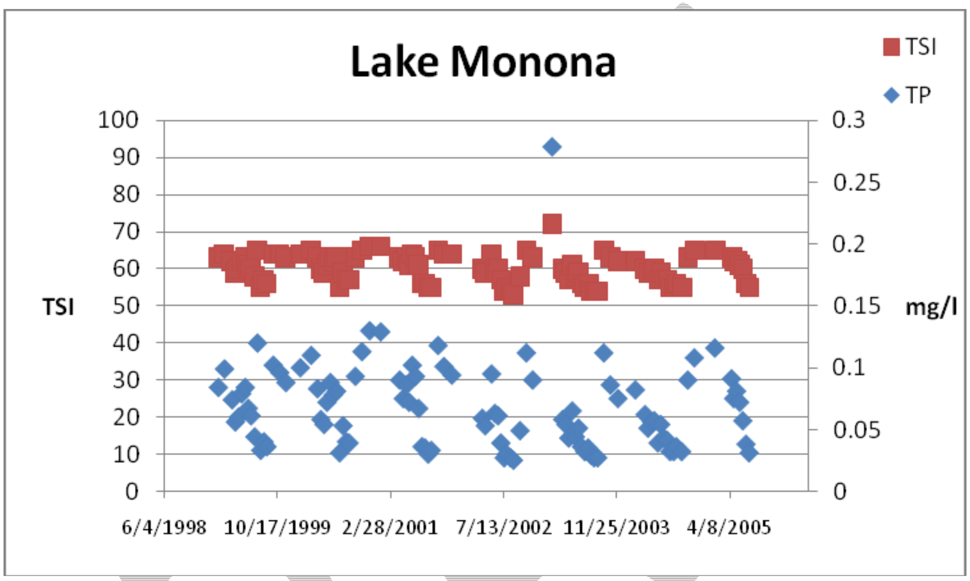


Figure 2b: Recent chlorophyll concentrations surface to 2 m in Lake Monona and associated TSI values (≥ 50 – 70 = eutrophic). LTER database.

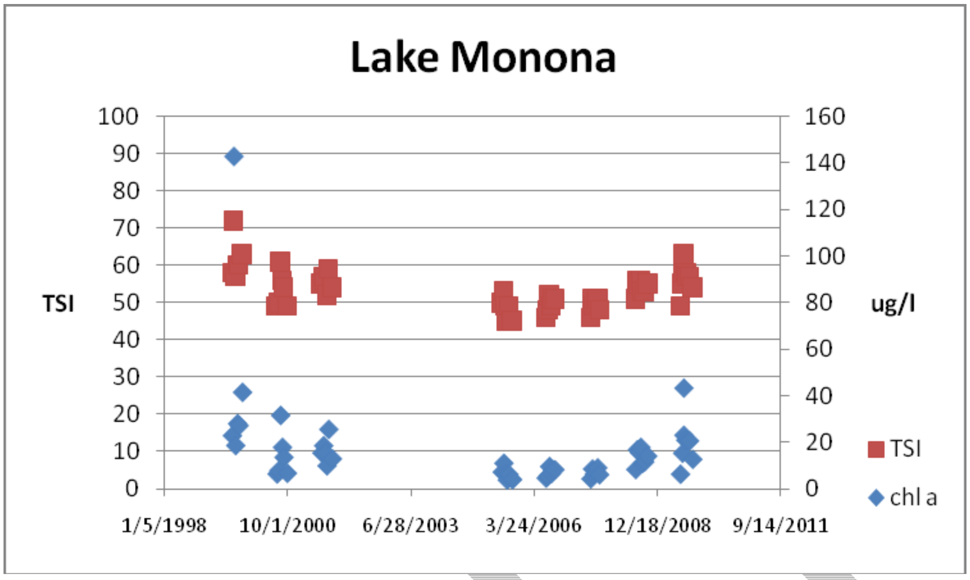
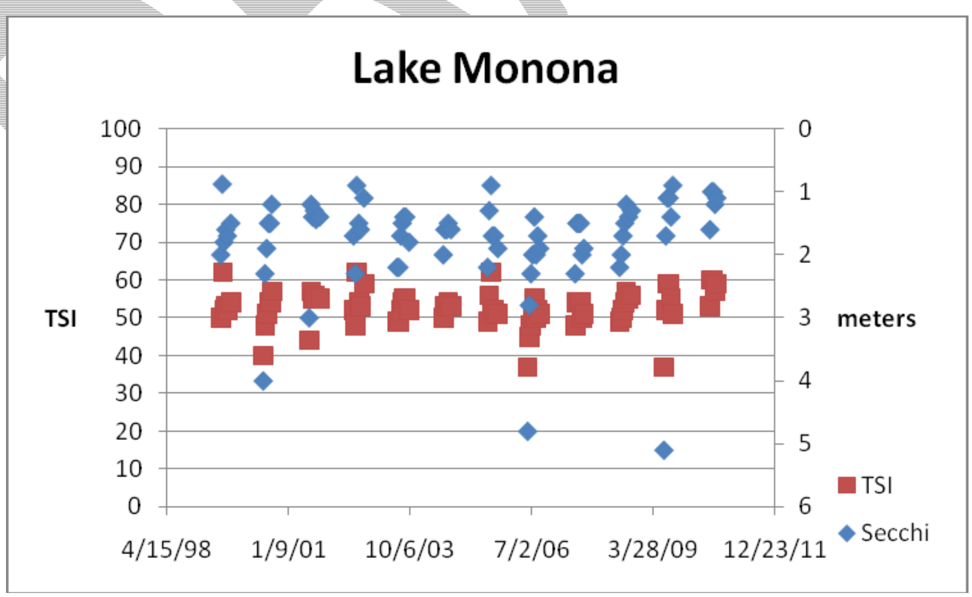


Figure 2c: Recent secchi measurements in Lake Monona and associated TSI values (≥ 50 – 70 = eutrophic). LTER database.



Lake Wingra

Three hundred-forty-five acre Lake Wingra is the smallest and shallowest of the Yahara lakes. Physical features of the lake and watershed appear in Table 1. 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 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 (Wenta et al. 2010). 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 displays a high propensity for internal phosphorus loading.

Common carp have been a long term problem in the lake reducing rooted plants in Lake Wingra and sustain turbid water due to heavy Cyanobacteria 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.

Dane County infrequently operates large-scale mechanical harvesters 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, chlorophyll and secchi data appear in Figures 3a, 3b and 3c along with the transformed TSI values. The data demonstrates the high degree of eutrophication but also establishes a baseline to assess long term common carp management in the lake. Median Lake Wingra TSI values for total phosphorus, chlorophyll and secchi are 59, 56 and 65 respectively.

Figure 3a: Recent surface total phosphorus data from Lake Wingra and TSI values (> 50 – 70 = eutrophic, > 70 = hypereutrophic). LTER database

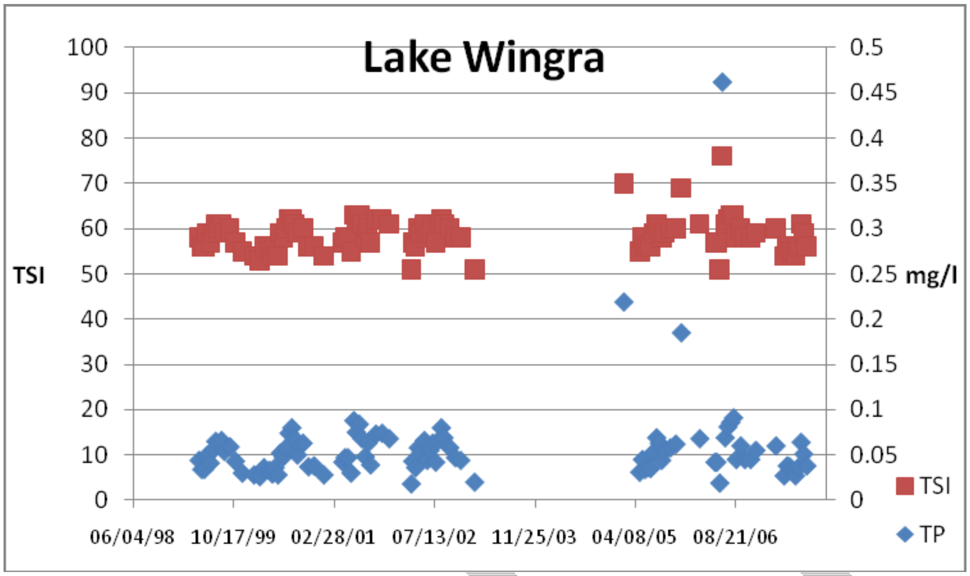


Figure 3b: Recent chlorophyll data (0 – 2 m) from Lake Wingra and TSI values (> 50 – 70 = eutrophic, > 70 = hypereutrophic). LTER database

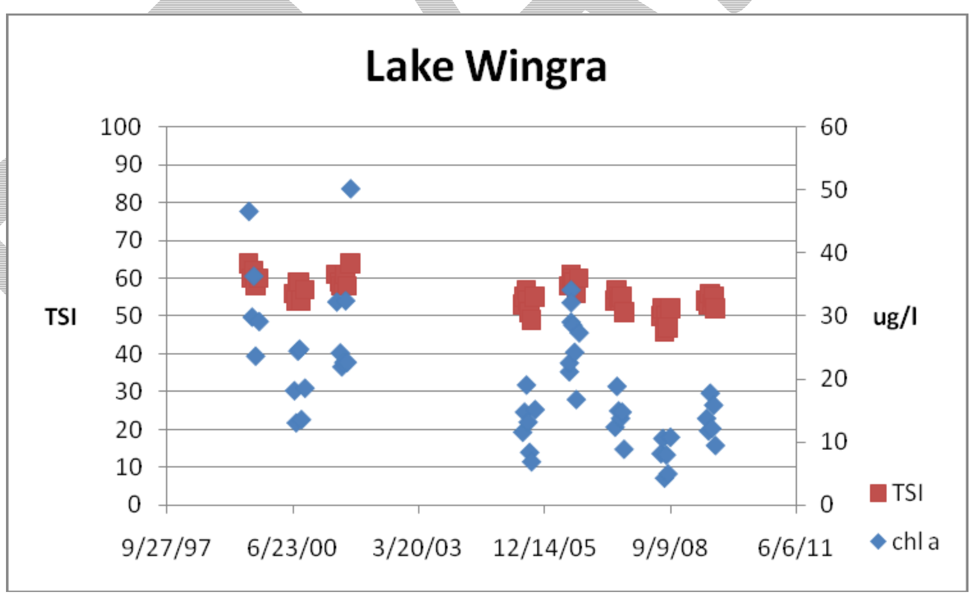
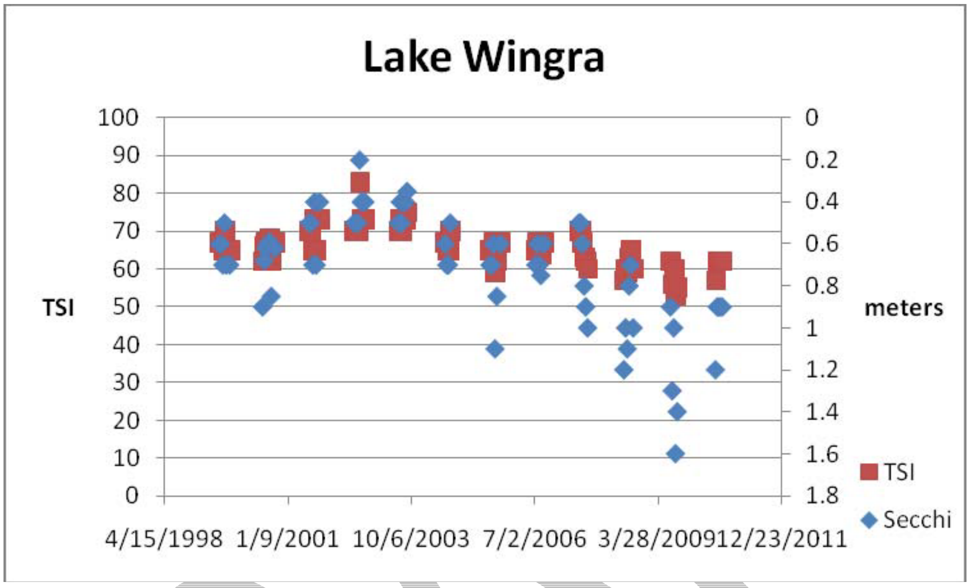


Figure 3b: Recent secchi data from Lake Wingra and TSI values (> 50 – 70 = eutrophic, > 70 = hypereutrophic). LTER database



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 1. It is third in a series of lakes that were formed as morainic damming of 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 advanced eutrophic conditions such as reduced water clarity and Cyanobacteria blooms than both Lake Monona and Lake Mendota. Since the upper lakes are the primary environmental driver for Lake Waubesa by contributing more than 50% of the annual phosphorus load (34,400 lbs/yr), lack of sustained thermal stratification and internal nutrient loading is the primary factor sustaining greater level of eutrophication in the lake.

Median secchi disc readings are typically much lower and averaged only about 1 meter from 1980-2006 (Lathrop 2007).

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. Lake Waubesa is currently on the USEPA 303(d) list of impaired waters due to a fish consumption advisory for mercury.

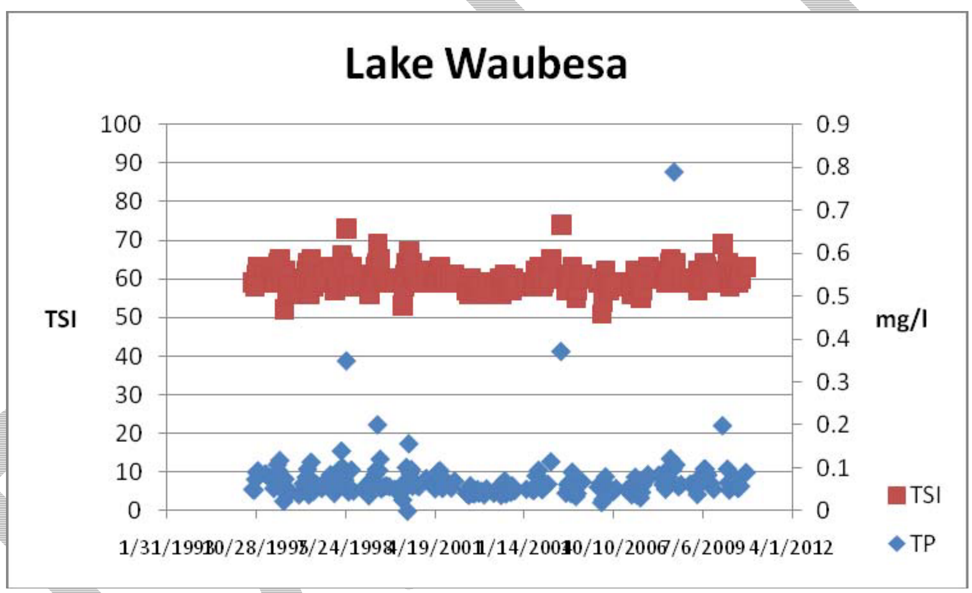
Eurasian watermilfoil beds are periodically a problem for recreation and boating on Lake Waubesa and Dane County operates large-scale mechanic harvesters as needed. As required under NR 109, the county updated the aquatic plant management plan for Lake Waubesa in 2008 and conducting a point intercept 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 dearth 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 (see map) 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 spatterdock (*Nuphar variegata*) and 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 (*Char*a) 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 (Winkelman and Lathrop) aquatic plant management plan as Sensitive Areas.

Wisconsin DNR SWIMS database holds an extensive total phosphorus database. Figure 4 displays surface total phosphorus concentrations and TSI values from 1995 through 2010.

Figure 4: Recent surface total phosphorus data from Lake Waubesa and TSI values (> 50 – 70 = eutrophic, > 70 = hypereutrophic). WDNR SWIMS database.



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 1. 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 bluegreen algal blooms during the summer.

Lake Kegonsa lies within the Yahara Kegonsa Watershed where agriculture is the dominant land use (81%). 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 bluegreen 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 over 50% of the annual phosphorus load (44,500 lbs/yr) originates upstream.

Lake Kegonsa is algal dominated and displays poorer water clarity than Lake Waubesa. While the water quality had improved in recent years, secchi disc readings from 1980-2006 were typically less than 1 meter (Lathrop 2007). Figure 5 displays the WDNR SWIMS annual water clarity data and TSI values from 1989 to 2010.

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:

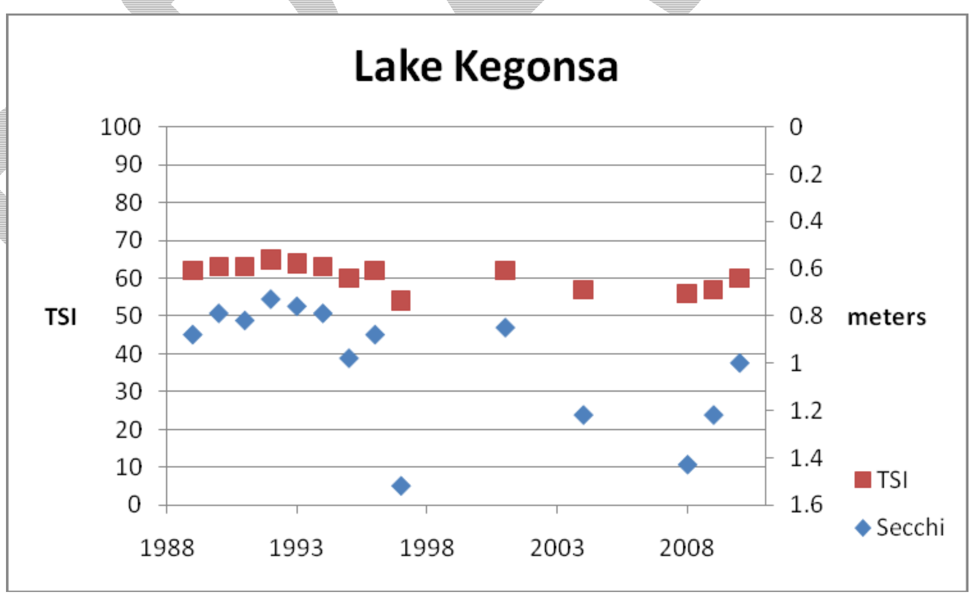
Lake Kegonsa

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.

Lower Mud Lake

1. Conduct large-scale mechanical harvesting to maintain flow between the inlet and outlet of Lower Mud Lake.
2. Limit 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.
3. 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.
4. 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.

Figure 5: WDNR SWIMS annual water clarity and TSI values for Lake Kegonsa (> 50 – 70 = eutrophic)



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Sugar River Basin

Introduction

The Sugar River Basin in Dane County lies in the Driftless Area of Wisconsin. The driftless area lies in the southwest 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[167].

SUGAR RIVER BASIN MAP WITH WATERSHEDS

The north boundary of the Sugar River 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 basin has dissected uplands with a well developed dendritic drainage pattern consisting of a series 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 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[168]. Bedrock is close to the surface on hills and ridge tops or is occasionally exposed and is 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[169].

The eastern part of the Sugar River 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

[167] Mickelson, 2007. Also see *The Physical Geography of Wisconsin* by Lawrence Martin or *Wisconsin's Foundations* by Gwen Schultz for a more detailed discussion of glacial impacts on Wisconsin.
[168] Martin, 1965.
[169] DCRPC, 1992.

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 basin. They are all of the Upper Sugar River watershed and the Mt. Vernon and West Branch Sugar River watershed, and small portions of the Little Sugar River watershed, and the Allen Creek and Middle Sugar River watershed.

Upper Sugar River Watershed

The Upper Sugar River Watershed is in the unglaciated southwestern Dane County. It has an area of 103.7 square miles. Approximately 16% of its area is developed (residential, commercial, industrial or institution/government) while 56% of its area is devoted to agriculture, 11% is in woodlands and 14% is in other land uses (other open or vacant land). The remaining 3% of its area is outdoor recreation and wetlands[170]. 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 Village of Verona, 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 the Madison Metropolitan Sewerage Districts discharge to Badger Mill Creek (more on this in the Badger Mill Creek narrative below).

Table_______. Upper Sugar River Watershed Land Cover

Resource Characteristics	in acres
Agricultural	37,328
Woodland	7,209
Residential	5,253
Hydric Soils	4,507
Transitional**	3,955
Wetlands	2,270
Outdoor recreation	1,695
Industrial	509
Open water	446
Commercial	400
Institutional/Governmental	359
Other*	9,155

170 Jones (Ed.), 2008

Size of watershed	**66,351**

*includes codes other open or vacant land; vacant, unused land

**includes transportation, communication and utilities.

The Upper Sugar River Watershed has over 115 stream miles. The named streams are the Sugar River, Badger Mill Creek, and Henry 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 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 feet per mile[171]. 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 303d list of impaired waters in 1998. These discharges have been eliminated resulting in improved water quality and instream habitat. The creek was removed from the state's 303d list in 2002. Flow in Badger Mill downstream of CTH PD is augmented by a large springs near the Military Ridge trail head and other smaller springs and groundwater seepage. MMSD has also augmented flow since 1998 (see discussion below). Badger Mill receives stormwater runoff from Verona and the southwest side of the City of Madison. Both areas are intensely developed or are rapidly developing. Verona's estimated population has increased about 52% in the period between 2000 and 2010. Verona's 2025 estimated population is 15,850 or 47% higher than 2010 and more than double the 2000 census population[172]. Impervious surfaces are estimated to cover about 19.6 percent of the Badger Mill drainage area. The most significant threat to water quality in Badger Mill at this time is from urban stormwater runoff from developments in Verona and Madison.

Badger Mill Creek at STH 69 South of Verona

171 DCRPC, 1992.

172 Estimates derived from Wisconsin Department of Administration Demographics Services population data and estimates.

Water Resources Quality. Badger Mill Creek is considered a Cold Water Community supporting a Class II trout fishery upstream from the Sugar River to Bruce Street[173]. Beyond Bruce Street it is considered Warm Water Forage Fishery and a Limited Forage Fishery stream. Water quality and instream habitat have improved significantly in Badger Mill Creek since 1978. A stream assessment done in 1989 indicated the stream's classification as a limited forage fishery stream should be upgraded to warm-water forage fishery stream[174]. DNR aquatic invertebrate monitoring was done at four sites on Badger Mill between 1996-1999. The results indicated water quality conditions ranging from "fair" (fairly significant organic pollution) to "very good" (slight organic pollution)[175]. Brown trout (*Salmo trutta*) are now regularly found in Badger Mill. DNR fish monitoring done it 1994 and 1995 found brown trout reproduction and abundant mottled sculpin (*Cottus baiardi*), a pollution intolerant cold-water forage fish

[173] Welke, *Badger Mill Creek Fisheries Classification*, 2005.
[174] WDNR Upper Sugar River Watershed webpage accessed 11/2010. http://www.dnr.state.wi.us/water/basin/gpsp/spbasin/surfacewaterfiles/watersheds/sp15.html
[175] WDNR South Central Region Water Resources Files, 2010.

species[176]. However, coldwater IBI monitoring done by the DNR in 1997 at three sites on Badger Mill for "poor" biotic integrity at all three sites[177] indicating major environmental degradation has occurred and biotic integrity has been severely reduced[178]. A 2001 reclassification study recommended that Badger Mill be classified a coldwater (COLD) water resource based on the presence of brown trout and mottled sculpin[179] Subsequent DNR coldwater IBI monitoring done in 2000 and 2005 at several locations found "poor" or "very poor" biotic integrity. A 2005 DNR stream classification report noted that cool water intolerant fish species (mottled sculpin and brook stickleback (*Culaea inconstans*) populations have declined in Badger Mill Creek since MMSD began its discharge to the creek. The report also noted increased levels of chlorides, total phosphorus, dissolved phosphorus and ammonia in the water column. The report concluded the creek was still able to support its designation as a cold water stream because of its cool water temperatures and the continued presence of brown trout[180]. A 2005 DNR fisheries classification report conclude that Badger Mill Creek met the definition of a Class II trout stream[181] based on the presence of brown trout at all sample stations, multiple ages of trout, and occurrence of young of year trout. Temperature and dissolved oxygen data also supported this proposed designation[182]. USGS data taken at a monitoring station downstream of Bruce Street in Verona between 1996 and 2006 show a monthly mean water temperature range of 5.2^0 C (41.4^0 F) for January to 18.3^{0}C (64.9^0 F) for July over that span of years[183]. Wisconsin Citizens-based Stream Monitoring done by the Upper Sugar River Watershed Association on Badger Mill at STH69 also showed cool water temperatures[184].

[176] Stewart, Scot. *The Fishery of Badger Mill Creek and Potential Impacts from a Sewer Treatment Plant Discharge*. 1996.
[177] WDNR South Central Region Water Resources Files, 2010.
[178] Lyons and Wang, 1996.
[179] Welke, 2005.
[180] Amrhein, *Stream Reclassification: Badger Mill Creek*, 2005.
[181] See the DNR Fisheries Management webpage for an explanation of trout streams classes. http://dnr.wi.gov/fish/species/trout/streamclassification.html
[182] Welke, 2005.
[183] USGS data accessed 2010. http://waterdata.usgs.gov/wi/nwis/monthly?referred_module=sw.
[184] UW-Extension, 2008. http://watermonitoring.uwex.edu/pdf/level2/reportUSRWA.pdf

Badger Mill Creek upstream of Bruce Street,

Verona

Badger Mill Creek and MMSD. Madison Metropolitan Sewerage District (MMSD) began discharging about 3.3 million gallons per day (MGD) of highly treated effluent to Badger Mill Creek in 1998 as a means of maintaining baseflow in the creek. The effluent conveyance return and outfall are designed for up to 3.6 MGD. The 3.3 MGD represents between 30% and 50% of its baseflow at Bruce Street depending on time of year and climatic conditions. The temperature of the effluent as it leaves the Nine Springs wastewater treatment facility ranges from 54^{0}F in winter to 70^{0}F in summer[185]. MMSD has been conducting fish and aquatic invertebrate monitoring on Badger Mill since 1994. MMSD initially monitored at four sites, but more recent fish monitoring has been done at two locations: upstream of the Bruce Street bridge (BM7) and upstream of the STH 69 bridge over Badger Mill Creek (BM9). The three dominant fish species in 2009 at BM7 were white sucker (60.7%), brown trout (21.1%) and fathead minnow (5.2%). Dominant fish species at BM9 were white sucker (68.9%), brown trout (19.4%) and mottled sculpin (8.4%)[186]. MMSD conducted Wisconsin warmwater IBI and coldwater IBI analysis along with an Illinois IBI analysis at both locations in 2009. MMSD's 17 years of Wisconsin coldwater IBI at the two Badger Mill sites shows virtually no variation in coldwater IBI scores. The Wisconsin warmwater IBI scores do show a little more variation occasionally rising into the "fair" range (30-49 WWIBI score[187]). MMSD uses the Illinois IBI protocol as it is thought by MMSD to provide a better characterization of the creek's condition[188]. The Illinois IBI data appears similar to the Wisconsin warmwater IBI results in that "fair" biotic integrity has occasionally been found at the two Badger Mill sites over the 17-year MMSD monitoring history.

Table __________ 2009 MMSD Badger Mill IBI Scores

Site	Ill IBI	Wis WWIBI	Wis CWIBI
BM7	Fair (44)	Poor-Fair (29-32)	Poor (20)
BM9	Fair (42)	Poor (22-27)	Poor (20)

Brook stickleback and mottled sculpin were present at the Bruce Street location (BM 7) in 2009 but in very low numbers. Both species were more prevalent at the STH 69 (BM 9) monitoring site. The MMSD monitoring at BM 7 found the most brown trout and the greatest number of different species since the inception of the MMSD monitoring program in 1994. One troubling find at BM 7 were 6 common carp, which had never been found in Badger Mill prior to 2008. The carp likely migrated up the Sugar River from Lake Belleview. At BM 9 the numbers of

185 Taylor, Dave, MMSD. Personal Communication, 2010.
186 Steven, *Sugar River Watershed Fish Survey*, 2009.
187 See Lyons (1992) and Lyons and Wang (1996) for a detailed discussion of Wisconsin's warmwater and coldwater IBIs.
188 Steven, 2009.

brown trout collected were the highest since program's inception and the greatest numbers of mottled sculpin since 1997 were collected[189].

In addition to collecting fish IBI data, MMSD has also been doing aquatic invertebrate biotic data (HBI) for Badger Mill Creek since 1994. At the BM 7 monitoring site the HBI values range from 4.12 indicating "very good" water quality with little organic pollution, to 6.43 indicating "fair" water quality with fairly significant organic pollution. A slight declining trend in water quality is seen at BM 7. The causes of this apparent downward trend need further evaluation. HBI values at BM 9 ranged from 4.2 indicating "very good" water quality to 6.24. No trend in HBI values was discernable at BM 9.

The continued growth of the Verona-west Madison area will result in additional inter-basin water transfer. The transfer of up to an additional 4.3 MGD is possible The MMSD 50-year master plan addressed this is by laying out for discharging up to another 4.3 MGD of highly treated effluent to the Sugar River basin. An option in the MMSD 50-plan that involved Badger Mill Creek would increase discharge at the current Badger Mill outfall to 7.9 MGD. A second Badger Mill option evaluated was constructing a satellite wastewater treatment plan that would discharge to Badger Mill at Nesbitt Road[190]. No estimate of potential adverse impacts to the aquatic ecosystem, stream morphology or chemistry has been done for such an increase in effluent discharge to Badger Mill Creek.

Badger Mill Creek Stormwater and Groundwater Issues. Badger Mill Creek's drainage area includes the southwest side of Madison and most of Verona. Much of its drainage area is heavily urbanized, being developed or probably will be developed in the next 10 to 15 years. Approximately 19% of the sub-watershed drainage area was estimated covered by impervious surfaces in year 2000, and the CARPC estimates that up 30 percent of its drainage area may be covered by impervious surfaces in the future[191]. The hydrologic impacts of watershed urbanization are well established and include:

- More bank full or higher stream volumes;

[189] Ibid.
[190] MMSD, 50 Year Master Plan, http://www.madsewer.org/50YearMasterPlan.htm 2010.
[191] Dane County Regional Planning Commission, 2005.

- More frequent and higher floods;
- Higher peak flows and longer peak flow duration;
- Greater stream flashiness (large pulses of runoff);

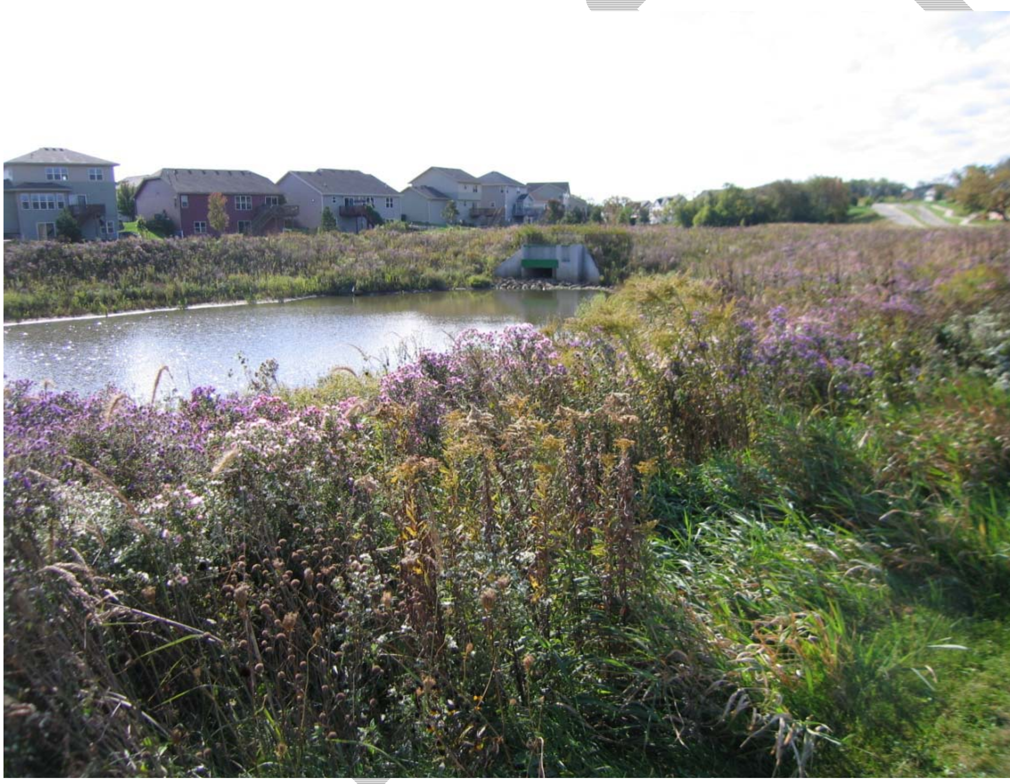
Two studies by Wang and others[192] indicated that when connected imperviousness (a strong measure of urbanization) of an urbanizing watershed exceeds 11% for coldwater streams and 12% for warmwater streams, IBI scores and stream baseflow were inevitably low. At levels connected imperviousness less than 6% for cold water stream watersheds, possible IBI scores, abundance of trout and percentage of intolerant fish could have high values. Both studies suggest that low levels of urbanization can adversely affect stream ecosystems. The connected impervious surface area coverage "break point" can be extended if communities in an urbanizing watershed employ a variety of structural and vegetative measures to reduce runoff and peak storm flows and infiltrate precipitation and stormwater back into local groundwater.

Badger Mill Creek is located in the thermal sensitive part of Dane County. Thermal sensitive areas are areas tributary to existing or potential cold or cool-water streams[193]. Urban stormwater usually has a higher temperature than nearby receiving waters. A sudden or longer term increase can adversely affect cold and cool water fisheries and the aquatic ecosystem needed to support these fisheries. Both the cities of Madison and Verona have stormwater master plans. Both have been very active in constructing stormwater facilities 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 of a longer time frame. USGS data from a monitoring station at USH 18-151 downstream of the Nesbit Road stormwater ponds showed mean monthly water temperatures ranging from 22.9^{0}C for June to 24.4^{0}C for July over a five year period 2005-2009. The highest monthly mean was 25.66^{0}C in July of 2006. Summertime (June-August) daily <u>mean</u> temperatures immediately downstream of the Nesbitt Road stormwater retention ponds range between 20^0 C (68^{0}F) and 26.3^{0}C (79.3^{0}F), with a maximum daily high temperature mean of

[192] Wang, et.al. *Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota*, 2003 and Wang, et.al. *Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spacial Scales*, 2001.
[193] To see a map of thermal sensitive areas, go to the Dane County Land and Water Resources webpage http://www.countyofdane.com/lwrd/landconservation/cws/index3.html

30^{0}C (86^{0}F)[194]. These high stormwater temperatures in Badger Mill Creek's headwater reach are moderated somewhat by the MMSD discharge and the springs at the Military Ridge bike trail parking lot. However, continued increases in summertime stormwater flows from Verona and Madison could alter the creek's temperature regime and lead to reduction or elimination trout and other cold and cool water species from the creek, changing the creek to a warmwater ecosystem. 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[195].

.**Stormwater Pond in Madison on an Urban Tributary to Badger Mill Creek**



The urbanization in the Badger Mill Creek sub-watershed can affect groundwater supporting baseflow in two ways. First, the significant increase in impervious surfaces both increases peak and longer-term stormwater flows and reduces infiltration to groundwater needed to support baseflow conditions in Badger Mill. Second, increased groundwater withdrawal for public water supply lowers the groundwater level reducing the creek's baseflow. Ellefson and others have

[194] USGS data accessed 2010. http://waterdata.usgs.gov/wi/nwis/monthly?referred_module=sw
[195] Marshall et.al. *Water Quality Monitoring Report for Schlapbach Creek*, 2007.

estimated that total groundwater use in Dane County has increased from 53 million gallons per day to 62 million gallons per day between 1985 and 2000[196].

Reduction of baseflow can significantly alter stream hydrology, instream habitat, and aquatic life. The groundwater withdrawal by municipal wells in Verona and on the southwest side of Madison diverts groundwater needed for baseflow support for Badger Mill Creek and, to a lesser extent, the Sugar River out of the Sugar River basin. A 2004 DCRPC report estimates that Badger Mill baseflow has declined about 35 percent (5.37 MGD to 3.50 MGD) from pre-settlement times. The report estimates baseflow will decrease another 20 percent by 2030[197]. The 2004 report indicates groundwater drawdown of 20 to 45 feet in the Badger Mill Creek sub-watershed. The groundwater drawdown and declining infiltration due to increased impervious surfaces leading to the decline in baseflow are some of the reasons MMSD located a discharge outfall to Badger Mill Creek. The 3.3 MGD of highly treated effluent is intended to replace lost baseflow to Badger Mill and ultimately the Sugar River.

Stormwater management practices are available to use to help limit peak flows, recharge groundwater and maintain stream baseflow. Dane County ordinances require developers to include stormwater management practices and provisions to reduce the temperature of runoff in thermal sensitive areas[198]. The *Dane County Erosion Control and Stormwater Manual* has more detailed information on stormwater infiltration including infiltration practices and modeling techniques[199]. Commonly used stormwater measures are infiltration basins and rain gardens. Both measures are being use to address stormwater runoff issues in addition to other common practices. A recent resource assessment and development report done for the southwest side of Verona highlighted some of the challenges of locating infiltration features the Driftless Area. Those challenges include shallow and/or fractured bedrock and fine-grained soils[200], and shallow depth to groundwater in some areas. The report by Montgomery Associates and a technical paper by Gaffield and others identified the issues of new development in this part of Verona and

[196] Ellefson et.al.*Water Use in Wisconsin*, 2002.
[197] DCRPC, *Dane County Regional Hydrology Study*, 2004.
[198] Dane County Ordinances, Chapter 14, Subchapter II, Erosion Control and Stormwater Management. http://danedocs.countyofdane.com/webdocs/pdf/ordinances/ord014.pdf
[199] See http://www.danewaters.com/business/stormwater.aspx .
[200] Montgomery Associates. 2008. *Resource Assessment and Development Analysis for the Upper Sugar River and Badger Mill Creek Southwest of Verona, WI.*

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[201].

Badger Mill Creek Summary. 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. However, there is a concern regarding increased levels of chlorides, total phosphorus, dissolved phosphorus and ammonia in the water column. Impacts of a potential increase of MMSD's discharge have not been evaluated. The greater concern at this point relates to the long-term, cumulative impacts of increased urbanization on the creek and its ecosystem. The increase in impervious surfaces will lead to increased stormwater volume getting to the creek, warming ambient stream temperatures to the point the creek would be unable to support a trout fishery. Other problems, loss of baseflow, channel alteration, habitat modification and low dissolved oxygen levels, all would adversely affect the existing aquatic ecosystem of Badger Mill. Innovative stormwater management measures to maximize stormwater infiltration recharging local groundwater are needed in the Badger Mill Creek sub-watershed.

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 feet per mile. About the lower two-thirds of Henry flows through a wetland complex that functions as a buffer. There is evidence of past stream straightening. Henry Creek was placed on Wisconsin's 303d list of impaired waters in 1995 due to habitat impairments caused by sedimentation. USDA Environmental Quality Improvement Project (EQIP) completed in 1999 with the assistance of the Dane County Land and Water Conservation mitigated much of the sedimentation problem leading to improved stream quality[202]. A 2002 survey found improved habitat. The fish survey also found brook stickleback and mottled sculpin both considered cool-water indicators. The Wisconsin coldwater IBI done in 2002 found "fair" biotic integrity, and

[201] Gaffield et.al., *Infiltration Modeling to Evaluate Tradeoffs in Planning for Future Development*, 2008.
[202] Wisconsin Department of Natural Resources, *TMDLs for Sediment Impaired Streams in the Sugar-Pecatonica Basin*, 2005.

aquatic invertebrate HBI of 3.97 indicating "very good" water quality with possible slight organic pollution. Two coldwater IBI samples in 2005 on Henry indicated "good" stream biotic integrity. Henry Creek was delisted from the state's 303d list in 2006 and is considered a cool water fishery. It may be capable of sustaining a brook trout population[203].

Henry Creek Summary. While conditions in Henry Creek have improved, sedimentation from agricultural activities in its headwaters area is still a concern. Maintaining an adequate stream buffer, coupled with 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 east to the Sugar River near the community of Klevenville. It flows about four miles and has a drainage area of about five square miles and has a moderate stream gradient of about 24 feet per mile[204]. Much of it drainage area is agricultural with wooded steep-sided ridges on either side of its narrow done to CTH P. At P, the gradient flattens and the stream is buffered by a 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 creeks 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[205].

Water Resources Quality. Schlapbach Creek is spring-fed, thermally sensitive stream and is considered to have good water quality. Schlapbach has never been officially classified so the default warmwater fish and aquatic life standards apply. It is a Wisconsin 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[206]. Thirty years ago the stream

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[203] WDNR Upper Sugar River Watershed webpage accessed 11/2010. http://www.dnr.state.wi.us/water/basin/gpsp/spbasin/surfacewaterfiles/watersheds/sp15.html
[204] DCRPC, 1992.
[205] WDNR, *Feasibility Study, Master Plan and Environmental Impact Statement for the Southwest Wisconsin Grassland and Stream Conservation Area*, 2009.
[206] Jones (Ed.), 2008.

supported mostly eurythermal[207] nongame fish, but now supports predominately stenothermal 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 rainwater and snowmelt[208]. One recent study linked watersheds with high Conservation Reserve Program participation resulted in a shift from a warmwater, more tolerant fish community top a cool and coldwater community[209]

Schlapbach Creek is considered as an excellent candidate for brook trout introduction by DNR fisheries staff[210]. A year 2000 aquatic invertebrate sample done near Klevenville had a HBI score of 1.91 indicating "excellent" water quality with no apparent organic pollution. Earlier HBI monitoring done in 1997 "good" water quality conditions at Klevenville-Riley (some organic pollution evident) and "very good" water quality conditions (slight organic pollution evident) at Sletto Road[211]. Temperature data collected by the Upper Sugar River Watershed Association during the summer of 2005 indicated Schlapbach suffered from thermal stress due to urban runoff[212]. However, the water temperature increases appear to be localized and brief in duration[213]. Coldwater IBI monitoring done at Sletto Road between 2000-2005 consistently resulted in "fair" biotic integrity (CWIBI score = 50-30) indicating the stream has experienced moderate environmental degradation and the biotic integrity has been reduced. 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[214]. Citizen Based Stream Monitoring done at two locations on Schlapbach done by the Upper Sugar River Watershed Association has shown dissolved oxygen levels and water temperature levels within the range to fully support coldwater communities[215]. Redside dace (*Clinostonmus elongates*), a pollution intolerant cool water forage fish on the DNR species special concern list, is no longer found in Schlapbach and

[207] Eurythermal fish can tolerate a wide range of temperatures and are usually pollution tolerant.
[208] Marshall et.al. 2007.
[209] Marshal, et.al. 2008.
[210] Fetter, *Schlapbach Creek Protection and River Management Plan*, 2005.
[211] Data from WDNR SWIMS water resources data base accessed in 2010.
[212] Fetter, 2005a.
[213] Marshall, 2007.
[214] Ibid.
[215] UW-Extension, 2008.

has likely been extirpated from it. This is part of a general decline in some non-game species in small streams in southern Wisconsin[216].

Schlapbach Creek at Sletto Road

Urban development in Mount Horeb will increase stormwater flows and reduce local infiltration. The watershed has about 10.6 percent impervious cover and is planned to increase to 14.1 percent based on year 2000 land use[217]. The impervious surface area is concentrated in the headwaters area in Mount Horeb. Studies by Wang and others[218] indicated that when connected imperviousness (a strong measure of urbanization) of an urbanizing watershed exceeds 11% for coldwater streams, IBI scores and stream baseflow were inevitably low.

Schlapbach Creek Summary. Schlapbach Creek is a coldwater stream and designated as an ERW stream. It has good water quality and fair fisheries biotic integrity. Its primary threat is

[216] Marshall, et.al, 2004.
[217] DCRPC, 2005.
[218] Wang, et.al. *Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota*, 2003 and Wang, et.al. *Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spacial Scales*, 2001.

from urban stormwater from the Village of Mount Horeb that results in increased loading of suspended solids and associated nutrients to Schlapbach Creek. More aggressive stormwater management measures 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.

Sugar River

The Sugar River rises in Section 6 of the Town of Springdale and flows southeast leaving Dane near the Village of Belleville. It has a low overall stream gradient of 4.1 feet per mile. The river drains over 200 square miles in Dane County. The river's direct drainage area is about 76.5 square miles excluding the major tributaries of Badger Mill Creek and the West Branch Sugar[219]. The river wide valley overlays deep glacial outwash and has important sand and gravel deposits. Sections of the river have been channelized, particularly north of USH 18-151. Agriculture is the primary land use with row crops and dairying including some larger animal operation adjacent to the river. There are three small communities, Riley, Paoli and Basco in the Sugar's immediate drainage area, and the towns of Montrose, and parts of the towns of Springdale, Cross Plains, Middleton and Verona. While the primary land use is agriculture, rural homes and small developments have resulted in farm and woodland fragmentation.

Stream morphology changes as one goes downstream from the headwaters. Stream width in the headwaters area is 6 to 10 feet and widens to 35 to 65 feet where it enters Lake Belleview. 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[220]. 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.

[219] DCRPC, 1992.
[220] Amrhein, *Stream Reclassification: (Upper) Sugar River*, 2004.

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. Much of its valley bottom adjacent the river was covered with wetlands prior to European settlement. Large wetlands areas have been drained for agriculture. There are still significant wetland areas adjacent to the river. Perhaps the most ecologically significant is the large wetlands complex extending from Valley Road near Verona northward past the community of Riley. There are areas of significant wetlands diversity including a calcareous fen community, a rare wetland type, in the Sugar River Natural Area. There are also springs and groundwater seeps in or adjacent this important wetlands complex.

With the exception of Belleville, the Sugar River does not have any urban direct drainage areas. However its total drainage area includes all of the City of Verona, the southwest side of the City of Madison, a small area of the City of Fitchburg and the eastern part of the Village of Mount Horeb. The only municipality with a direct wastewater discharge to the Sugar River is Belleville although MMSD has a discharge via Badger Mill Creek.

Municipal groundwater pumping for public water supply purposes has lowered the groundwater levels in the eastern part of the watershed (see the groundwater discussion for Badger Mill Creek). This could lower stream baseflow in part of the headwaters area affecting the rivers ecosystem in this area. A partial remedy to this potential problem was to allow MMSD to return about 3.3 MGD of highly treated effluent to the Sugar River system via Badger Mill Creek. Aggressive stormwater management efforts by Madison, Verona and Dane County to infiltrate more runoff would also help to reduce the lowering of groundwater levels in this area.

Sugar River at CTH S, Near the Headwaters

Water Resources Quality. Water quality in the Sugar River is generally considered good. It supports a diverse cool and coldwater fishery above Lake Belleview and a cool to warmwater sport fishery below the Lake Belleview dam. It is on the Wisconsin Exceptional Resource Waters (ERW) list due to its diverse fishery and water quality from it headwaters downstream to the Green-Rock county line. The Sugar River in Dane County had been classified as a warm water sport fishery (WWSF) stream up to 1993, with smallmouth bass (*Micropterus dolomieu*) as the dominant game species. Land use practices in the watershed had improved during the late 1980s and early 1990s due to participation in USDA land conservation program, streambank improvements and the elimination of industrial point sources of pollution[221]. Conditions in the upper reaches of the Sugar River above Frenchtown Road improved to the point where the river could support a cold water fishery. A 1993 classification study recommended that the Sugar River from its headwaters downstream to Frenchtown Road be classified as a cold water fish and

[221] Amrhein, 2004.

aquatic life stream[222]. A 2004 DNR Water Resources report recommended the Sugar be classified as a Coldwater stream from its headwaters downstream to Frenchtown Road[223]. Subsequent to River the water Resources report, a DNR South Central Region Fisheries Management report recommended classifying the Sugar River as a Class II trout stream[224]. Both reports mention the abundance of brown trout and other coldwater species, and presence of cool water temperatures and good habitat conducive to sustaining trout and other coldwater fish populations as justification for reclassification of the river. Wisconsin Coldwater IBIs taken by the Department of Natural Resources at several sites on the Sugar between 2000 and 2002 showed biotic integrity ratings ranging from "poor" (CWIBI score = 0-20) to "fair" (CWIBI score = 30-50). It was noted that populations of mottled sculpin generally declined as one went downstream and disproportionately high numbers of white suckers (*Catostormus commersoni*), a common warmwater fish[225]. The Capital Area Regional Planning Commission (CARPC) expressed concern regarding a dissolved oxygen (DO) reading below water quality below water quality standards for a warm water sport fishery stream. Additional data was provided by CARPC indicating DO levels below coldwater aquatic life standards[226]. 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.

. **Sugar River at Frenchtown Road**

[222] Marshall and Stewart, *Sugar River Classification Survey, Dane County Wisconsin*, 1993.
[223] Amrhein, 2004.
[224] Welke, *Trout Stream Classification: (Upper) Sugar River*, 2005.
[225] Welke, 2005.
[226] Letter from Mike Kakuska (CARPC) to Nicole Richmond (WDNR), June 18, 2009.

Monitoring was done at Remy Road in 2007 downstream of the Lake Belle View dam on the Sugar River. Results of warm water IBI at Remy indicated the river had "excellent" biotic integrity (WWIBI=85) with a good population of smallmouth bass and good instream habitat. Aquatic invertebrate monitoring at the same site indicated "fair" water quality conditions with fairly significant organic pollution (HBI score=5.58)[227].

Sugar River and MMSD. Drawdown of groundwater levels by municipal water supply pumping by Madison and Verona functioned to transfer water from the Sugar-Pecatonica basin to the Yahara River basin. Groundwater modeling indicates that groundwater withdrawals will affect baseflows in Badger Mill Creek and has the potential to reduce baseflow in the Sugar River. To offset the groundwater losses, MMSD completed a pipeline returning 3.3 MGD of highly treated effluent back to the Sugar River basin via Badger Mill Creek in 1998.

MMSD has been conducting fish and aquatic invertebrate surveys in the Sugar River since 1994. The monitoring provides a pre- and post-effluent discharge look at fish assemblages in the river, and also provides IBI and HBI based water quality information about the river. MMSD monitors

[227] WDNR South Central Region Water Resources Files, 2010.

at two sites on the river; at Valley Road upstream of Badger Mill Creek (SR5), and at the STH 69 bridge (SR7) over the Sugar River downstream of Badger Mill. Aquatic invertebrate (HBI) monitoring scores at SR5 between 1994 and 2006 ranged between 4.36 (very good water quality) to 5.97 (fair water quality) with an average HBI score of 5.15 indicating good water quality with some organic pollution present. HBI monitoring scores at SR7 between 1994 and 2006 ranged between 4.92 (good water quality) and 6.25 (fair water quality) with an average HBI score 5.52 indicating fair water quality with fairly significant organic pollution present. HBIs at both sites appear to have a slight upward trend between 1994 and 2006 indicating a slight decline in water quality may be occurring.

MMSD found the third highest number of brown trout (119) in 2009 since monitoring began at SR5 in 1994. The three dominant species at SR5 were white sucker (43.2%), brown trout (29.4% and mottled sculpin (24.2%). The three dominant species at SR7 were white sucker (80.9%), brown trout (14.9%) and mottled sculpin (1.4%)[228]. MMSD conducted Wisconsin warmwater IBI and coldwater IBI analysis along with the Illinois IBI analysis at both locations in 2009. MMSD uses the Illinois IBI protocol as it is thought by MMSD to provide a better characterization of the creek's condition[229].

Table __________ 2009 MMSD Sugar River IBI Scores

Site	Ill IBI	Wis WWIBI	Wis CWIBI
SR5	Poor-Fair (36)	Poor (22-29)	Poor (20)
SR7	Fair (40)	Poor (20-26)	Fair (40)

Species richness appears to be declining at both SR5 and SR7 based on 16 years of MMSD monitoring data. The total number of brown trout collected by MMSD on the Sugar and Badger Mill shows a strong upward trend since monitoring began. The MMSD IBI scores for the modified Illinois IBI and the Wisconsin warm water IBI both appear to be slightly trending down over the period of record. The MMSD cold water IBI scores for SR5 are fairly constant (poor

228 Steven, 2009.
229 Ibid.

biotic integrity), while the cold water IBI at the upstream SR5 site are somewhat better, but still poor biotic integrity, except for the 2009 cold water IBI.

The continued growth of the Verona-west Madison area will result in additional inter-basin water transfer. The transfer of up to an additional 4.3 MGD is possible The MMSD 50-year master plan addressed this is by laying out for discharging up to another 4.3 MGD of highly treated effluent to the Sugar River basin. MMSD evaluated several options having a new discharge, or discharges, to the Sugar River. These options include:

- Building a new pumping station and force main to discharge 4.3 MGD at a new outfall to the Sugar River downstream of Badger Mill Creek,
- Building a new pumping station and force main to discharge 4.3 MGD at a new outfall at CTH PD,
- Building a new advanced secondary wastewater treatment plan with a discharge of up to 4.3 MGD to the Sugar River downstream of Badger Mill Creek, and
- Building a new advanced secondary wastewater treatment plan with a discharge of up to 4.3 MGD to the Sugar River downstream of Badger Mill Creek and a discharge at CTH PD northwest of Verona[230].

Building a new treatment plant with a Sugar River discharge is not likely in the short term (before 2020) due to costs that would be incurred by strict chloride limits[231] and other limit requirements based on the river's ERW and cold-water classifications.

Sugar River Summary. Water quality in the Sugar River is generally good. It is an ERW stream. The Sugar River has been re-classified to a cold water community and a Class II trout stream. The primary water quality threats are from agricultural nonpoint sources of pollution and from urban nonpoint sources, particularly urban stormwater runoff entering the river via Badger Mill Creek. Phosphorus concentrations in the river are high, estimated to be 410 parts per billion (ppb). This is significantly above the concentration that promotes algae growth (30

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[230] MMSD, 50 Year Master Plan http://www.madsewer.org/50YearMasterPlan.htm 2010.
[231] Dave Taylor, MMSD, Personal Communication, 2010.

ppb) in downstream impoundments[232]. Groundwater withdrawal by municipal water supply system is a long-term threat. Such withdrawals, coupled with the significant increase in impervious surfaces that comes with urbanization, can lower groundwater levels that support local springs and stream baseflow conditions. The DNR is concerned about the long-term, cumulative effects of urbanization on water quality and instream habitat in the upper reaches of the Sugar River. Programs that would protect and possibly improve water quality and habitat are the various land conservation programs run by the Dane County Land Conservation Division and the USDA Natural Resources Conservation Service, and aggressive stormwater management programs that maximize infiltration opportunities in addition to other stormwater management practices. More intensive, ongoing monitoring of the aquatic and physical condition of the river would be necessary to determine if the effects of urbanization are adversely affecting current conditions.

Recommendations

1. The DNR, Dane County, Madison Metropolitan Sewerage District (MMSD) and the Madison Area Municipal Stormwater Partnership should partner in establishing two long-term monitoring stations on the Sugar River above and below Badger Mill Creek.
2. The DNR and Dane County, in cooperation with MMSD and other partners, should establish regular fish IBI, macroinvertebrate and habitat monitoring at several locations on the Sugar River.

Lake Belle View

Lake Belle View is a shallow impoundment on the Sugar River at Belleville. 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. The Sugar River is considered a cold water fishery above Frenchtown Road and a warm water sport fishery downstream of Frenchtown Road. The Sugar River downstream of the Lake Belle View dam has a very diverse cool water and warm

[232] Montgomery Associates, *Project Summary Report for the Lake Belle View Restoration Planning Project*, 2009.

water sport fishery. The river is considered an Exceptional Resource Water of the state from its headwaters in Dane County downstream to the Green-Rock county line.

Lake Belle View covered 94 acres, plus 18 acres of forested islands before its 2009 drawdown. It is a hyper-eutrophic 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. Lake Belle View is shallow with a maximum depth of 7 feet and an average depth of 1-2 feet. The Sugar River delivers an estimated 59,800 pounds per year of phosphorus to Lake Belle View[233].

The Village of Belleview initiated a project to restore Lake Belle View with construction starting in the fall of 2010. 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 project entails separating the Sugar River from the lake, dredging the lake and doing in-lake habitat creation[234]. The project began by drawing down the lake in 2009 to consolidate bottom sediments and to eradicate carp. The river will be separated from the lake by constructing a berm creating a new lake of about 40 acres in size. There would be another 30 acres on the river side of the berm that revert to wetlands and upland habitat. The lake would be dredged to a depth of 8-10 feet with the deepest part located near the park. Some of the dredge material would be used to enlarge existing islands for floodplain forest habitat enhancement and restoration.

Separating the river from the lake will:

- reduce the amount of sediment and nutrient entering the lake thereby improving water quality;

[233] Montgomery Associates, 2009.
[234] See the Montgomery Associates report for details.

- reduce thermal impacts on the Sugar River both upstream and downstream of the dam; and
- create more public access to both the restored Lake Belle View and the Sugar River from the berm.

Construction of the berm and dredging started in the fall of 2010. Vegetation and fishery restoration will begin in 2011, with vegetation diversity enhancement and tree planting in 2013. Monitoring of aquatic and terrestrial conditions would continue through 2020[235].

Goose Pond

Goose Pond is a small pothole seepage pond east of Verona just off USH 18-151. Being a pothole and seepage pond, water levels tend to fluctuate. It has a maximum depth of 10 feet. Summer water clarity has been declining based citizen lake monitoring reports[236]. Reports from 2005 through 2009 show fluctuating secchi disk (a measure of water clarity) readings of between 0.25 to 4 feet. Algae growth and blooms, a sign of excessive nutrient loading, is a problem inhibiting enjoyment of the lake[237]. Increased stormwater flows in a drainage ditch also threaten water quality of the lake.

Morse Pond

Morse Pond is a 10 acre shallow pothole pond on the edge of the driftless area. It is adjacent the University of Wisconsin golf course on the west edge of Madison. The pond was unique in that it supported large beds of American lotus (*Nelumbo lutea*). American lotus beds are uncommon in Dane County and may be declining[238]. Construction of the UW golf course resulted in significant sediment loading to the pond in the 1990's. Herbicides, pesticides and excess nutrient due to golf course turf management are threats to the water quality and in-pond aquatic habitat.

West Branch Sugar River Watershed

[235] Agrecol Environmental Consulting and Montgomery Associates, *The Lake Belle View Restoration Project*, 2010
[236] Jones (Ed.), 2008.
[237] Information from WDNR Citizen's Lake Monitoring website http://dnr.wi.gov/lakes/CLMN/reportsanddata/station.asp?folder=CLMN&stationid=133463
[238] Marshall, et.al. 2007.

The West Branch Sugar River Watershed lies in the Driftless Area of southwest Dane County. Its drainage area is about 66.8 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% 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.

Table _____ West Branch Sugar River Watershed Land Cover

Resource Characteristics	in acres
Agricultural	26,692
Woodland	7,140
Other*	6,425
Hydric Soils	3,462
Transitional**	1,607
Wetlands	1,124
Residential	599
Outdoor recreation	94
Industrial	66
Institutional/Governmental	61
Open water	42
Commercial	25
Size of watershed	**42,750**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

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 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 are West Branch Sugar River, Mt. Vernon Creek, Deer Creek, Fryes Feeder, Primrose Branch, Flynn Creek, and Milum Creek. The named streams in the watershed are cold water trout streams.

West Branch Sugar River

The West Branch Sugar River rises in the Village of Mount Horeb and flows 18 miles southeast to the Sugar River north of Lake Belle View. It has a stream gradient of 13.6 feet per mile above its confluence with Mt. Vernon Creek. Below Mt. Vernon Creek the river's valley widens and it flattens to a gradient of 1.5 feet per mile downstream to the Sugar River[239]. The West Branch is considered a Class II trout stream by the DNR. A portion of the developing southwest side of Mount Horeb drains to the head waters of the West Branch. The Mount Horeb wastewater treatment plant discharges treated effluent to the river in its headwaters. The 1923 USGS New Glarus topographic map indicated that 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 (or attempted draining) has reverted back to wetlands. Nongame fish species has declined in the West Branch, similar to declines in other small streams in the Sugar-Pecatonica and Rock River basins[240].

[239] DCRPC, 1992.
[240] Marshall et.al, 2004.

West Branch Sugar River at Docken Road

The stream water quality and habitat of the West Branch Sugar River were adversely affected by stream bank erosion, overgrazed riparian areas, cattle access to the stream, barnyard runoff, upland and cropland erosion, sediment and nutrient delivery, and discharge from the Mount Horeb wastewater treatment plant. For these reasons the West Branch was put on the Wisconsin 303d list of impaired streams.

From 2000 to 2003, the Dane County Land Conservation Department (LCD) received four Targeted Runoff Management (TRM) grants from the WDNR for streambank restoration and habitat enhancement projects. The USDA Natural Resources Conservation Service and the Department of Agriculture, Trade and Consumer Protection also provided funds to implement conservation practices along the river. Nonprofit organizations provided funds as well as volunteer labor to build fish habitat structures. Conservation practices implemented included stream fencing to keep cattle away, stream bank stabilization projects, installing artificial in-stream habitat structures (LUNKERS) and the acquisition of stream bank easements for protection and recreational use purposes. Dane County acquired easements totaling 2.75 in length in 2007 and 2008 alone. The various projects were funded by the USDA, DNR and Dane County. The projects were led by the Dane County Land Conservation Department (DCLCD) and included DCLCD staff, DNR Fisheries and Water Resources staff, and volunteer efforts from private non-profit groups such as the Deer Creek Sport and Conservation Club, Trout Unlimited, and the Upper Sugar River Watershed Association. As a result of these combined efforts, the West Branch Sugar River was removed from the state's 303d list in October of 2004. It was the first stream removed from the 303d impaired waters list in Wisconsin. 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 (see map). The DNR also has easement and holdings on the lower reaches of the river.

INSERT COUNTY TROUT FISHING MAP FOR WEST BRANCH SUGAR RIVER

Water Resources Quality – West Branch Sugar River. Fish surveys done in 1997 showed no young-of-year (YOY) trout at any sampling sites of the West Branch. Surveys in 2003, after the beginning of stream and riparian restoration activities, showed the presence of YOY trout at 10 of 13 stations indicating that natural reproduction was occurring in the West Branch[241]. WDNR's 2008 *Trout Management in Dane County* states the West Branch has "excellent habitat for all life stages of trout[242]". The DNR continues to stock brown and rainbow trout in the West Branch.

[241] USEPA, *Steam Restoration Efforts Result in Rebound of Brown Trout Population*, http://water.epa.gov/polwaste/nps/success319/wi_sugar.cfm Accessed 2010.
[242] WDNR, *Trout Management in Dane County*, South Central Region Fisheries Management, 2008.

Coldwater IBIs done at the STH 92 crossing of the West Branch Sugar River done in 2005 and 2008 showed "fair" biotic integrity indicating the stream has experienced moderate environmental degradation[243]. Coldwater IBIs done in 2005 at the Primrose Center Road and the CTH U crossings also showed "fair" biotic integrity. Coldwater IBIs done 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 severely reducing biotic integrity. By 2003 at CTH JG, the Coldwater IBI biotic index had risen to "fair", the aquatic invertebrate HBI score (3.15) indicated "excellent" water quality and a DNR habitat evaluation showed good aquatic habitat[244]. 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 on the West Branch Sugar River.

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[245]. A significant improvement in coldwater IBI scores for the West Branch Sugar River was noted in pre- versus post CRP implementation (see Figure 1 in the Pecatonica River Watershed section).

West Branch Sugar River at CTH G Southwest of Mt. Vernon

[243] Lyons, Wang and Simonson, *Development and Validation of an Index of Biotic Integrity for Coldwater Streams in Wisconsin*, 1996.
[244] Coldwater IBI data from WDNR fisheries data base provided by the DNR, 2010.
[245] Marshall et.al., 2008.

The West Branch of the 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 6 miles of the river down to near the Primrose Branch. This fish kill, along with other similar events on other streams, 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[246]. A steep-slope farm field where manure had been recently applied was identified as the source of the fish kill[247]. In 2008 the DNR noted that river was recovering from the fish kill and that trout populations were fair to good[248]. This indicates the resilience of trout streams as was noted with a similar situation in Black Earth Creek.

The Village of Mount Horeb sits on top of Military Ridge. The headwaters of six coldwater streams, in three watersheds and two river basins, are in the Village. Mount Horeb has taken positive steps regarding stormwater management at the policy level. However, implementation

[246] 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.
[247] Fetter, 2005b.
[248] WDNR, 2008.

of the village's stormwater management plan has not kept pace with development[249]. Stormwater thermal spikes are concern. Additional regional and smaller distributed detention facilities, as well as distributed infiltration measures where possible, are needed to reduce the thermal spikes and provide some local groundwater recharge. Studies by Wang and others[250] indicated that when connected imperviousness (a strong measure of urbanization) of an urbanizing watershed exceeds 11% for coldwater streams, IBI scores and stream baseflow were inevitably low.

Mount Horeb is a growing community that at some point will 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 may adversely affect stream hydrology and morphology, instream habitat and alter the coldwater fish assemblages.

West Branch Sugar River Summary. Significant water quality and aquatic habitat improvements have occurred since year 2000. The river is no longer on the state's 303d list of impaired waters and is considered a coldwater fishery for most of its length. Threats are increased urban stormwater and melt water runoff from the Village of Mount Horeb, agricultural nonpoint sources of pollution, and a potential expansion of the Mount Horeb wastewater treatment facility. The winter spreading restrictions of Dane County's ordinance may not be sufficient to protect streams in the Driftless Area where instantaneous field slopes may exceed average field slopes of 12%.

Mt. Vernon Creek

Mt. Vernon Creek is formed by the confluence of Deer Creek and Fryes Feeder in the Driftless Area southeast of Mount Horeb. It flows seven miles to the West Branch Sugar River and has a stream gradient of 18.5 feet per mile. 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. It is one of the best trout streams in southwest Wisconsin. It has excellent aquatic habitat to support a coldwater fishery. About four miles of its length is a Class I trout stream while the remainder of the stream is a Class II trout stream.

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[249] Fetter, *Upper Sugar River Headwaters Protection and River Management Plan*, 2005b.
[250] Wang, et.al. 2001.

The Class I portion is also an Outstanding Resource Water (ORW) while the Class II portion is considered an Exceptional Resource Water (ERW) of the state. Its deep pools and long run-riffle habitats hold multiple year classes and sizes of trout[251]. There is public easements or ownership of most of its length.

The dominant land use in its drainage area is agricultural. Agricultural nonpoint sources of pollution are a water quality and aquatic habitat threat. Increased nitrate levels have been documented. A reach near the downstream end had been dredged and straightened in the past but has since recovered. 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[252].

Mt. Vernon Creek at CTH U

Mt. Vernon Creek Water Resources Quality. As mentioned above, Mt. Vernon Creek is a high quality coldwater trout stream with excellent aquatic habitat over much of its length. It is

[251] WDNR, 2008.
[252] Jones (Ed.), 2008.

well buffered over most of its length. Intensive efforts at soil conservation and streambank protection programs in the Mt. Vernon Creek watershed have demonstrated that substantial (up to 50%) reductions in erosion and positive impacts on stream habitat. A 2008 coldwater IBI done at CTH U resulted in a "good" biotic integrity rating (coldwater IBI score = 80). Coldwater IBIs done in 2002 upstream of CTH G and upstream of STH92 showed biotic integrity ratings of "good" (coldwater IBI score = 70) at CTH G and "fair" (coldwater IBI score = 50) at STH 92. This not unexpected as the CTH U and CTH G sites are in the Class I reach while the STH site is in the Class II reach of Mt. Vernon.

Mt. Vernon Creek Summary. 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 may also affect Mt. Vernon at some point in the future.

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 feet per mile[253]. 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. The Dane County Regional Planning Commission (now the Capital Area Regional Planning Commission) estimated that 5.94% of it drainage area was covered by impervious surfaces. The DCRPC projects impervious cover will increase to about 6.9%[254]. Deer Creek is a Class II trout stream for about 4.7 miles of length

[253] DCRPC, 1992.
[254] DCRPC, 2005.

and the entire length is considered an ERW stream. Springs in its middle reach augment flow[255]. Dane County Land Conservation Department received a TRM grant from the DNR to improve instream habitat and stabilize stream banks. This led to an improvement of the creek's cold water 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[256].

Deer Creek at Sutter Lane

Water Resources Quality. 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 a narrowing and deepening of 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 an ERW stream. Forty-three coldwater IBI monitoring at ten locations on Deer between 1999 and 2007 resulting in

[255] Fetter, 2005b.
[256] See the SW Dane County Trout Stream Easements map at http://danedocs.countyofdane.com/webdocs/pdf/lwrd/acquisition/Stream_Easements.pdf

biotic integrity ratings ranging from eleven “excellent” (coldwater IBI score = 90-100) to one “fair” (coldwater IBI score = 50), with the remaining biotic integrity ratings were “good” (coldwater IBI scores = 60-80). Twelve aquatic invertebrate (HBI) samples were taken at six sites between 1997 and 2000. The HBI vales ranged between 3.12, indicating “excellent” water quality (no apparent organic pollution), to 5.1 indicating “good” water quality (some organic pollution)[257], with an average HBI score of 3.99 indicating “very good” water quality with slight organic pollution present.

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[258]. A significant improvement in coldwater IBI scores was noted for Deer Creek in pre- versus post CRP implementation (see Figure 1 in the Pecatonica River Watershed section).

Sediment deposition is still a problem in Deer Creek[259]. Mount Horeb urbanization is a threat to the quality of water resources as a result of increase runoff from construction sites and impervious surfaces, thermal impacts and reduced infiltration,. Mount Horeb has installed regional stormwater detention facilities that appear to be mitigating thermal pollution to Deer Creek. Increased impervious surfaces due to urbanization will increase Deer Creek’s flashiness. This will result in increased stream bank erosion and downstream sediment deposition without adequate stormwater detention and local infiltration best management practices being implemented.

The Village of Mount Horeb should promote 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.

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 feet per mile. The steep stream gradient, coupled with steep hillside slopes, causes the creek to be very flashy during major runoff events. It is

[257] Data from WDNR SWIMS data base and Fisheries Management data accessed in 2010.
[258] Marshall et.al., 2008.
[259] Fetter, 2005b.

5.3 miles long joining with Deer Creek to form Mt. Vernon Creek. Fryes is a Class II trout for about 2 miles upstream from its confluence with Deer Creek. The entire stream is an ERW stream. 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[260]."

Fryes Feeder has good populations of both brook and brown trout and serves as a nursery feeder to Mt. Vernon Creek.

Fryes Feeder at Town Hall Road

Water quality has been affected by runoff from farm fields carrying sediment and nutrients to Fryes. This resulted in sediment deposition affecting aquatic habitat and fish populations. The Dane County Land Conservation Department received a TRM grant for the DNR to do stream bank and habitat improvement work immediately above and below STH 92 in 1999. The TRM project work and implementation of agricultural conservation measures reduced runoff resulting

[260] WDNR, 2008.

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[261]. Forty-six coldwater IBIs done at several locations on Fryes Feeder between 1999 and 2008 resulted in three biotic index ratings of "excellent" (coldwater IBI score = 90), three biotic index ratings of "fair" (coldwater IBI score =50), and the remaining biotic index ratings of "good" (coldwater IBI score =50). HBI monitoring done at several sites on Fryes between 1997 and 2000 showed a range of scores from 2.89 (excellent water quality) to 3.95 (very good water quality), with an average HBI score of 3.41 indicating "excellent" water quality.

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[262]. An improvement in coldwater IBI scores for Fryes Feeder was noted in pre- versus post CRP implementation (see Figure 1 in the Pecatonica River Watershed section).

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 base flow, stream hydrology, water quality, habitat and the coldwater fish community of Fryes Feeder.

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.

Flynn Creek

Flynn Creek is a three-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 feet per mile. There are springs along the creek that allow it to maintain water temperatures cold enough to support a Class II trout fishery and coldwater

[261] WDNR South Central Region Water Resources Files, 2010.
[262] Marshall et.al., 2008.

community. Flynn is also classified by the DNR as an ERW stream. Flynn supports both a brown and brook trout population.

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 (BMPs) 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[263]. 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[264].

Flynn Creek at Fritz Road

[263] Fetter, 2005b
[264] Marshall et.al., 2008.

Coldwater IBI done 1997 on Flynn Creek at Fritz Road resulted in a biotic index rating of "excellent" (coldwater IBI 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" (coldwater IBI scores = 60-70) to "excellent" (coldwater IBI score = 90) indicating very little or slight environmental degradation. While these coldwater IBI scores and biotic indices indicate very good coldwater aquatic conditions, the scores show a slight decline over the period. For example, the coldwater IBI score at CTH A was 90 ("excellent" BI rating) in 2000 but had declined to 70 ("good" BI rating) in 2004[265]. Macroinvertebrate monitoring (HBI) done at Fritz Road and CTH A between 1997 and 2000

[265] Data from DNR Fisheries Data Base accessed in 2010.

ranged between 2.8 (excellent water quality) and 4.26 (very good water quality), and an average score of 3.65 indicated very good water quality with slight organic pollution[266].

Additional monitoring and sub-watershed land use and land practices assessment needs to be done to determine if this slight decline is an anomaly or result of changing land use.

Primrose Branch

The Primrose Branch begins in the unglaciated Town of Primrose and flows east six miles to the West Branch Sugar River in the Town of Primrose west of STH 92. It has a moderate gradient of 19.4 feet per mile and drains an area of about nine square miles. There are abundant springs that maintain coldwater conditions to support a coldwater fishery. About 2 miles of its 6-miles 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[267]. A significant improvement in coldwater IBI scores was noted for Primrose in pre- versus post CRP implementation (see Figure 1 in the Pecatonica River Watershed section).

The DNR has done coldwater IBI monitoring at four sites on Primrose between 2002 and 2008. All the monitoring episodes resulted coldwater biotic integrity ratings of "good" (coldwater IBI scores = 70-80)[268] indicating slight environmental degradation. Aquatic invertebrate (HBI) sampling done in 1997 indicated water quality conditions ranging from "good" to "very good"[269].

[266] WDNR SWIMS database accessed 2010.
[267] Marshall et.al., 2008.
[268] Data from DNR Fisheries Data Base accessed in 2010.
[269] WDNR SWIMS database accessed 2010.

The primary threat to Primrose Branch is runoff from farm fields carrying sediment and nutrients to the stream and downstream impoundments.

Milum Creek

Milum Creek is a three 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 feet per mile[270]. It is on the state's ERW list. Redside dace (*Clinostomus elongates*), a rare aquatic species, had been found in Milum in the 1980s. Fish surveys in 2000 and 2002 did not find any redside dace in Milum. It is likely the redside dace has been extirpated from the creek. Milum Creek has experienced an almost 80% 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[271]. 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.

[270] DCRPC, 1992.
[271] Marshall et.al., 2004.

Milum Creek at Fritz Road

Monitoring over the last two decades has indicated moderate level of environmental degradation and a reduction in biotic integrity. A 2002 HBI sample "good" water quality (HBI score = 4.11)[272]. However, the 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[273].

Allen Creek and Middle Sugar River Watershed

The Allen Creek and Middle Sugar River watershed is located in south central Dane County, northeastern Green County and northwestern Rock County. About 28% of the watershed's area is in Dane County.

Table _____ Allen C reek and Middle Sugar River Watershed Land Cover

Resource Characteristics	**in acres**
Agricultural	16,726
Other*	3,485
Hydric Soils	2,637
Woodland	2,136
Wetlands	1,131
Residential	1,107
Transitional**	833
Open water	109
Outdoor recreation	50
Industrial	46
Institutional/Governmental	36
Commercial	13
Size of watershed in Dane County	**28,309**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

272 WDNR SWIMS database accessed 2011.
273 WDNR, 2010.

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. Belleville's wastewater treatment plant discharges to the Sugar River upstream of Remy Road (see Sugar River discussion above). 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 Middle Sugar River Watershed in Dane County are Story (Tipperary) Creek, Lake Harriet, and the wetlands of the Brooklyn Wildlife Area.

Story Creek

Story Creek rises on the southwest flank of the Johnstown Moraine and flows through a wide flat valley south 12 miles to the Sugar River in Green County. About three miles of its length is in Dane County. The creek has relatively low stream gradient of 8.7 feet per mile.

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 an Exceptional Resource Water. Much of its length in Dane County is in the Brooklyn Wildlife Area affording the creek additional protection from agricultural or other human disturbance.

Little Sugar Watershed

Story Creek at Bell Brook Road

Portions of the 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[274]. Twenty-five coldwater IBIs done between 1993 and 2009 ranged from "fair" biotic integrity (coldwater IBI=40) to "excellent" biotic integrity (coldwater IBI score=90)[275]. 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[276] 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.

Lake Harriet

Lake Harriet is a 34.7 acre pothole lake in southern Dane County. It has no natural outlet and has no public access. Nothing is known about the water quality, habitat of fishery of the lake.

Little Sugar River Watershed

Most of the Little Sugar River Watershed is in Green County. Approximately 7% 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. Agricultural land uses dominate with dairying, corn and soybeans, and animal feeder operations.

Table _____ Little Sugar River Watershed Land Cover

Resource Characteristics	**in acres**
Agricultural	3,223
Woodland	1,304
Other*	1,187

274 WDNR, Allen Creek and Middle Sugar River Watershed, http://dnr.wi.gov/water/WatershedDetailTabs.aspx?ID=SP13&Name=Allen Creek and Middle Sugar River accessed 2011.
275 Data from DNR Fisheries Data Base accessed in 2010.
276 WDNR SWIMS database accessed 2011.

Hydric Soils	582
Transitional**	204
Wetlands	86
Residential	52
Industrial	8
Open water	3
Institutional/Governmental	2
Outdoor recreation	0
Commercial	0
Size of watershed in Dane County	**6,651**

*includes codes other open or vacant land; vacant, unused land; under construction
**includes transportation, communication and utilities

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 joining the Sugar River near Albany. 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 into Dane County. This reach is also an ERW stream. 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[277].

[277] Data from DNR Fisheries Data Base accessed in 2010.

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Table ____. Streams of the Sugar River Basin

Stream Name	Length (Miles)	Existing Use	Potential Use	Supporting Potential Use	Fish & Aquatic Life Condition	303(d) Status	Impairment Source	Impairment Impact	F-IBI/ (No
Badger Mill Creek	0-2	Cold II	Cold II	Partially	Poor-Fair	N	MuniPointSource, UrbNPS, Hydro.Modification	Tot.P Tot.Sus.Solids, Habitat	10(7)$^{\#}$/5.1
	2-5	Cold II	Cold II	Partially	Poor				
Deer Creek	0-4.7	Cold II ERW	Cold II ERW	Partially	Fair-Good	N	AgNPS, UrbNPS,	Habitat, Sedimentation, Thermal	80.3(43)*/3
Fryes Feeder	4.7-5.8	Cold Comm ERW	Cold Comm ERW	Partially	Fair-Good	N	AgNPS	Sedimentation, Habitat	74.2(48)*/3
Flynn Creek	4.6	Cold II ERW	Cold II ERW	Partially	Fair-Good	N	AgNPS	Sedimentation, Habitat	75(8)*/3.
Henry Creek	1	Cold II	Cold II	Partially	Fair	N	AgNPS	Sedimentation, Habitat	56.7(3)*/3
Little Sugar River	3.9 (Dane County)	LFF/ERW	Unknown	Unknown	Unknown	N	AgNPS	Habitat, Sedimentation	--/4.26
Milum Creek	2	WWFF ERW	Cold Comm. ERW	Unknown	Poor	N	AgNPS	Habitat Sedimentation	25(2)*/4.
Mount Vernon Creek	0-3.5	Cold II ERW	Cold II ERW	Partially	Poor-Fair	N	AgNPS	Sedimentation, Habitat	66.7(3)*/4
	3.5-5.9	Cold I ORW	Cold I ORW		Fair-good			Sedimentation Habitat	
Primrose Branch	6.3	Cold II	Cold II	Partially	Fair-Poor	N	AgNPS, Hydro Modification	Habitat, Sedimentation	76(10)*/4
Schlapbach Creeek	3	Cold II/ERW	Cold II/ERW	Partially	Poor-Fair	N	UrbNPS, AgNPS	Thermal, Habitat, Sediment, TotSusSolids	55(6)*/
Story (Tipperary) Creek	7 (Dane County)	Cold II/ERW	Cold II/ERW	Partially	Fair	N	AgNPS, Streambank Erosion	Habitat, Sedimentation	60.4(23)*/4
West Branch Sugar River	0-7.6	Cold II	Cold II	Partially	Fair-Poor	N	AgNPS	Habitat, Sedimentation	30.4(28)*/
	7.6-18.8	Cold II	Cold II		Fair		AgNPS	Habitat, Sedimentation	
	18.8-22.3	Cold II	Cold II		Poor		UrbNPS, MuniPointSource, AgNPS	Habitat, Sedimentation,TotSusSolids, Thermal	
Sugar River	6.0	WWSF/ERW	WWSF/ERW	Partially	Fair	N	AgNPS, UrbNPS, MuniPoint Source	Sedimentation, Tot.Sus Solids, Habitat, Tot.P	32(2)**#/5
	18	Cold II/ERW	Cold II/ERW						25(12)$^{*\#}$/5

*= Coldwater IBI

#= Does not include data collected by MMSD. MMSD has done extensive HBI and IBI monitoring of the Sugar River downstream of Badger Mill Creek

**= Warmwater IBI

For statewide planning purposes, the Pecatonica River Watershed is part of the Grant-Platte-Sugar-Pecatonica Basin. In Dane County, the greater Pecatonica River Watershed includes the Gordon Creek Watershed (30,792 acres) and Upper East Branch Watershed (1,172 acres). These areas lay within Southwest Savanna Ecological Landscape that offers many opportunities for restoring rare oak savannas and grassland habitats (WDNR Wildlife Action Plan). And restoring savanna and grassland habitats also offers considerable water quality benefits. The greater Pecatonica River Watershed lies within the unglaciated Driftless Area. Land use data are presented in Tables 1 and 2.

There are no named streams within the Upper East Branch Watershed. 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.

Seven named streams bisect the broad ridge tops within the Gordon Creek Watershed. The streams are currently managed for trout and coldwater communities. All are classified as Rural Streams and sensitive to impervious surfaces runoff. 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 Nonpoint Source Water Pollution Abatement Program. Three of the streams, German Valley Creek, Syftestad Creek and Pleasant Valley Creek, were listed on the 303d impairs waters.

Recent monitoring data and research demonstrated significant improvements in Gordon Creek Watershed streams (Marshall 2003). Syftestad Creek is now classified as coldwater communities and has been removed from the 303d list. German Valley Creek was reclassified as a trout stream and is expected to be removed from the 303d list soon. The primary reasons for these and other water quality improvements are linked to trends in agriculture and conservation efforts (Marshall et al. 2008).

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 was 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. Total animal unit numbers declined, along with associated problems such as over-grazing woodland corridors, as the numbers of farms declined. Ultimately, BOD and nutrient loading to the streams decreased (Marshall et al. 2008). Not surprising, research had demonstrated that runoff and peak flow rates in Driftless Area streams declined as farm land use practices were gradually improving and intensive agriculture was declining on less productive lands (Gebert and Krug 1996). Additional research suggested that long term increased minimum and median flows in Driftless Area streams were primarily linked land use changes rather than increased precipitation rates (Juckem et al. 2008, Kochendorfer and Hubbart 2010).

As some indicators suggested that agricultural land uses had 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. In areas such as the Gordon Creek Watershed, reaching 20% CRP enrollments by 2002, environmental benefits were significant including improved hydrology, reduced soil erosion, reduced nutrient loading and increased wildlife habitat. Hydrology improved as surface runoff declined by 50% or more while infiltration increased inter-lateral groundwater flow to cold water streams. Sustained spring flow from perched hillside aquifers are important Driftless Area streams (Carter et al. 2010). Grass cover reduced phosphorus and sediment loading by 90% while the larger grassland tracts provide essential habitat for some of the most threatened bird populations in the United States, migratory grassland birds (Marshall et a. 2008). The relative high densities of these rare bird populations thrive in the Gordon Creek Watershed and surrounding Driftless Area watersheds 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 (WDNR 2009). These projects focus on public-private partnerships designed to protect grasslands, prairie remnants, oak savannas, agriculture and water quality. The measured improvements in Gordon Creek Watershed streams reflect ecological and management connections between 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 their farms, and in return, provide important public benefits.

Without any direct management, fisheries in Gordon Creek Watershed streams gradually shifted from relatively diverse populations of eurythermal species to populations of stenothermal species more typical of ecologically healthy trout streams. Over the span of decades, species richness declined in the streams (Figure 1) while coldwater Index of Biotic Integrity scores greatly improved (Figure 2) (Marshall et al. 2008). There is a negative correlation between these two indicators of coldwater habitat. Healthy trout streams typically support low diversity of fish species adapted to living in perpetually cold water conditions (Lyons et al 1996). 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 (Marshall 2008). Higher IBI scores generally occurred in watersheds where non-cropland uses, particularly grasslands, were higher (Figures 3 and 4)

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 Department of Land and Water Resources 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 of box elder growth over incised channels with eroding stream banks.

The changes in agriculture and streams in the Gordon Creek Watershed 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 (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 un-fragmented grassland and can destroy scenic views that are important for the local tourism economy; undermining the goals of MRPHA and Southwest Wisconsin Grassland and Stream Conservation Area (WDNR 2009).

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 USEPA, WDNR, and Midwest Biodiversity Institute) that will develop sampling designs to improve monitoring strategies.

Table 1: Upper East Branch Watershed Characteristics

Resource Characteristics	**In Acres**
Hydric soils	0
Wetlands	0
Agriculture	832
Commercial	2
Institutional/Governmental	5
Industrial	11
Open Water	0
Vacant Land or Under Construction	45
Outdoor Recreation	38
Residential	103
Transportation, utilities etc.	101

Woodland	23
Total Watershed Area	89,791
Dane County Portion	1,172

Dane County State of the Waters Report

Table 2: Gordon Creek Watershed Characteristics

Resource Characteristics	**In Acres**
Hydric soils	1,293
Wetlands	394
Agriculture	20,534
Commercial	1
Institutional/Governmental	10
Industrial	46
Open Water	1
Vacant Land or Under Construction	3,092
Outdoor Recreation	81
Residential	270
Transportation, utilities etc.	906
Woodland	5,831
Total Watershed Area	49,260
Dane County Portion	30,792

Dane County State of the Waters Report

Figure 1: Species Richness changes after CRP Enrollments in Southwest Dane County and Southeast Iowa County. Low species richness reflects healthy trout streams.

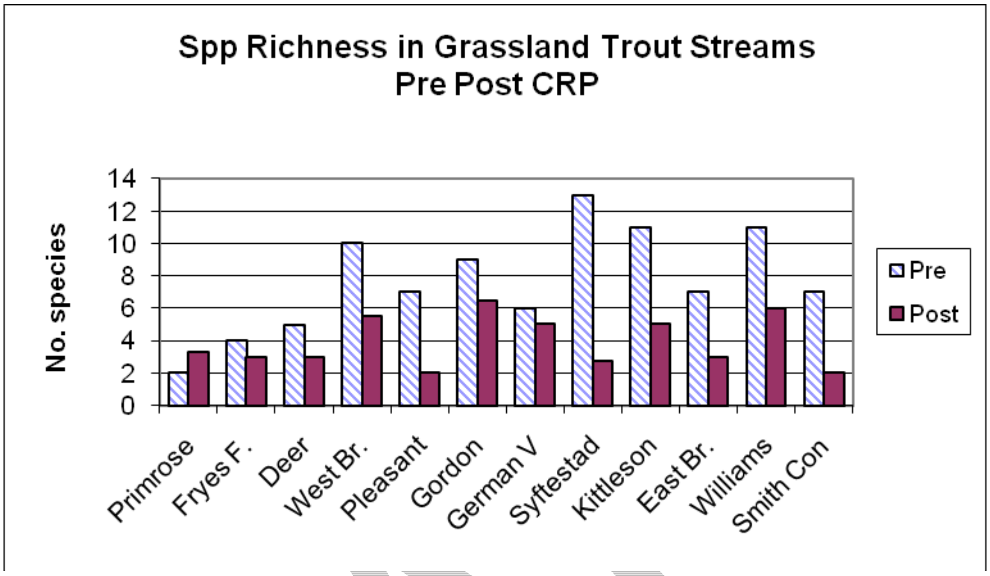


Figure 1: Cold water Index of Biotic Integrity (IBI) Scores for Southwest Dane County and Southeast Iowa County before and after CRP enrollments. IBI "good" range = 60-80.

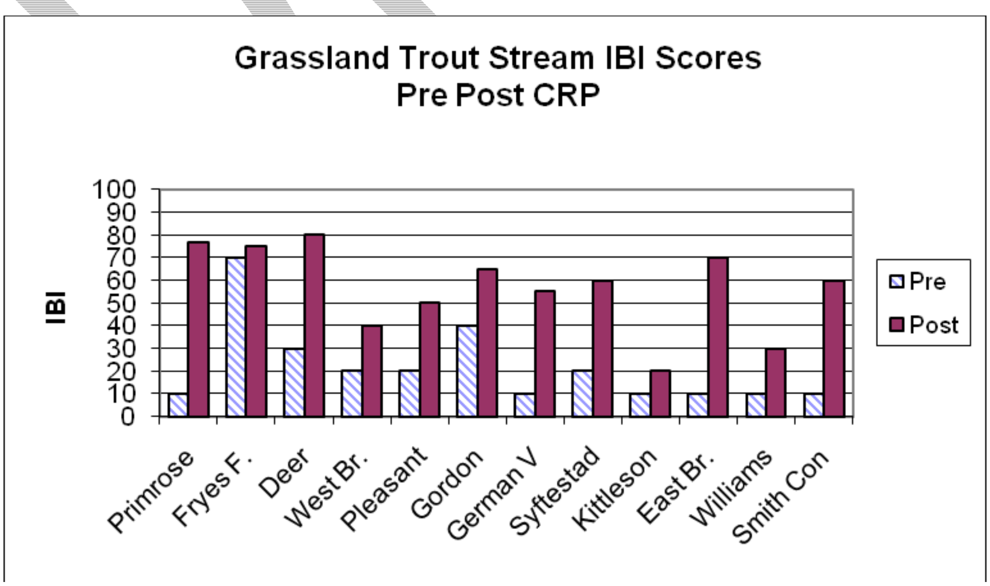


Figure 3: Higher IBI scores (left side) occurred in watersheds with lower intensity agriculture.

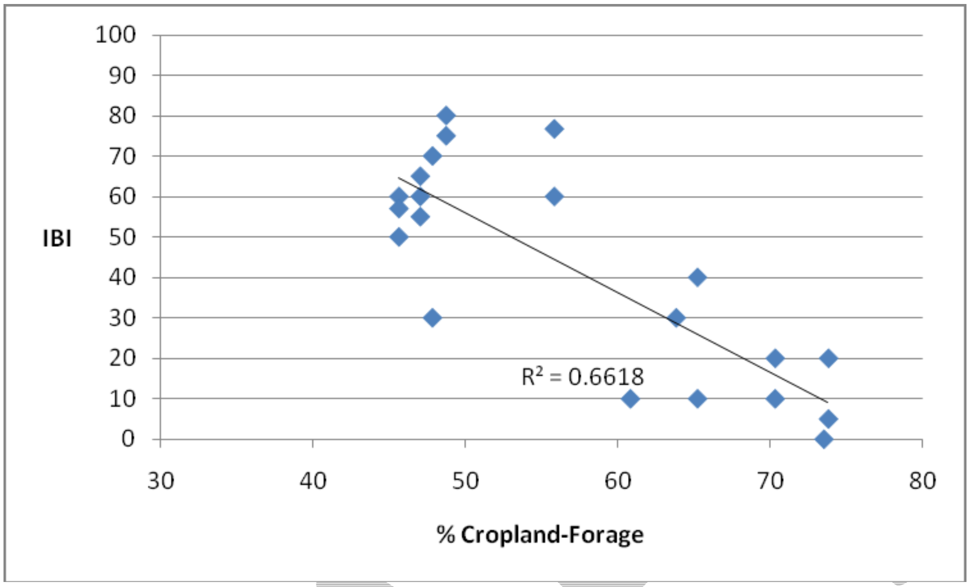
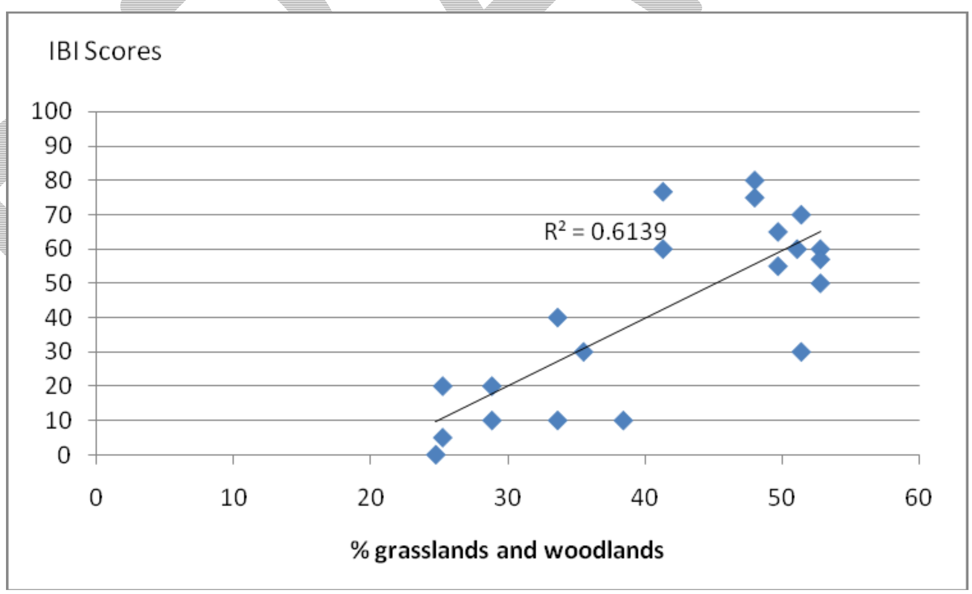


Figure 4: Lower IBI scores (left side) coincided with lower grasslands and woodlands



Gordon Creek

Gordon Creek (WBIC 907300, also known as Blue Mounds Branch and Big Spring Creek) arises in Section 8 of Blue Mounds Township and flows south for about six miles to the confluence with German Valley Creek. 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 classified as Exceptional Resource Waters (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 5 demonstrates how the fish community changed over the years, from eurythermal 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 6 reveals improved cold water IBI scores over time with the best scores beginning in 2001. In 1994, the IBI score reflected poor cold water 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. Figure 7 displays daily maximum mean temperatures and sustained cold water habitat based on Onset Hobo data loggers. Hilsenhoff Biotic Index scores from samples collected in 1994 through 2002 indicated very good water quality (HBI 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 hyporhyeic zone. The macroinvertebrate community in Big Spring-Gordon Creek typically supports abundant stonefly populations, primarily *Isoperla signata*).

German Valley Creek

German Valley Creek arises in Section 10 of Blue Mounds Township and flows about seven miles to the confluence with Gordon Creek. Until recently, GVC 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 6). GVC 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. GVC is still listed as 303d impaired by it is expected to be removed from the list soon to reflect the significantly improved water quality and habitat and sustained brown trout population. And Dane County Department of Land and Water Resources continue to work with area farmers to improve manure management practices. The best trout habitat is located in the lower reaches where enough spring flow sustains habitat and cold water temperatures. Hilsenhoff Biotic Index scores ranged from 2.91 (excellent water quality) to 5.15 (good water quality) during the period from 1994 through 2002.

Figure 5: Fish community changes in Gordon Creek

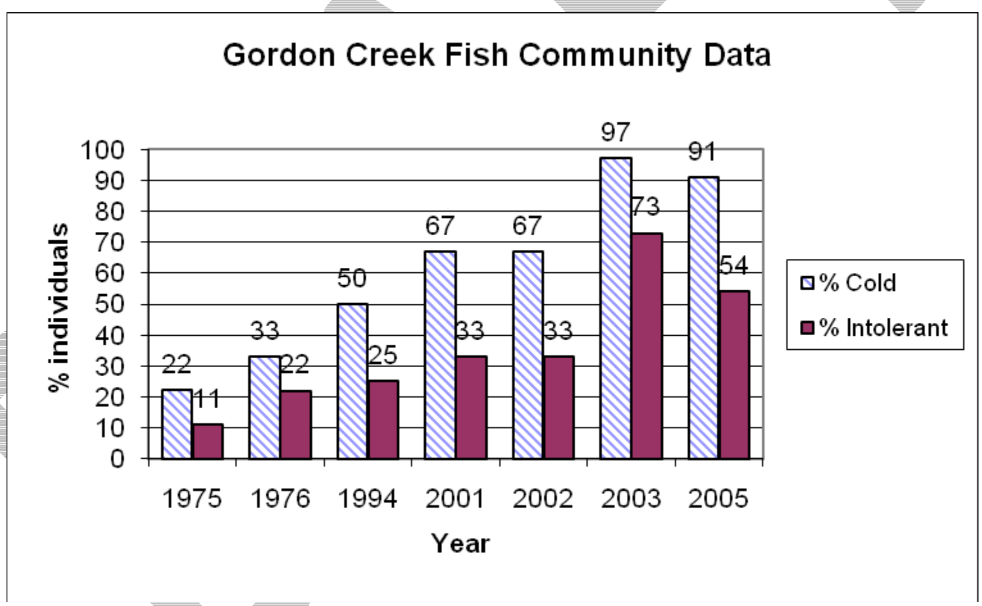


Figure 6: Changes in cold water IBI scores over time in Gordon Cr, German Valley Cr and Syftestad Cr

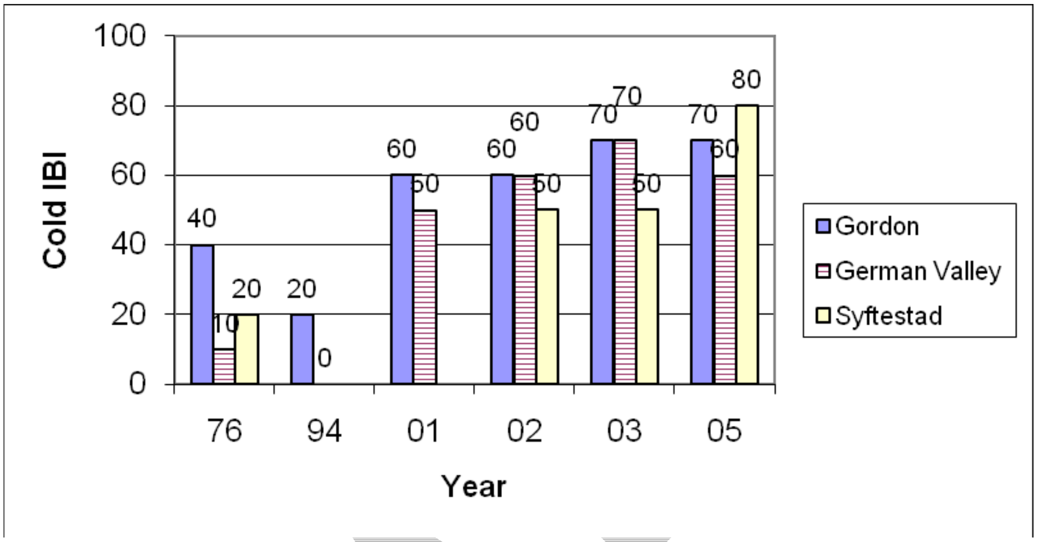
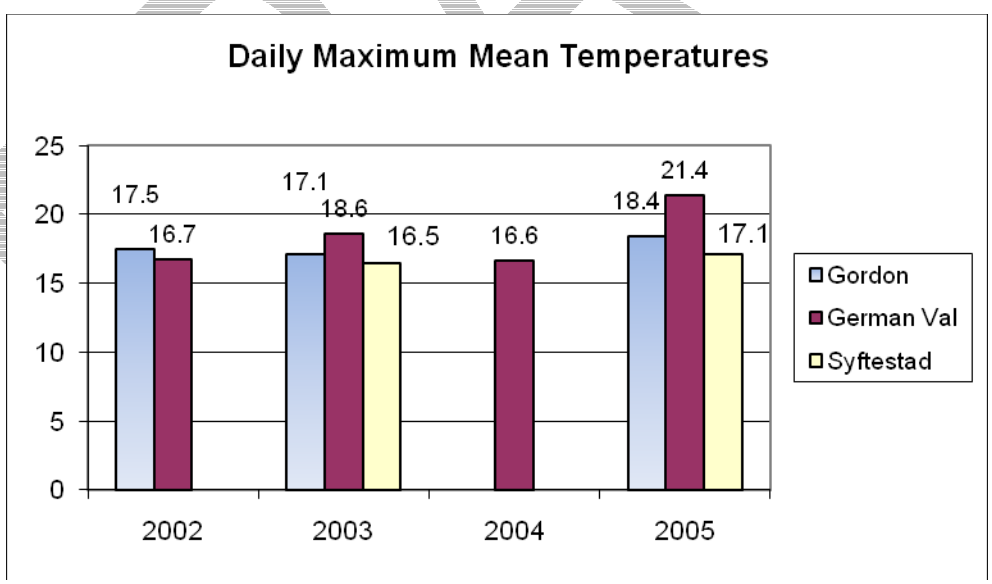


Figure 7: Summary of continuous water temperature data for Gordon Creek, German Valley Creek and Syftestad Creek.



Syftestad Creek

Syftestad Creek (also known as Daleyville Branch) is a small stream that arises in Section 25, Perry Township and flows south for about four miles to the 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 303d list in 2006 to reflect recent data that revealed conditions favorable for trout and cold water 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 6 and 7 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 MRPHA streams. Also consistent with the other trout streams in the area, HBI values reflected very good water quality in Syftestad Creek. 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 the stream had a coldwater IBI score of 90 or "excellent" integrity rating.

Kittleson Valley Creek

Kittleson Valley Creek arises in Section 25 of Perry Township and flows west to the confluence with Gordon Creek in Iowa 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 Kiittleson Valley Creek supported typical trout stream fish species; primarily brown trout and mottled sculpin. IBI scores ranged from 30 to 70 from 2006-08 with a mean score of 57 (N=6). 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. 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% of the annual phosphorus load (1,170 lbs.) and approximately 14% 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 (USGS 2008).

Pleasant Valley Creek

Pleasant Valley Creek is a small stream that arises in Section 3 of Perry Township and flows south for about four miles to the confluence with Kittleson Valley Creek. Pleasant Valley Creek is listed as 303d impaired and is a key focus of the Wisconsin Buffer Initiative. HBI scores from macroinvertebrates 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 cold water IBI scores ranging from 30 (fair) to 70 (good)(mean =50, n =11). The dominant species were brown trout and mottled sculpin. 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 Kittleson Valley Creek. The small trout stream displays “fair” coldwater habitat (IBI=30) near Tyrand Road but improves to “good” (IBI=60,70) trout stream habitat from Lee Valley Road to the confluence with Kittleson Valley. An HBI macroinvertebrate sample (1.46) collected in 2008 indicated “excellent” water quality.

Table 3: Fish and Aquatic Life Designations

Waterbody	2000 Impervious Cover	Planned Impervious Cover	Use	Use Potentiial	Codified Use
Gordon Cr.	5.11%	5.46%	Cold		ERW
German Valley Br.	4.33%	4.48%	Cold		303(d)
Jeglum Valley Br.	2.94%	2.94%	Cold		
Kittleson Valley Cr.	3.38%	3.38%	Cold		
Pleasant Valley Br.	3.62%	3.62%	wwff	Cold	303(d)
Syftestad Cr.	3.47%	3.47%	Cold		
York Valley Cr. (Lee Cr.)	3.07%	3.07%	Cold		

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Table ____. Streams of the Pecatonica River Watershed

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish & Aquatic Life Condition	303(d) Status	Impairment Source	Impairment Impact	F-IBI/HBI (No.)
German Valley Creek	7.6	Cold II	Cold II	Partially	Poor	Y	AgNPS, TotSusSolids	Habitat, Sedimentation	29.4(16)[#]/4.03(9)
Gordon (Blue Mounds) Creek	8 (Dane County)	Cold II ERW	Cold II ERW	Partially	Fair-Good	N	AgNPS, Steambank Erosion	Habitat, Sedimentation	60.4(23)[#]/3.74(21)
Jeglum Valley Creek	1.5	WWFF(?)	Unknown	Unknown	Unknown	N	Unknown	Unknown	/--
Kittleson Valley Creek	0-2.8	Cold II	Cold II	Partially	Poor	N	AgNPS, Streambank Erosion	Habitat Sedimentation	44.7(11)[#]/4.70(7)
	2.8-6.7	Cold III	Cold II (?)	(?)	Poor				
	6.7-12.7	Cold II	Cold II	Partially	Poor				
Lee Creek	0-2	Cold II	Cold II	Partially	Fair	N	AgNPS	Habitat, Sedimentation	53.3(3)[#]/1.46(1)
	2-3	Unknown	Unknown	Unknown	Unknown				
Pleasant Valley Creek	5.9	WWFF	Cold	No	Poor	Y	AgNPS	Habitat, Sedimentation	45(12)[#]/5.97(5)
Syftestad Creek	5.2	Cold II	Cold II	Partially	Fair	N	AgNPS	Habitat Sedimentation	52(10)[#]/4.15(3)

#= Cold IBI

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-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 upland Driftless Area trout streams, agricultural ditched streams, a regionally popular trout stream – Black Earth Creek, 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. Land uses for the four watersheds appear in Tables 4-7.

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 (Marshall and Lyons 2008). 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 (WDNR Wildlife Action Plan). In 1989, Act 31 established the Lower Wisconsin State Riverway to protect the scenic beauty and natural character of 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 (Matthews 2009). 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 partners (including Dane County) 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 tainted fish flesh and rafts of foam floated downstream from the Prairie du Sac dam (WDNR Draft LWSRW Fisheries Plan). 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 (Marshall 2009).

The Dane County reach of the Lower Wisconsin River is about 14 miles long. 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 (Marshall and Unmuth 2004).

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 (Marshall and Jopke 2010). 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 contamination and runoff pollution (Marshall and Jopke 2010). 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 medium flow rates (Figure 8). 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 (Amoros and Bornette 2002, Amoros 2001).

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 (Camargo et al. 2005). 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 (Pfeiffer et al. 2005). Recommendations from the Dane County small-scale lake planning grant study:

(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 expanded buffer zones to protect both upland groundwater and reduce surface runoff pollution.

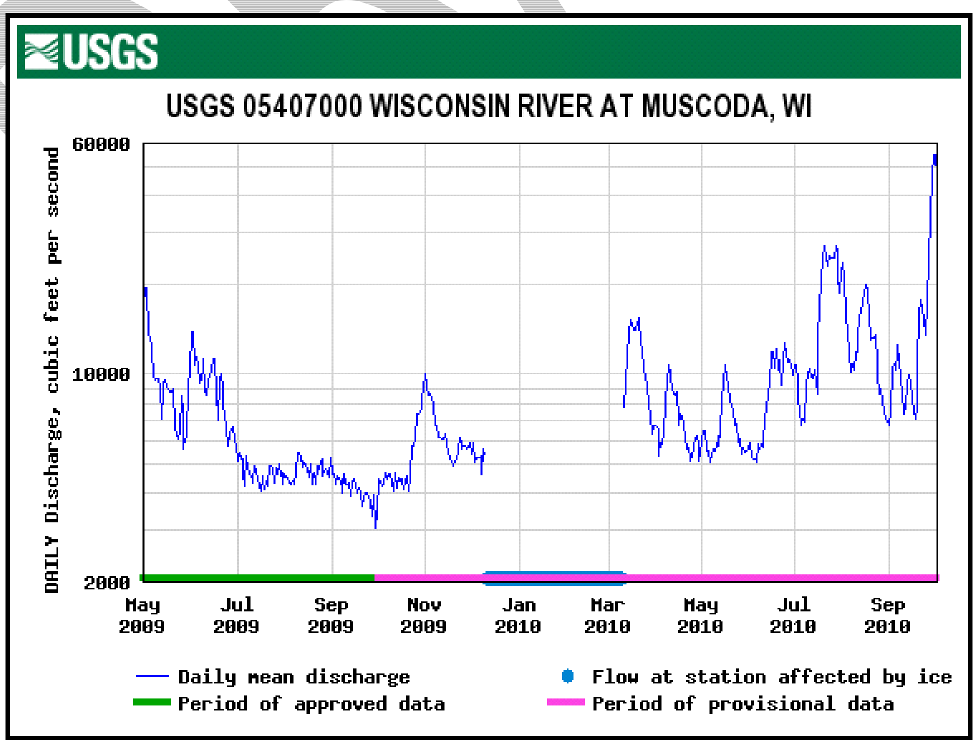
(2) Given the environmental sensitivity and important ecological functions of the floodplain lakes, the Department of Natural Resources should classify these waterbodies as Outstanding Resource Waters (ORW).

(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 8: Lower Wisconsin River Flow Rates in 2009-10 demonstrate variable conditions within the river floodplain



Black Earth Creek Watershed

The Black Earth Creek Watershed encompasses 66,326 acres in Dane County including 75 miles of streams and 22 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 (Dane County State of the Waters Report 2008). Most of the streams in the watershed are classified as Rural except for the lower reach of Brewery Creek in Cross Plains and Black Earth Creek from Middleton downstream below Cross Plains where the classifications are Developing Waters.

Table 4: Black Earth Creek Watershed Characteristics

Resource Characteristics	In Acres
Hydric soils	4,865
Wetlands	1,511
Agriculture	30,959
Commercial	101
Institutional/Governmental	170

Industrial	492
Open Water	280
Vacant Land or Under Construction	7,523
Outdoor Recreation	773
Residential	2,614
Transportation, utilities etc.	2,537
Woodland	20,876
Total Watershed Area	67,383
Dane County Portion	66,326

Dane County State of the Waters Report

Black Earth Creek

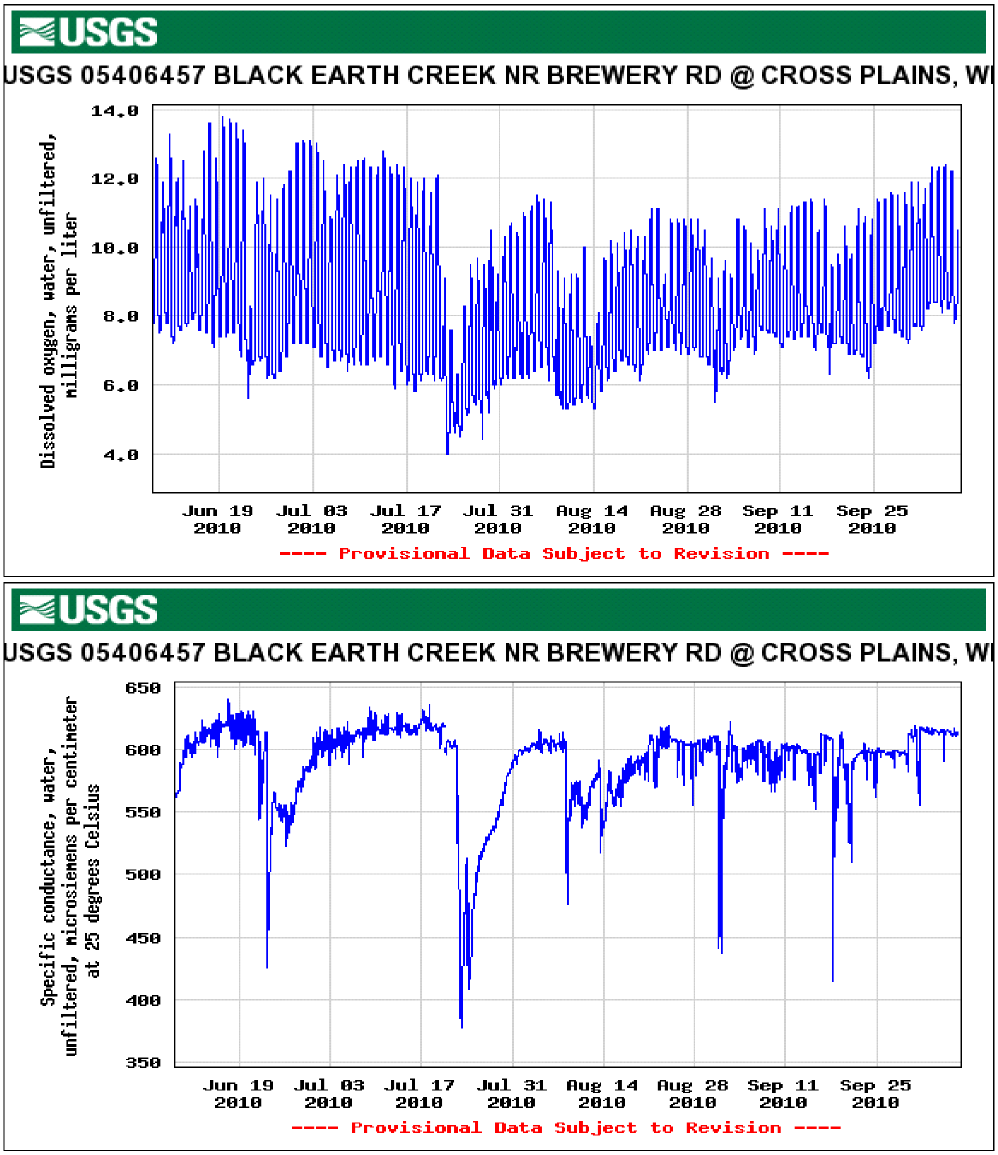
Black Earth Creek arises from the terminal moraine west of Middleton and flows about 27 miles to the confluence with Blue Mounds Creek. Most of the watershed is dominated by thick deposits of glacial outwash and alluvium, materials that form an excellent aquifer for sustained stream flow (DCRPC 1992). 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 (Potter et al. 1995). 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 warm 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 warm fish. While Black Earth Creek supports high densities of wild brown trout, coldwater IBI scores from 2001-08 indicate “fair” environmental conditions with a mean score of 42.5 (range from 20 to 70, n=18). Below the Village of Black Earth, coldwater IBI scores (20) indicate "poor" conditions and reflect the mixed stenothermal –eurythermal fish populations. 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 Dane County trout streams within the Driftless Area. Environmental problems that threaten Black Earth Creek include agricultural ditching, the Refuse Hideaway Landfill USEPA 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 (BMPs) that exceeded pollution reduction goals (Dane County State of the Basin Report 2008). 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 and nutrient management. In spite of these successes, however, frequent dissolved oxygen criterion violations, periodic fish kills, expanding development and impervious surfaces continue to pose long term threats to the stream.

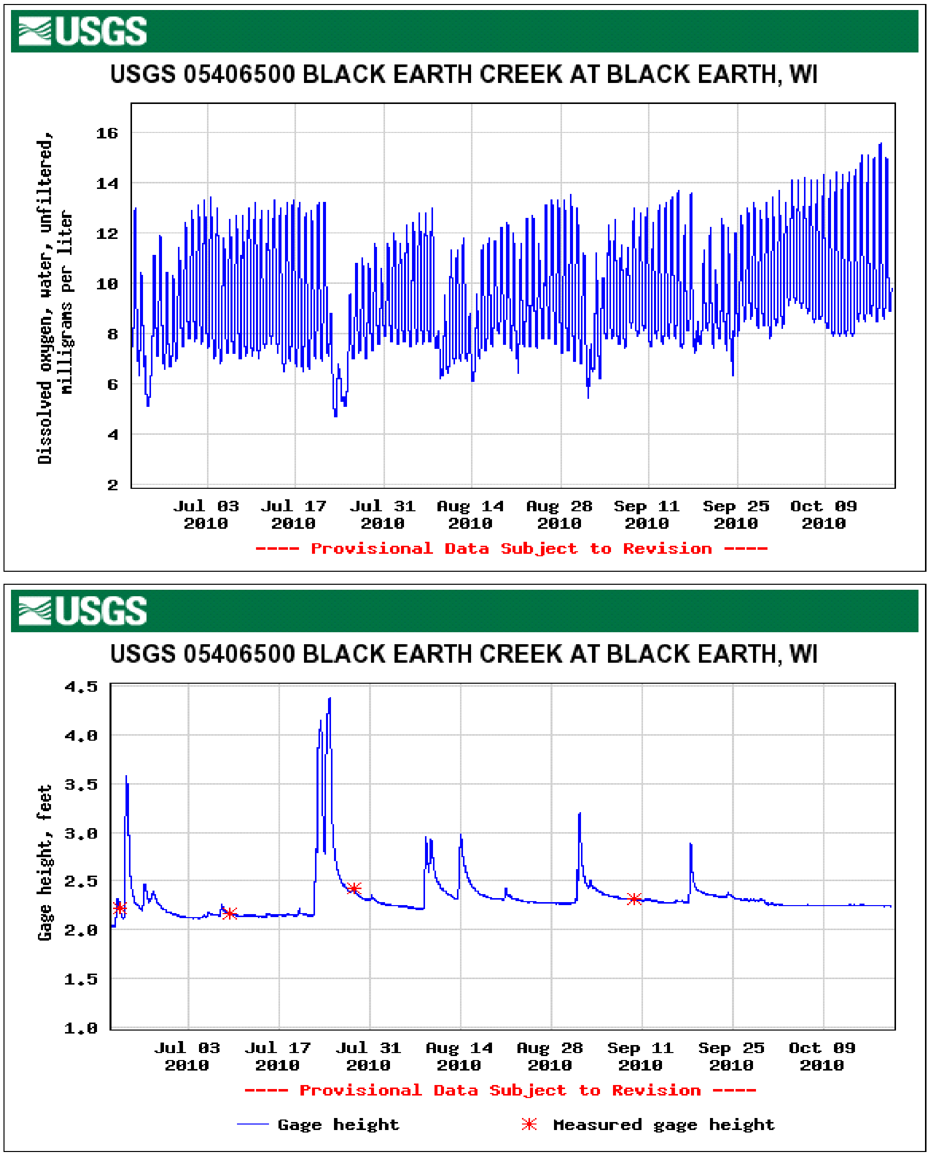
The United States Geological Surveys (USGS) maintains "Realtime" water quality monitoring stations along Black Earth Creek at Cross Plains, South Valley Road and Village of Black Earth. Dissolved oxygen levels frequently drop below trout stream criterion limit of 6 mg/l at all three stations and these violations typically occur during storm events when specific conductance levels are lower (reflecting soft rain water inputs) and when creek levels rise (Figures 9 and 10). Chronic low dissolved oxygen in the stream had been previously well documented (Walker et al. 2001). 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% west of Cross Plains (WDNR 2001). 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 factory dairy farms, urban runoff and tile drains from former wetlands (now cropped) that could potentially discharge pesticides, crop oils 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 (WDNR Waters File 2003). Macroinvertebrates sampling immediately after the fish kill revealed no measureable impact of the pollution.

Figure 9: 2010 dissolved oxygen and specific conductance data from the Cross Plains Realtime Monitoring Site



(USGS)

Figure 10: 2010 dissolved oxygen and gage height from the Black Earth Realtime Monitoring Site (USGS)



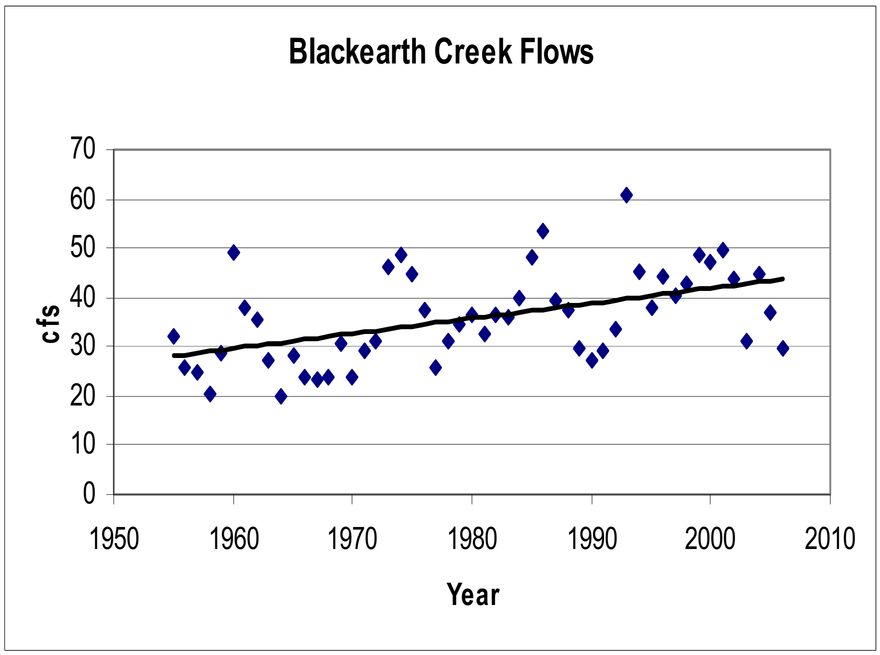
Additional information gleaned from the USGS monitoring station in Black Earth revealed that Black Earth Creek flow has been gradually increasing (Figure 11 – Krohelski et al. 2002). This trend is consistent with other Driftless Area streams where long term base flow rates had increased and may reflect conservation efforts (Gebert and Krug 1996, Juckem et al. 2008).

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", prepared by Kakuska (2003) with input from a diverse steering committee, recommended 10 specific actions that will 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 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.
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).

Figure 11: Black Earth Creek Mean Annual Stream Flow Trend (R^2=0.71)



Brewery Creek (Enchanted Valley Creek, Dry Run Creek)

Brewery Creek is a small tributary of Black Earth Creek that enters from the north. The stream is 6.1 miles long and drains a 10.5 sq. mile watershed. Brewery Creek had a long history of water quality degradation and parts of the stream had been ditched (DCRPC 1992). Dissolved oxygen had dropped to 0 mg/l during a storm event in 1990. A recent study 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 (Selbig et al. 2004). As part of that study biological indicators indicated that the stream had improved from a watershed perspective and it now supports a numerous brown trout that migrate upstream from Black Earth Creek. In the 1980s, manure management problems had eliminated environmentally intolerant macroinvertebrate populations in Brewery Creek. But from 1985 HBI values as high as 7.6 (= poor w. q.) declined to values less than 5 (= good w. q.) from 1995 through 2002 (R^2=0.58). The stream improvements may have reflected best management practices completed as part of the Priority Watershed Project and more general water quality and land use trends that had been occurring within the Driftless Area (Gebert and Krug 1996, Juckem et al. 2008).

While HBI values indicated good water quality 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 and 100% tolerant fish that were previously found in the stream during the 1980s.

The improved fish and macroinvertebrate communities in the stream appear to contradict another study. Graczyk et al. (2003) demonstrated that pre and post Priority Watershed Project storm related sediment and nutrient loads were not significantly different at the 0.05 probability level. 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. The maximum daily mean temperatures recorded from 2000-02 in Brewery Creek now indicate coldwater or trout habitat and reflect groundwater inputs.

Since Brewery Creek is an important tributary to Black Earth Creek, it is designated a "Priority Stream" in the Dane County Open Space Plan for land acquisition and streambank protection.

Garfoot Creek

Garfoot Creek is a 3.8 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 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 (DCRPC 1992). More recently, Graczyk et al. (2003) determined that levels of ammonia nitrogen during storm events was statistically lower following completion of best management practices (BMPs) in the watershed. Levels of phosphorus and suspended sediment were not statistically different before or after implementation of BMPs. 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 in under consideration for Class I management.

Vermont Creek

Vermont Creek arises in Section 25 of Vermont Township and flows six 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. Also, some of the springheads had been impounded. As a result, it displays marginal Class III trout habitat and was added to the 303d list of impaired waters in 2004. Recent habitat restoration efforts, involving Dane County Department of Land and Water Resources, Southern Wisconsin Chapter Trout Unlimited, WDNR and 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, mean = 27, n = 12) reflect the degraded habitat in the stream. Future WDNR electroshocking surveys will document effectiveness of the habitat restorations.

Halfway Prairie Creek

The headwater of Halfway Prairie Creek is located at the outlet of hypereutrophic Indian Lake. The stream flows 11 miles before entering Black Earth Creek in the Village of Mazomanie. Most of the stream channel had been ditched with minimal riparian buffers. As a result, the stream displays very poor habitat and supports predominantly an environmentally tolerant fisheries. While a few brown trout occasionally found in the stream, WDNR baseline electroshocking surveys(2006) demonstrated very poor coldwater IBI scores (range 0 - 20, mean = 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 (mean = 4.1, n = 4) reflected “very good” water quality and influence of groundwater inputs.

Wendt Creek (Spring Brook)

Wendt Creek arises from wetlands in Sections 17 and 18 in the Town of Berry. The stream flows six miles to the confluence with 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 303d impaired but may have potential for trout management if buffers are expanded and habitat improved. Poor coldwater IBI scores (range 10 - 20, mean = 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, macroinvertebrate collections from 2006 indicated "good" water quality with HBI scores ranging from 4.3 - 5.5 (mean = 4.6, n = 5).

Indian Lake

Indian Lake is a 27 ha (66 acres) shallow kettle lake that is maintained by groundwater and surface runoff. The entire lake is surrounded by the 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 bluegreen 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 (Lathrop 1988). The findings indicated that nitrogen applications were not effective due to short-term responses and other complicating factors. Since then, bluegreen 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 Fish and Crystal lakes, Indian Lake water levels have increased over time. The maximum recorded depth during the 1970s was 6 feet (Day et al. 1985). 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 (Gebert and Krug 1996). The lake area also expanded significantly.

More recently, EWM and coontail had become established in the lake and apparently suppress phytoplankton blooms. Harvesting the dense beds 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 (Marshall 2007). Lake volunteer secchi measurements (SWIMS database) taken from 2007-09 ranged from 0.5 meters to 1.7 meters (mean Trophic State Index Value 56 = eutrophic). Longer term secchi trends indicated improved water clarity and likely reflect increased macrophytes densities in the lake (Figure 13).

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*) (Lathrop 1988, Day et al. 1985). 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 harvesting improves the habitat.

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 (Marshall 2007). The goals for managing Indian Lake macrophytes are to (1) improve non-motorized boat access within dense coontail, Eurasian watermilfoil and curly-leaf pondweed beds, (2) sustain lake-wide aquatic plant beds in desirable densities to prevent bluegreen algal blooms that had historically occurred (3) manage aquatic plants to enhance the largemouth bass and bluegill fisheries and (4) enhance native floating-leaf plant populations.

Figure 12: Mean coldwater IBI scores for Black Earth Creek Watershed streams

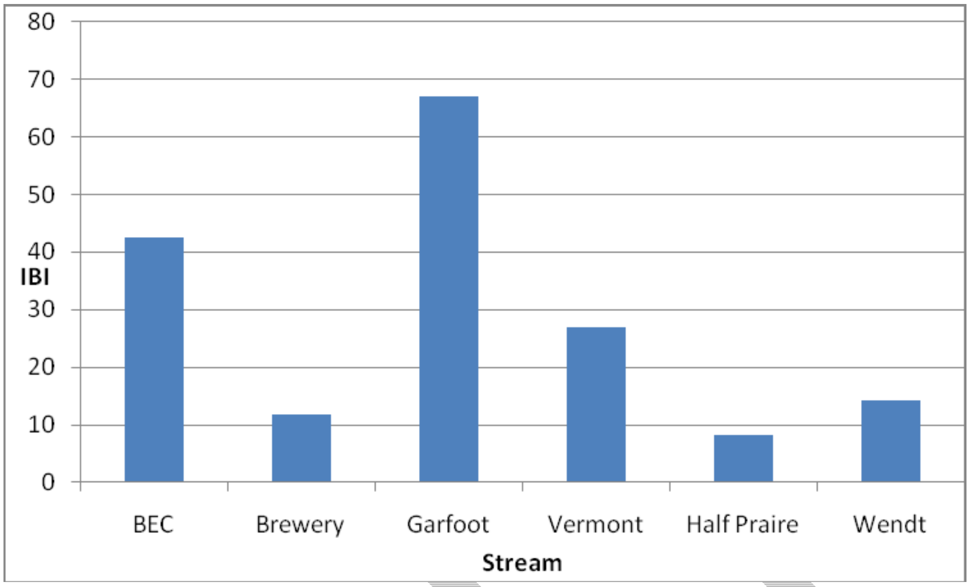


Figure 13: Water clarity trend in Indian Lake (WDNR volunteer monitoring data)

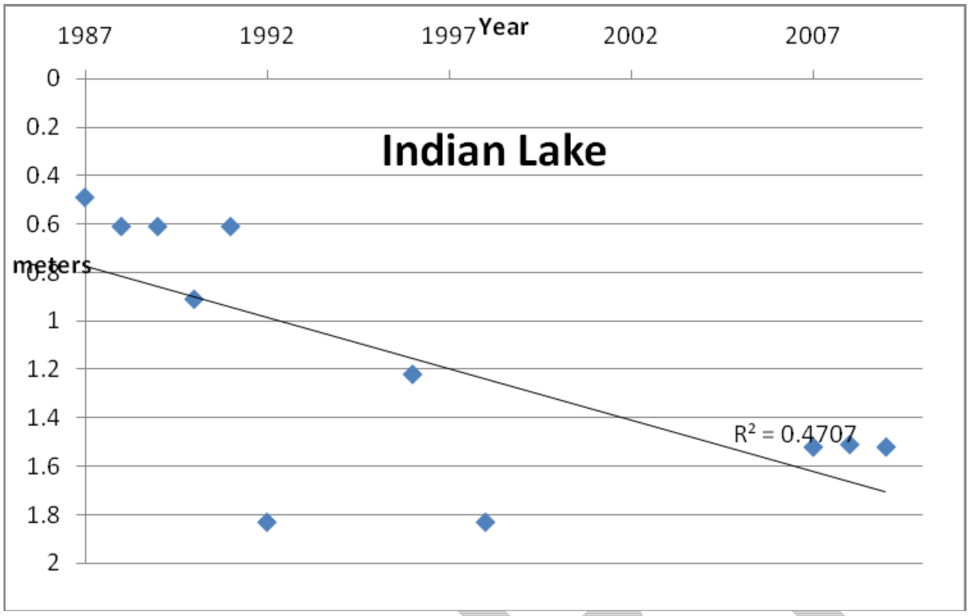


Table 5: Fish and Aquatic Life Designations

Waterbody	2000 Impervious Cover	Planned Impervious Cover	Use	Use Potentiial	Codified Use
Black Earth Cr. (Lower)	5.19%	5.83%	Cold	Cold	
Black Earth Cr. (Middle)	5.68%	6.47%	Cold		
Black Earth Cr. (Upper)	7.06%	8.53%	Cold		ORW
Brewer Cr.	6.24%	7.42%	wwff	Cold	
Garfoot Cr.	2.99%	2.99%	Cold	Class 1	ERW

				trout	
Vermont Cr.	3.57%	3.9%	Cold	Class 11 trout	303d
Halfway Prairie Cr.	3.99%	4.07%	wwff	Cold	303d
Wendt Cr.	3.32%	3.32%	wwff	Cold	303d

Mill and Blue Mounds Creeks Watershed

The Dane Count y portion of the Mill and Blue Mounds Creeks Watershed encompasses 22,851 acres 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 construction erosion and impervious surfaces runoff. Other concerns have included overtopping manure storage pits near streams and polluted runoff. More detailed resource characteristics appear in Table 6. The streams in this watershed typically display good trout habitat based on resident fish communities.

Table 6: Mill and Blue Mounds Creeks Watershed

Resource Characteristics	In Acres
Hydric soils	829
Wetlands	507
Agriculture	7,145
Commercial	31
Institutional/Governmental	21
Industrial	43
Open Water	8
Vacant Land or Under Construction	3,309
Outdoor Recreation	481

Residential	512
Transportation, utilities etc.	665
Woodland	10,594
Total Watershed Area	119,615
Dane County Portion	22,851

Dane County State of the Waters Report

Moen Creek

Moen Creek originates in Section 2 of Blue Mounds Township and flows northeast about two miles to the confluence with Elvers Creek. The headwaters are impounded to form Stewart Lake. A recent study of the creek near the dam determined that thermal impacts from the lake are minimal and did not alter the coldwater fish community (Dane County Dept. of Land and Water Resources 2006). Recent biological monitoring data indicate that the stream is supporting its Class II trout fishery with a coldwater IBI score of 40 (= fair) and HBI value of 4 (= very good water quality). The gradient is very steep at 103 ft/mile with a discharge of approximately 4 cfs near the confluence with Elvers Creek (Dane County Dept. of Land and Water Resources 2006).

Elvers Creek

Elvers Creek arises in Section 11 of Blue Mounds Township and flows north eight miles to the confluence with Ryan Creek. WDNR manages about 105 acres of public fishing grounds along the classified trout stream that is also designated ERW under Wisconsin Administrative Code NR 102. Portions of the lower 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. WDNR biologists recommended the stream for polluted runoff abatement efforts since the stream has potential for Class I trout management (Lower Wisconsin River State of the Basin Report). WDNR electrofishing surveys conducted from 2002 to 2008 had demonstrated favorable trout habitat in the stream with coldwater IBI scores ranging from 50 to 70 (mean = 58.3, n = 6).

Bohn Creek

Bohn Creek arises in Section 9 of Blue Mounds Township and flows north three miles to the confluence with Elvers Creek in Vermont Township. The lower part of the creek is managed as a Class II trout stream and it is also designated ERW under Wisconsin Administrative Code NR 102. 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 habitat with a mean coldwater IBI score of 93 (n = 3). The very high scores reflected in part the presence of native brook trout in the creek.

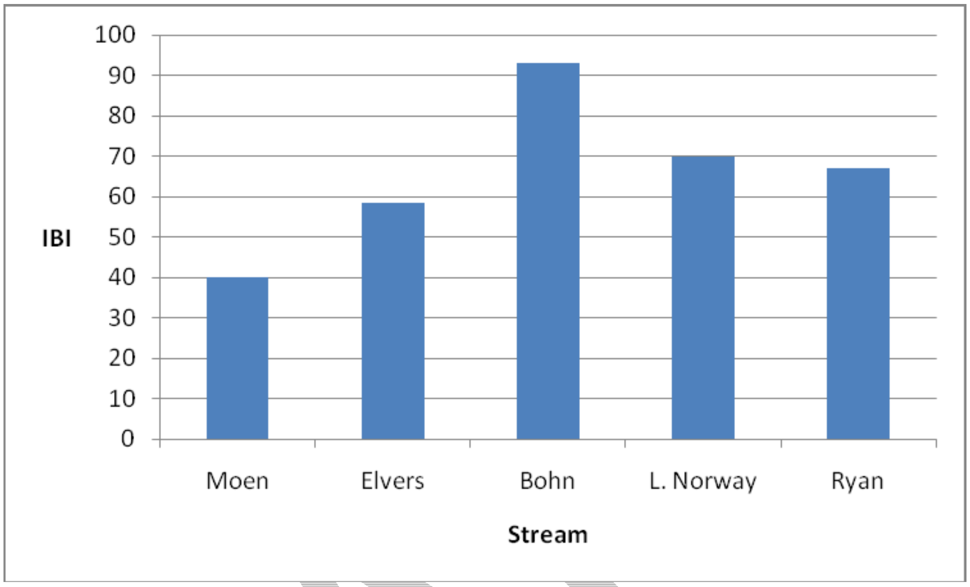
Little Norway Creek

Little Norway Creek is a small tributary to Bohn Creek and arises in Section 4 of Blue Mounds Township. The creek is very steep 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 habitat with a coldwater IBI score of 70.

Ryan Creek

Ryan Creek is a six mile long Class II trout fishery that is also designated ERW under Wisconsin Administrative Code NR 102. While problems in the creek have been linked to channel ditching and cattle grazing, coldwater IBI scores from WDNR electroshocking surveys (2002, 2003 and 2009) revealed good trout habitat (range 50 – 80, mean = 67, n = 6). Very good HBI scores (1.975 and 2.875) were revealed from macroinvertebrate samples collected in 2003. The stream is ranked high for polluted runoff abatement funding.

Figure 14: Comparative coldwater IBI scores from Mill and Blue Mounds Creek Watershed



Stewart Lake

The Dane County Department of Land and Water Resources 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 (Dane Co. Dept. Land and Water Resources 2006). Results indicated that excessive lake fertility continued to undermine 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 dissolved oxygen deficits. When the aquatic plants were growing in early June 2006, supersaturated dissolved oxygen levels were evident and reflected photosynthesis (Figure 15). 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.

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.

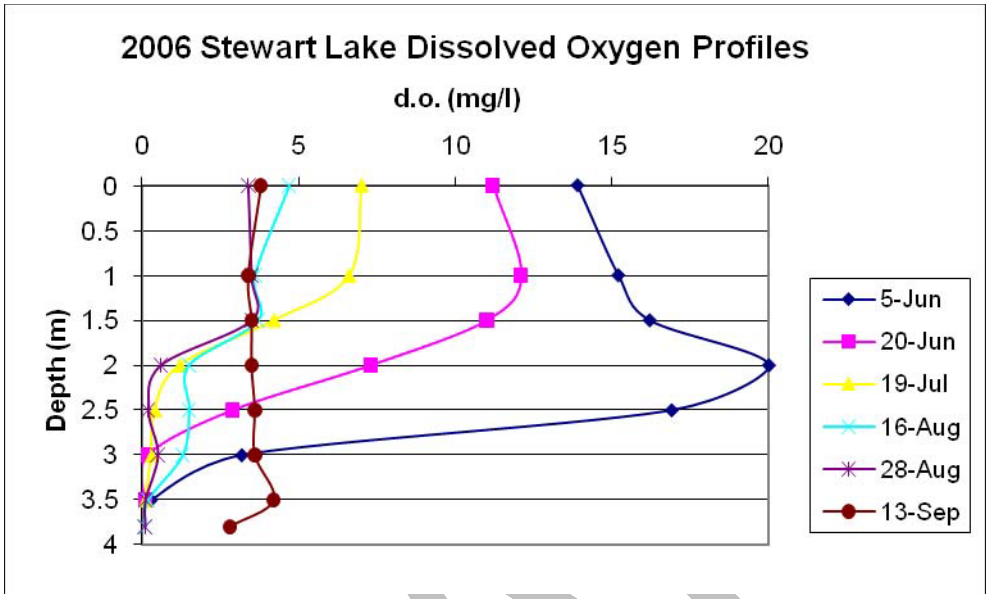
Water quality and thermal impacts of the lake were minimal below the dam. Groundwater flow to the stream rapidly increased below the dam and data loggers indicated water temperatures were typical of Driftless Area trout streams. The aquatic insect community reflected a healthy stream and fish populations 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 (Dane County Dept. of Land and Water Resources 2006).

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 Dept. of Land and Water Resources 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.

Table 7: Fish and Aquatic Life Designations

Waterbody	2000 Impervious Cover	Planned Impervious Cover	Use	Use Potential	Codified Use
Bohn Creek	6.51%	6.51%	Cold	Cold	ERW
Elvers Creek (upper)	7.61%	8.84%	Cold	Class II	ERW
Elvers Creek	4.51%	4.72%	Cold	Class I	ERW
L. Norway Cr.	4.46%	4.46%	Cold		
Moen Creek	8.08%	9.39%	Cold		
Ryan Creek	3.75%	3.81%	Cold		ERW

Figure 15: 2006 dissolved oxygen profiles in Stewart Lake



Roxbury Creek Watershed

The Dane County portion of the Roxbury Creek Watershed encompasses 38,199 acres with agriculture the dominant land use. The principle water quality problems within this watershed are polluted runoff and channel ditching. Of concern to lake property owners 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. Table 7 displays the watershed characteristics.

Table 7: Roxbury Creek Watershed

Resource Characteristics	In Acres
Hydric soils	7,197
Wetlands	3,717
Agriculture	18,816
Commercial	16

Institutional/Governmental	12
Industrial	164
Open Water	1,729
Vacant Land or Under Construction	4,259
Outdoor Recreation	339
Residential	842
Transportation, utilities etc.	1,090
Woodland	10,929
Total Watershed Area	45,553
Dane County Portion	38,199

Dane County State of the Waters Report

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 (DCRPC 1992). The upper portion of Dunlap Creek is managed as a Class II trout stream and is designated ERW under Wisconsin Administrative Code NR 102. It was the focus of a small-scale priority watershed project in 1991 with BMPs designed to reduce gulley erosion. Between 1992 and 2003, coldwater IBI scores from electroshocking surveys in the upper reaches of Dunlap Creek ranged from 20 to 30 (mean = 24, n = 10) and revealed poor trout habitat. These results reflect sedimentation from cultivated fields and grazing (Dane County State of the Waters Report 2008).

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 (Marshall and Jopke

2010). 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 arises in Section 4 of Mazomanie Township and flows 3.5 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 (Unmuth, personal communication).

Roxbury Creek (Blums Creek)

Roxbury Creek arises 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 current stream classification is Limited Forage Fish from the headwaters downstream to Section 17. Downstream from that location the stream is classified Warm Water Forage Fish with a moderately diverse 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 (Unmuth, personal communication).

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 Lusier 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 (Marshall et al. 1996) 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 (DCRPC 1979). 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 (DCRPC 1979). 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% 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 mesotrophic to moderate eutrophic condition. The long term water quality decline in the lake had been linked to watershed nutrient sources (Marshall et al. 1996). 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 (Smith and Barko 1990). 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 (Lillie 1996). 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 (Madsen et al. 1991). With the exception of coontail, the remaining native macrophytes occupied near-shore areas (Lillie 1996). 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 (Lillie 2000, Creed 1998). Native weevils can reduce the viability of EWM by boring into the stems (Mazzei et al. 1999). 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 (Unmuth et al. 2000). 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 (Engel 1987, Savino et al. 1992). Local efforts to develop new methods for improving habitat within dense EWM beds began in 1989 (Marshall 1990). 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 (Unmuth et al. 1999, Unmuth et al 1998, Olson et al. 1998, Trebitz et al 1997). 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 (Krohelski et al. 2002) was likely a third factor contributing to redistribution of native plants. As 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 (FLOW 2009). WDNR is currently monitoring the water quality 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 (Becker 1983). The banded killifish is classified as State Special Concern and the other three species are classified as environmentally sensitive to degraded habitat (Lyons 1992). 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 16a, 16b and 16c display recent Trophic State Index (TSI) values and LTER data for total phosphorus, chlorophyll and secchi. The highly variable phosphorus levels and TSI data in general reflect complex factors including lake morphology (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; a requirement of NR 109.04 (Marshall 2007). The recommendations listed in that plan include:

6. 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.

7. 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.
8. 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.
9. 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 contributing to high EWM growth in the lake. Potential sources of polluted runoff should be re-evaluated given reductions linked to surrounding park land acquisitions.)
10. 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 16a: Recent surface total phosphorus trends in Fish Lake (TSI $\geq$ 50 = eutrophic). LTER data

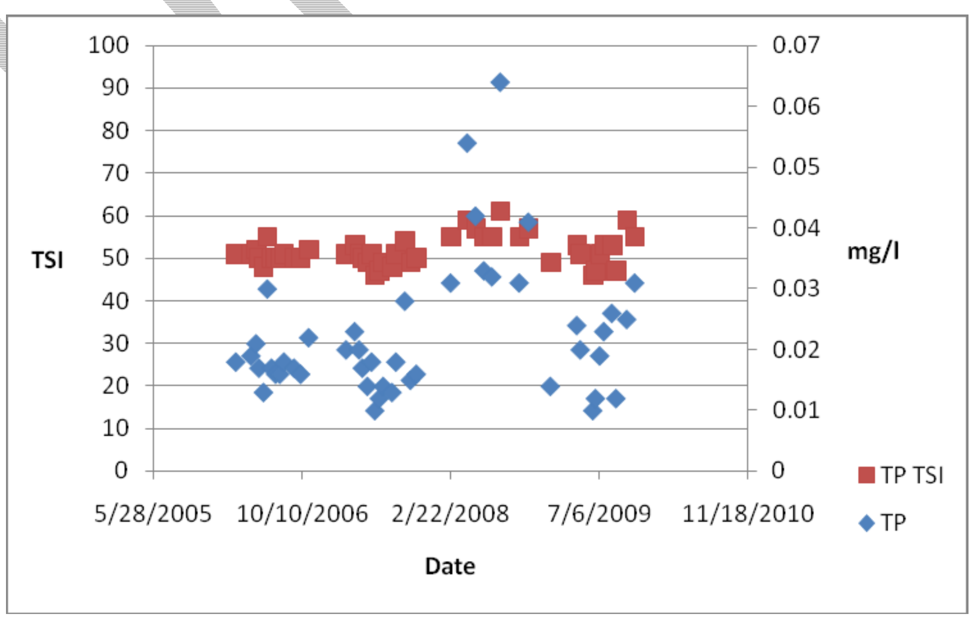


Figure 16b: Recent surface chlorophyll a trends in Fish Lake (TSI ≥ 50 = eutrophic) LTER data

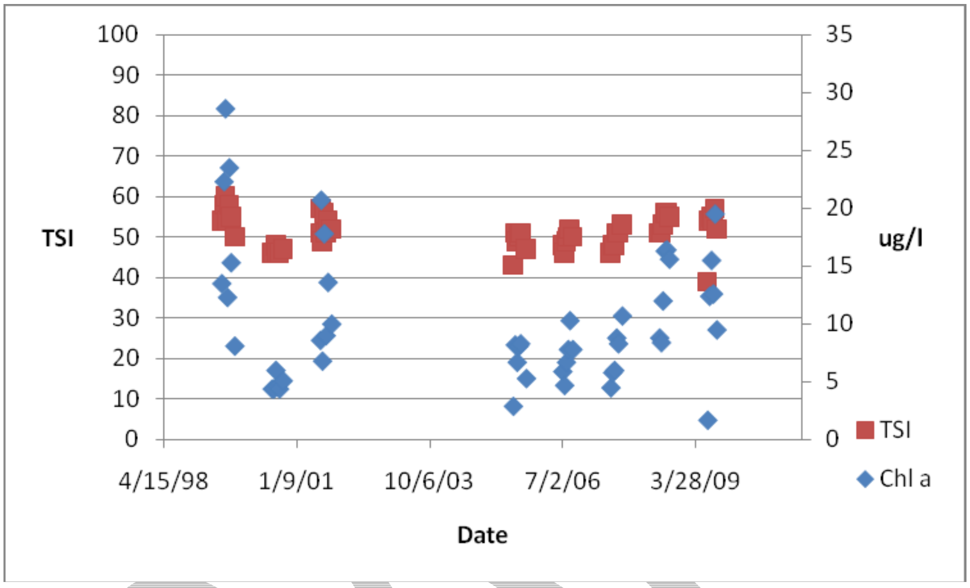
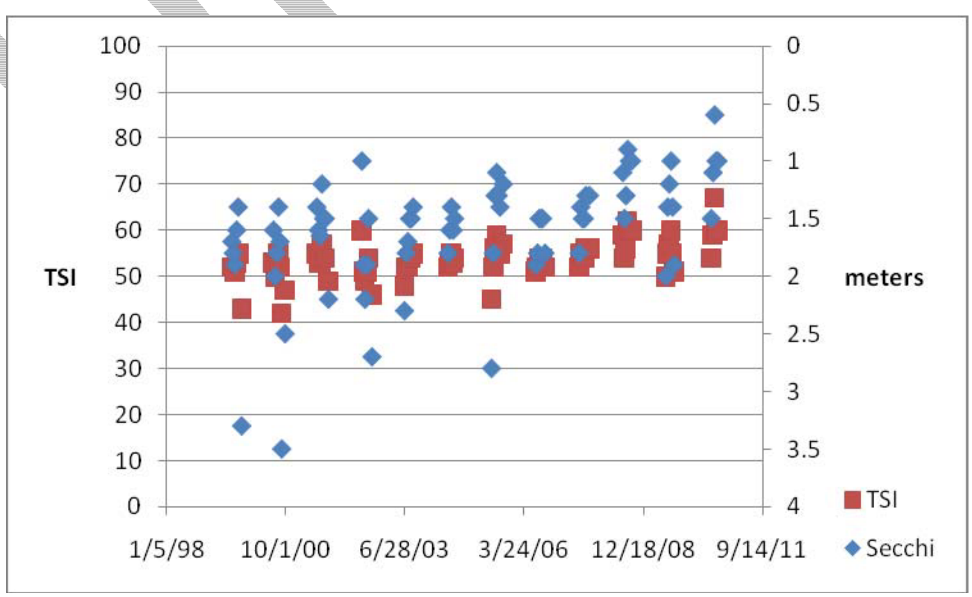


Figure 16c: Recent secchi measurements in Fish Lake (TSI ≥ 50 = eutrophic). LTER data



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). 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 (Krohelski et al. 2002). 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 (DCRPC 1979). 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 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*) (DCRPC 1979). 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 (DCRPC 1979). 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 (Unmuth and Larson 1999). Cyanobacteria 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; a requirement under Wisconsin Administrative Code NR 109.24 (Marshall 2007). The surveys demonstrated that Eurasian watermilfoil was a minor component in an aquatic plant community already limited by heavy Cyanobacteria (bluegreen 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 bluegreen 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.

Table 8: Fish and Aquatic Life Designations

Waterbody	2000 Impervious Cover	Planned Impervious Cover	Use	Use Potential	Codified Use
Dunlap Creek	3.43%	3.48%	Cold		ERW
Marsh Creek	5.42%	5.42%	wwff		
Roxbury Creek	4.26%	4.69%	lff/wwff		

Spring Creek *	4.33%	4.56%	Cold		ERW

*Lake Wisconsin Watershed

Lake Wisconsin Watershed

Dane County captures a small portion (14,244 acres) of the Lake Wisconsin Watershed that also occurs in Columbia and Sauk Counties. While Lake Wisconsin is the dominant feature of the watershed and falls outside of Dane County, it is a factor that affects the water quality of the Dane County portion of the Wisconsin River. Development is another issue of water quality concern since rapid growth rates have occurred in the Village of Dane and Lodi (Dane County State of the Waters Report 2008). Table 9 contains more detailed watershed characteristics.

Table 9: Lake Wisconsin Watershed

Resource Characteristics	In Acres
Hydric soils	876
Wetlands	698
Agriculture	9,541
Commercial	6
Institutional/Governmental	11
Industrial	23
Open Water	41
Vacant Land or Under Construction	1,118

Outdoor Recreation	9
Residential	321
Transportation, utilities etc.	461
Woodland	2,712
Total Watershed Area	137,695
Dane County Portion	14,244

Dane County State of the Waters Report

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 ERW under Wisconsin Administrative Code NR 102. In Dane County, Spring Creek flows through Lodi Marsh, a State Natural Area. WDNR describes the Natural Area as: a large wetland complex with numerous springs and spring runs, southern sedge meadow, and cat-tail 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 good trout habitat. 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.

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Table ____. Streams of the Wisconsin River Basin

Stream Name	Length	Existing Use	Potential Use	Supporting Potential Use	Fish & Aquatic Life Condition	303(d) Status	Impairment Source	Impairment Impact	F-IBI/HBI (No.)
Black Earth Creek	0-11.1	WWSF	WWSF	Partially	Unknown	N	FieldErosion, BarnYds, AgNPS,MuniPtSource, HydroModification	Habitat, Sedimentation TotalP	
	11.1-16.8	Cold II	Cold II	Partially	Fair-Poor		FieldErosion, BarnYds, AgNPS,MuniPtSource, HydroModification	Habitat, Sedimentation TotalP, TotSusSolids	20(2)[#]/5.02(3)
	16.8-19.4	Cold II ERW	Cold II ERW	Partially	Fair		FieldErosion, BarnYds, AgNPS,MuniPtSource	Habitat, Sedimentation TotalP, TotSusSolids	44(10)[#]/4.81(19)
	19.4-24	Cold I ORW	Cold I ORW	Partially	Fair		UrbNPS, AgNPS	Habitat, Sedimentation	47.5(6)[#]/4.71(27)
	24-27.1	LFF ORW	LFF(?) ORW	Partially	Poor		UrNPS, AgNPS,HydroModification	Habitat, Sedimentation, TotSusSolids	--/--
Bohn Creek	0-2	Cold II	Cold II	Partially	Unknown	N	AgNPS	Sedimentation, Habitat	93.3(3)[#]/--
	2-3.5	Cold II	Cold II						
Brewery Creek	6.1	WWFF	Cold	Not	Poor	N	AgNPS, UrbNPS	Sedimentation, Habitat	25(2)[#]/4.33(4)
Dunlap Creek	0-6.1	LFF ERW	WWSF(?) ERW	Unknown	Poor	N	HydroModification, AgNPS	Habitat, Sedimentation	24(10)[#]/4.27(2)
	6.1-10	Cold II ERW	COLD II ERW	Partially	Poor		Field/gully erosion; AgNPS	Sedimentation, Habitat	
East Branch Blue Mounds Creek	0-1.2	Cold II	Cold II	Partially	Poor	N	AgNPS	Sedimentation, Habitat	**25(2)[#]/---**
	1.2-5.1	Cold III	Cold II	Not					
Elvers Creek	0-4	Cold III ERW	Cold II ERW	Not	Poor	N	HydroMod., AgNPS	Sedimentation, Habitat	58.3(6)[#]/#3.8(2)
	4-10	Cold II ERW	Cold I ERW	Not	Poor-Fair		AgNPS	Sedimentation, Habitat	
Garfoot Creek	4.3	Cold II ERW	Cold II ERW	Partially	Fair	N	AgNPS	Sedimentation, Habitat	67(7)[#]/4.5(10)
Halfway Prairie Creek	11	WWFF	Cold	Not	Poor	Y	AgNPS, HydroModification	Sedimentation, Habitat	8.3(6)[#]/4.1(4)
Little Norway Creek	1.3	Cold	Cold	Unknown	Unknown	N	Unknown	Unknown	70(1)[#]/--
Marsh Creek	4	WWFF	WWFF	Partially	Poor	N	HydroModification, AgNPS	Sedimentation, Habitat	25(1)[##]/5.33
Roxbury Creek	0-4	LFF	LFF	Partially	Poor	N	AgNPS, HydroModification	Sedimentation, Habitat	45(2)[###]/--
	4-8	WWFF	WWFF						
Ryan Creek	6.4	Cold II ERW	Cold II ERW	Partially	Fair-poor	N	AgNPS, HydroModification	Sedimentation, Habitat	67(6)[#]/2.65(3)
Spring (Lodi) Creek	8.3-11.9 (Dane County)	Cold II ERW	Cold II ERW	Fully	Good	N	AgNPS	Sedimentation, Habitat	52.5(8)[#]/--

Vermont Creek	0-3.5	Cold III	Cold II	Not	Poor	Y	HydroModification, AgNPS	Sedimentation, Habitat	27(12)#/5.0(6)
	3.5-9.6	Cold II	Cold II	Partially		N	AgNPS, HydroModification		
Wendt Creek (Spring BrooK)	0-3.6	LFF	WWFF	Not	Poor	Y	AgNPS, HydroModification	Sedimentation, Habitat	14.3(7)#/4.62(5)
	3.6-8.3	LFF	Cold III	Not					

#= Cold IBI

##=Warm Water HBI

###=Intermittent IBI

Future Issues

Climate Change and Surface Waters

<u>Population Growth</u>. Dane County is one of the fastest growing counties in Wisconsin. The Wisconsin Department of Administration projects the county's population will grow to about 650,000 by the year 2035, an increase of over 50% from the year 2000 population of 426,526[278]. While the City of Madison will still be the largest municipality in the county, approximately 55% of the county's 2035 population will live outside of Madison.

The rapid projected population growth for Dane County will put increased environmental stress on the terrestrial and aquatic natural resources of the county. More farmland and open land will be converted to residential, commercial and industrial uses. The result of the population increase and land use alteration means more impervious surfaces and less infiltration of stormwater and meltwater into groundwater and increased municipal groundwater withdrawal. The increased impervious surfaces, coupled with increased annual precipitation and more intense rain events, will result in higher and more frequent peak or flood flows. Decreased rainwater infiltration may result in declining stream baseflows necessary in support existing aquatic life, particularly in cold or cool water headwater streams.

<u>Climate Change and Dane County Water Resources</u>. 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 teat in the atmosphere. This results in global warming. The Wisconsin Initiative on Climate Change Impacts (WICCI)[279] 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

[278] Data from Wisconsin Department of Administration's Demographic Services Wisconsin Population & Household Projections: 2000-2035 website
http://www.doa.state.wi.us/subcategory.asp?linksubcatid=105&linkcatid=11&linkid=64&locid=9

[279] See the WICCI website for more information on the effects of climate change on Wisconsin.
http://www.wicci.wisc.edu/

the last 50 years while the average fall-winter-spring air temperature has increased[280]. A trend of more intense precipitation events, the one-inch, two-inch and three-inch storms over this time period, 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[281]. 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…"[282]. Lyons et.al. [283] 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 et.al. study suggest that small increases in summer air and water temperature will have major effects on the distribution of fish in Wisconsin streams.

Infiltration of precipitation to groundwater will decrease due to increased impervious surfaces, although the potential decrease in infiltration may be offset in areas of the county with more permeable soils. Decreased infiltration renewing or maintaining groundwater, coupled with increased municipal groundwater withdrawal, may result in reducing stream baseflow which in turn supports a stream's aquatic ecosystem. A recent study by the University of Wisconsin-Extension and the Wisconsin Geological and Natural History Survey provided an updated estimate of groundwater recharge in Dane County. The study's soil-water balance (SWB) model found that recharge rates varied from less than 7 inches per year to almost 14 inches per year across the county. The model estimated the highest recharge rates occur in the unglaciated western and southwestern parts of the county where there are thin soils with low storage capacity.

Several studies have been done looking at municipal groundwater withdrawal in Dane County. The Dane County Regional Hydrologic Study predicted year 2030 stream baseflow reductions of between 3% (Spring Creek-Lodi) and 100% (E. Branch Starkweather at STH 30 and Koshkonong Creek at Bailey Road) from pre-development conditions for several Dane County streams[284]. A study of the Frederick Springs recharge area concluded the "effects of urbanization may reduce ground-water recharge and adversely affect down-gradient features

[280] Magnuson, John J., 2009, *The Potential Influence of Climate Change on Inland Waters, & Fish and Fisheries Ecology*, Minnesota Waters Lakes and Rivers Conference.
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[282] Pomplum, Steve, Richard Lathrop, Alison Coulson and Elizabeth Katt-Reinders, 2011, *Managing our future: Getting ahead of a changing climate*, Wisconsin Natural Resources Magazine.
[283] Lyons, J. J.S. Stewart, M. Mitro, 2010, *Predicted effects of climate warming on the distribution of 50 stream fishes in Wisconsin*, Journal of Fish Biology, Vol.77, Issue 8.
[284] Dane County Regional Planning Commission, 2004, *The 2004 Modeling and Management Program: Dane County Regional Hydrologic Study*.

such as Frederick Springs"[285]. Municipal groundwater pumping has lowered the groundwater level in the Madison area by more than 60 feet in some areas. The Madison lakes and area wetlands once were discharge areas for groundwater. Now they lose water to the groundwater system due to pumping and water diversion[286]. The lower water levels in the shallow groundwater aquifer have led to a decline in the flow of several local springs[287].

Strategies to Protect Surface Waters in Urban and Urbanizing Areas

Managing stream flow, particularly increases and/or decreases in base flows and maximum flows, is very important in maintaining healthy stream ecosystems. Increases in maximum flows above an established background level due to major runoff events can result in several deleterious effects. These effects include pollutant loading, bottom scouring or increased sedimentation, loss of habitat for aquatic communities and bank erosion. Carlisle and others[288] determined that diminished base flow magnitudes were the primary predictors of biological integrity for fish and macroinvertebrate communities in streams in urbanizing areas.

Historically, urban stormwater management meant getting the stormwater out of the urban area as fast as possible. Stormwater management has evolved from reactive measures to address a problem to trying to proactively manage runoff and its associated pollutants to protect local water resources and aquatic systems. Identification of which streams are at greatest risk, determining what stormwater best management practices should be implemented and where in a watershed are important issues.

Several studies have linked percent of impervious surface or cover (IC) to the ecological health of streams. The impervious cover model (ICM) put forward by Tom Schueler of the Center for Watershed Protection in 1994 correlated the percent of impervious cover in a small headwaters watershed (approximately 2 to 20 square miles) with stream quality. The ICM general predictions were that streams with less than 10% impervious cover (IC) functioned as sensitive streams, able to support their hydrologic function and support good to excellent aquatic diversity. Streams with 10 to 25 % sub-watershed IC were impacted streams with declining stream health. Streams between 25-60% IC were so degraded so as to no longer able to support (nonsupporting) hydrology, channel stability, habitat, water quality or biological diversity pre-development uses. Streams with IC exceeding 60% functioned merely as stormwater conveyances[289]. The ICM can

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[285] Hunt, R.J. and J.J. Steuer, 2000, *Simulation of the Recharge Area for Frederick Springs, Dane County, Wisconsin*, U.S. Geological Survey, Water-Resources Investigation Report 00-4172.
[286] Hunt, Randall J. Kenneth R. Bradbury and James Krohelski, 2001, *The Effects of Large-Scale Pumping and Diversion on the Water Resources of Dane County, Wisconsin*, U.S. Geological Survey, Fact Sheet FS-127-01.
[287] Lathrop, Richard, Kenneth Bradbury, Bruce Halverson, Kenneth Potter and Davis Taylor, 2005,*Responses to Urbanization: Groundwater, Stream Flow and Lake Responses to Urbanization in the Yahara Lakes Basin,* LakeLine, North American Lake Management Society.
[288] Carlisle, Daren M., David M Wolock, and Michael R. Meador, 2010, *Alteration of stream magnitudes and potential ecological consequences: a multiregional approach*, Frontiers in Ecology and the Environment
[289] Schueler, Thomas R., Lisa Fraley-McNeal and Karen Cappiella, 2009, *Is impervious cover still Important? Review of recent research*, Journal of Hydrologic Engineering, Vol.14, No.4.

be thought of as a relatively easy means of establishing a baseline for subsequent efforts to protect or maintain existing stream quality in urbanizing stream sub-watersheds.

Schueler and others analyzed 35 recent peer-reviewed papers pertaining to the ICM. Nearly 69% confirmed or reinforced use of the ICM as a robust indicator of stream quality (Schueler, et. al. 2009). The analysis pointed out areas where the ICM could be improved. Schuler described a reformulated ICM intended to predict stream quality over a range of IC rather predicting the precise score.

Wang et.al. (2001) used models to predict maximum number of fish species, IBI scores and base flow for a given level of connected imperviousness. They found that all variables could have high values (good environmental quality) at less than 8% imperviousness. The variables were always low (negatively affected) if connected imperviousness levels were greater than 12%. Levels of connected imperviousness between 8-12% were a threshold region where minor changes in urbanization could result in major changes in stream physical and ecological conditions[290].

Wang et.al (2003) did a similar study looking at urbanization effects on trout streams in Wisconsin using maximum possible coldwater IBI scores, abundance of trout, and percentage of pollution intolerant fish. All three variables could have high values at a watershed connected imperviousness level less than 6%, while at connected imperviousness greater than 11%. The study indicates that low levels of urban development can damage coldwater stream systems[291].

The U.S. Geological Survey's National Water-Quality Assessment program (NAWQWA) generated several papers on the impacts of urbanization on surface waters. Some examples are:

- Richards and others[292] noted that the fish Index of Biotic Integrity was a reliable indicator of fish assemblage responses to urbanization.

- Cuffney and others found that invertebrate assemblages begin to change at very low levels of urbanization. Based on their findings limiting impervious surfaces to a maximum of 5-10% of total watershed cover would not protect invertebrate assemblages[293].

[290] Wang, Lizhu, John Lyons, Paul Kanehl and Roger Bannerman, 2001, *Impacts of Urbanization on Stream Habitat and Fish Across Multiple Spacial Scales*, Environmental Management, Vol. 28, No.2.
[291] Wang, Lizhu, John Lyons, and Paul Kanehl, *Impacts of Urban Land Cover on Trout Streams in Wisconsin and Minnesota*, Transactions of the American Fisheries Society, Vol. 132.
[292] Richards, Kevin D. Barbara C. Scudder, Faith A Fitzpatrick, Jeffery J. Steuer, Amanda H. Ball, Marie C. Peppler, Jana S. Stewart and Mitchell A. Harris, 2006, *Effects of urbanization on stream ecosystems along an agriculture-to-urban land-use gradient, Milwaukee to Green Bay, Wisconsin, 2003-2004*, U.S. Geological Survey, Scientific Investigations Report 2006-5101-E.
[293] Cuffney, Thomas F., Robin A. Brightbill, Jason T. May and Ian R. Waite, 2010, *Responses of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas*, Ecological Applications, Vol.20, No.5, Ecological Society of America.

- Harris et. al. noted that concentrations of chlorides and sodium in water and levels of several heavy metals in sediment increased with urbanization, while indices of benthic algal, macroinvertebrate, and fish biological communities declined as urban cover increased[294]

- Fitzpatrick and Peppler note that it is very difficult to predict urbanization effects on stream habitat characteristics and geomorphic responses based only on watershed derived land cover and natural features. The relationships between watershed-scale urbanization indicators and stream habitat alterations depends on a number of factors[295].

- Given the complexities of urban landscapes, caution is warranted when generalizing about biological responses to urbanization[296].

Eco-Hydrology and ELOHA

All the papers and research looking at the effects of impervious cover and the effects of urbanization on surface water ecosystems point to controlling stream hydrology in urbanizing areas as being the key factor for protecting aquatic resources and stream water quality. This approach is called *ecohydrology*; the relationship of hydrologic metrics to changes in algal, invertebrate and fish communities due to human impacts. It is also referred to as the Ecological Limits of Hydrologic Alteration (ELOHA).

A stream's flow regime is a primary determinant of the structure and function of aquatic and riparian ecosystems for streams and rivers. Much evidence exists that modification of stream flow induces ecological alteration[297]. Both ecological theory and abundant evidence of ecological degradation in flow-altered rivers and streams support the need for environmental flow management. The ecological damage to rivers and streams has already largely been done by water *quantity* impacts by the time water quality impacts become evident. Strategies that focus on reducing overland runoff also reduce pollutant loads since flow is a principle aspect of pollutant concentrations and loading. Environmental factors other than stream flow have been recognized. Flow management is needed to ensure that existing ecological conditions do not decline any further in order to conserve and restore freshwater ecosystems.

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[294] Harris, Mitchell A., Barbara C. Scudder, Faith A. Fitzpatrick, and Terri L. Arnold, 2005, *Physical, Chemical and Biological Responses to Urbanization in the Fox and Des Plaines River Basins of Northeastern Illinois and Southeastern Wisconsin*, U.S. Geological Survey, Scientific Investigations Report 2005-5218.
[295] Fitzpatrick, Faith A, and Marie C. Peppler, 2010, *Relation of urbanization to stream habitat and geomorphic characteristics in nine metropolitan areas of the United States*, U.S. Geological Survey, Scientific Investigations Report 2010-5056.
[296] Brown, Larry R., M. Brian Gregory, and Jason T. May, 2009, *Relation of urbanization to stream fish assemblages and species traits in nine metropolitan areas of the United States*, Urban Ecosystems, Vol.12, No.4.
[297] For a literature review, see Poff, N. LeRoy and Julie K. H. Zimmerman, 2010, *Ecological Responses to Altered Flow Regimes: A Literature Review to Inform the Science and Management of Environmental Flows*, Freshwater Biology, Vol. 55.

The Ecological Limits of Hydrologic Alteration (ELOHA) is a new framework offering a flexible, scientifically defensible approach for broadly assessing environmental flow requirements of rivers and streams when in-depth studies cannot be performed for all rivers in a given region. The scientific basis for the ELOHA approach has been summarized by Poff et.al[298]. Practical guidelines for the application of ELOHA were developed based on many years of experience working with water resources managers on environmental flows by these authors and other researchers. ELOHA builds upon the knowledge gained from decades of stream-specific studies, and applies that knowledge to geographic areas as large as a state, province, nation, or large river basin.[299] These relationships correlate measures of ecological condition, which can be difficult to manage directly, to stream flow conditions, which can be managed through water-use strategies and policies. The ELOHA approach has been or is being used in numerous case studies in the United States and elsewhere. Water resources managers, policymakers, stakeholders, and scientists with diverse expertise are using to accelerate the integration of environmental flows into regional water resource planning and management.

Environmental flows are the amount and timing of water flows required to maintain the species, function, and resilience of freshwater ecosystems and the sustainability and quality of life aspects characteristic of communities that depend on those healthy ecosystems. ELOHA synthesizes existing hydrologic and ecological databases from many rivers and streams within a region to generate flow alteration-ecological response relationships other for rivers and streams with similar types of hydrologic regimes. Detailed site-specific data need not be obtained for each individual river. ELOHA systematically translates understanding of the ecological ramifications of human-induced stream flow alterations from rivers and streams that have been studied to those that have not, without requiring detailed site-specific information for each river. ELOHA offers a robust regional environmental flows analysis framework grounded in scientifically-defined flow-ecology linkages that are subject to empirical testing and validation. It is intended for widespread use regardless of the stage of water resource development, the historical status of environmental flow protection, and the cause of flow alteration – from modified land use, to surface and groundwater diversions, to river regulation by dams. Because of its flexible design, the ELOHA framework may be adapted across a wide range of available data and scientific capacity.

While ELOHA is a necessary new advance in environmental flow determination, it does not supplant river-specific approaches for certain rivers that require more in-depth analysis where political, socio-economic, or conservation issues are of such magnitude that only a river-specific

[298]For example see: Poff, N. LeRoy , Brian D. Richter, Angela H. Arthington, Stuart E. Bunn, Robert J . Naiman , Eloise Kendy, Mike Acreman, Colin Apse, Brian P. Bledsoe, Mary C. Freeman, James Henriksen, Robert B. Jacobson, Jonathan G. Kennan, David M. Merritt, Jay H. O'Keeffe, Julian D. Olden, Kevin Rogers, Rebecca E. Tharme and Andrew W Warner, 2010, *The Ecological Limits of Hydrologic Alteration (ELOHA): A New Framework for Developing Regional Environmental Flow Standards*, Freshwater Biology, Vol. 55.

[299] http://www.conserveonline.org/workspaces/eloha

treatment will suffice. But at a time when population increases, land-use changes, economic development, and climate change are amplifying demands for sound science to inform decision making in water management, ELOHA offers the potential to accelerate the broad-scale comprehensive management of river and stream flows necessary to support the sustainability of aquatic ecosystems, aquatic and terrestrial biodiversity, and overall environmental quality of life that Dane County residents.

Researchers in Michigan are working on an ELOHA-based stream classification system and have identified eleven stream-river classes based on hydrology, temperature, and watershed size. It was developed to assess the impacts of groundwater withdrawal on the flow regimes of nearby streams and rivers. Flow alteration-ecological response relationships are developed by associating the extent of hydrologic alteration with subsequent changes in ecological condition. Flow-ecology relationships (for example, aquatic invertebrate species richness or larval fish abundance – i.e., "fish response curves") are developed that are sensitive to existing or proposed flow alterations. These relationships can be validated with monitoring data, and translate to community values and issues of sustainability.

A water resources tool similar to what Michigan is doing may be able to be developed in Dane County. Some streams and rivers in the county (e.g. Black Earth Creek, Pheasant Branch, and the Yahara River above Lake Mendota) have received intense monitoring efforts over the past several years as part of watershed projects. Wang, Lyons, Schueler and others have shown at some point (or breakpoint) urban development, represented by some physical characteristic measure or measures of urban development, stream aquatic ecosystems begin to degrade. Steuer et.al. identified five hydrologic condition metrics (HCMs) that are strongly associated with observed biological variations due to urbanization[300]. The data sources and related research could be the starting point for an ELOHA approach for future water resources management in Dane County. However, additional hydrologic, stream morphology and aquatic communities monitoring of Dane County streams is needed to develop a good predictive model. This is particularly true for the coldwater, headwater streams of western Dane County such as Fries Feeder, Flynn Creek, Gordon Creek and Dunlap Creek.

Summary

The differing stream ecologic analyses outlined above are reactive. They identify a breakpoint, the point where the effects of urbanization alter and degrade the ecologic conditions of a stream and its aquatic communities. Different urbanization factors (e.g. percent imperviousness, road network density, etc.) are used, as are differing ecological measures and outcomes (e.g. macroinvertebrate richness or fish response curves) in these analyses. Not factored in is how much that breakpoint can be moved delaying or even preventing stream degradation by the

[300] Steuer, Jeffrey J. Krista A Stensvold and Mark B. Gregory, 2010, *Determination of biologically significant hydrologic conditions metrics in urbanizing watersheds: an empirical analysis over a range of environmental settings*, Hydrobiologica, (published online 19, July, 2010).

implementation stormwater best management practices and policies. Maximizing infiltration of stormwater and meltwater to local groundwater systems in urban areas is considered key to sustaining the ecologic health of surface waters. Little research or modeling has been done on what combinations of infiltration measures or how much infiltration in any given watershed would be needed to sustain aquatic ecosystems. More research is needed to identify and quantify what and where urban stormwater best management should be implemented. However, based on the research to date, to not aggressively continue putting land use policies into effect and stormwater BMPs, particularly infiltration BMPs, would not sustain existing aquatic ecosystems or quality of life factors that incorporate Dane County's surface waters and aquatic ecosystems.

Recommendations.

1. Initiate or expand flow, habitat, fish assemblages, and macroinvertebrate monitoring of streams most at risk for ecosystem alteration due to urbanization utilizing the Steuer hydrolic conditions metric approach. Streams to initially consider for an expanded monitoring program are the Sugar River, Black Earth Creek, Elvers-Moen Creek, Schlapbach Creek, Deer Creek, Token Creek, and the Yahara River north of STH 19.

2. Do a biennial review of monitored data looking for water quality or biotic ecosystem trends or "hot spots" and prepare a report for local decision makers. This would lead to an adaptive management approach for water resources management in the county.

3. Require zero increase of stormwater runoff for all new residential, commercial and industrial development in the county, focusing on regional and distributed infiltration practices as well as detention and retention facilities.

4. Promote installation of rain gardens in previously developed areas through the expansion of the county's rain garden program.

List of environmental indicators and metrics 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.

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 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 and Family Level Biotic Index (FBI) reflect varying tolerances of stream aquatic invertebrates to organic pollution. The water quality scale for the HBI ranges from very poor (8.51 – 10) to excellent (≤ 3.5). There are many aquatic invertebrate IBIs developed to assess the environmental condition of streams but the HBI and FBI are the most widely and commonly used metrics in Wisconsin.

Hypereutrophic: Hypereutrophic are nutrient-rich lakes characterized by frequent and severe nuisance Cyanobacteria blooms, periodic fish kills and very low transparency. The TSI range for hypereutrophic lakes is 71 – 110.

Impaired waters or 303d list: A waterbody is "impaired" if it does not support full use by humans, wildlife, 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. Intolerant or environmentally sensitive species, and often species richness, are important metrics among others 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).

Mesotrophic: Mesotrophic lakes display an intermediate level of 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.

Oligotrophic: An oligotrophic lake has very low primary production, low nutrient concentrations and display very good water quality. 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), though they may receive runoff from nonpoint sources. New 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.

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.

Lake TSI Values

Lake Name	Years	Median Summer Secchi	Summer Secchi	Median Summer Chlorophyll	Mean Summer Chlorophyll	Median TP	Mean TP	Source
Barney	2003-05		50 - 60*					LakeSat.org
Crystal 0978900	2010		65**		70			SWIMS
Fish 0985100	1999-09	54	53.8**	51	51	51	51.7	LTER
Fishers 1253600	2009				58***		68***	Dane Co.
Goose 0810200	2003-05		60 - 70*					LakeSat.org
Harriet	2003-05		60 - 70*					LakeSat.org
Indian 1249000	1992-09	54	55.9**					SWIMS
Kegonsa 0802600	1992-10	60	60**					SWIMS
Mendota 0805400	1995-09	50	50.3**	53	52.2	62	60.8	LTER
Monona 0804600	1995-09	53	52.7**	53	53.6	60	60.1	LTER
Mud (Marx) 1006500	2003-05		60 - 70*					LakeSat.org
Mud 0810700	2003-05		40 – 50*					LakeSat.org
Rice 0779500	2003-05		60 - 70*					LakeSat.org
Waubesa 0803700	1995-10					60	60.2	SWIMS
Wingra 0805000	1995-09	65	65.8**	56	56.1	56	58.6	LTER

*Satellite range, **mean, ***single value

Trophic State	Value
Oligotrophic	< 40
Mesotrophic	40 - 50
Eutrophic	50 -70
Hypereutrophic	70 - 110