Water Quality

The Clean Water Act (CWA) is the cornerstone of surface water quality protection in the United States. (The Act does not deal directly with ground water nor with water quantity issues). The statute employs a variety of regulatory and nonregulatory tools to sharply reduce direct pollutant discharges into waterways, finance municipal wastewater treatment facilities, and manage polluted runoff. These tools are employed to achieve the broader goal of restoring and maintaining the chemical, physical, and biological integrity of the nation's waters so that they can support "the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water." For many years following the passage of CWA in 1972, EPA, states, and Indian tribes focused mainly on the chemical aspects of the "integrity" goal. During the last decade, however, more attention has been given to physical and biological integrity. Also, in the early decades of the Act's implementation, efforts focused on regulating discharges from traditional "point source" facilities, such as municipal sewage plants and industrial facilities, with little attention paid to runoff from streets, construction sites, farms, and other "wet-weather" sources. Starting in the late 1980s, efforts to address polluted runoff have increased significantly. For "nonpoint" runoff, voluntary programs, including cost-sharing with landowners are the key tool. For "wet weather point sources" like urban storm sewer systems and construction sites, a regulatory approach is being employed. Evolution of CWA programs over the last decade has also included something of a shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining state water quality and other environmental goals is another hallmark of this approach.

As of May 19, 2003, Wisconsin has identified and EPA approved a listing of 604 impaired waters under section 303(d) of the clean water act. The Rock River watershed contains 50 impaired waters, this is the largest number of impaired waters reported among Wisconsin’s watersheds (after excluding atmospheric deposition related impairments).

The DNR has identified and EPA has approved 15 impaired lakes and flowages within the SE Glacial Plains Ecological Landscape, 10 of those are shallow lakes (Table 6). Lake Koshkonong is among 8 of the 10 shallow lakes impaired due to excessive sediment and phosphorus.

Table 6. Approved (2002) 303(d) Impaired lakes and impoundments within the Southeast Glacial Plains Ecological Landscape. Bolded waters are impaired due to excessive sediment and phosphorus.

Water Body Name	County	WBIC	DNR Watershed	Pollutant	Impairment	Cont. Sediment	Atmos Dep.	Physical Habitat	NPS Dom.	Point S. Dom.	NPS/PS Blend
Barstow Imp.	Waukesha	742500	FX07	sediment, phos.	DO, turbidity						x
Sinnissippi Lake	Dodge	788800	UR08	sediment	sedimentation						x
Crawfish River at Columbus Millpond	Columbia, Dodge	829700	UR02, 06	PCB	FCA	x					
Fox River (Ill), including Lake Tichigan	Waukesha, Racine, Kenosha	742500	FX	PCBs	FCA	x					
Horicon Marsh	Dodge	861200	UR12	sediment	degraded hab.						x
Lac La Belle	Waukesha	848800	UR09	pcb	FCA	x					
Lake Butte des Morts	Winnebago	139900	UF	Hg,pcb,sed,phos.	FCA, DO,eutro.	x			x		
Lake Koshkonong	Jefferson, Rock, Dane	808700	LR11	phosphorus, sediment	DO, eutro, sed, hab						x
Lake Mendota	Dane	805400	LR09	pcb	FCA						
Lake Monona	Dane	804600	LR08	Hg,pcb	FCA						
Lake Waubesa	Dane	803700	LR08	Hg	FCA						

Lake Winnebago	Winnebago	131100	UF	sediment,phos.,Hg, PCB	sed., eutro.,DO,FCA	x			x		
Lake Winneconne	Winnebago	241600	UF	sediment,phos.,Hg	sed., eutro.,DO,FCA	x	x		x		
Pine Lake	Waukesha	779200	UR09	TBD	Aq. Toxicity	x					
Poygan Lake	Winnebago	242800	UF	sediment, phos, PCB	sedimentation, DO, FCA	x			x		

***Bolded waters are shallow lakes**

Existing, Potential and Codified Uses

BOD = biochemical oxygen demand;Cold = Cold water fish community; DO = dissolved oxygen; deg. Hab. = degraded habitat; FCA = fish consumption advisory; Hg = mercury; WWSF = warmwater sport fishery; pcb or PCB = polychlorobiphenyls WWFF = warmwater forage fishery; LFF = limited forage fishery; LAL = limited aquatic life; FAL = fish and aquatic life = cold, WWSF or WWFF; Bact. = bacteria; sed = sediment; SOD = sediment oxygen demand

Eutrophication is the natural process of physical, chemical, and biological changes (“aging”) associated with nutrient, organic matter, and silt enrichment of a lake. If the natural process is accelerated by human influences, it is termed “cultural” eutrophication. Lakes are subject to a variety of physical, chemical, and biological problems that can diminish their aesthetic beauty, recreational value, water quality, and habitat suitability. Among the most common lake problems, and the conditions that often occur with eutrophication are the following.

Algal blooms – Extensive and rapid growth of planktonic (floating and suspended) algae, caused by an increased input of nutrients (primarily phosphorus, but occasionally can also be caused by nitrogen), is a common problem in lakes. Lakes normally undergo aging over timescales of centuries or thousands of years, but the process can be accelerated rapidly to only decades by human activities that cause increases in sedimentation and nutrient inflow to the lake. Accelerated eutrophication and excessive algal growth reduces water clarity, inhibits growth of other plants, and can lead to extensive oxygen depletion, accumulation of unsightly and decaying organic matter, unpleasant odors, and fish kills.

Sedimentation/turbidity – Increases in accumulation and/or resuspension of sediments can be a detriment to water quality and habitat for many aquatic species. Such events usually are caused by heavy rains that produce erosion and intense runoff, carrying heavy sediment loads into lakes. High winds, boating activity, and bottom-feeding fish, such as carp, may also resuspend bottom sediments and increase turbidity.

Oxygen depletion – Decreases in dissolved oxygen to less than 3 mg/L (milligrams per liter) in the water can be harmful or lethal to many desirable species of aquatic life. The primary mechanism of oxygen loss is consumption by high rates of respiration and organic decomposition. Ideally, such consumption is offset by oxygen inputs from the atmosphere and from photosynthesis by aquatic plants. However, in stratified lakes, the atmospheric source is cut off from the hypolimnion (deep lake layer), and oxygen concentrations in the hypolimnion may decline to zero (anoxia) until the lake mixes again. Under anoxic conditions, phosphorus may be released from the bottom sediments into the overlying water. This “internal loading” may be considerable with phosphorus-enriched sediments and prolonged anoxia. Prolonged low oxygen concentrations in the summer or under ice in the winter can lead to fish kills.

Growth of aquatic plants (macrophytes) – Normal macrophytic growth generally is beneficial for the lake ecosystem; among other benefits, the plants provide refuge for fish and other organisms. However, in some lakes, the growth of aquatic plants (“weeds”) can become excessive and create a serious nuisance for lake users, interfering with swimming, boating, and other recreational activities. Excessive macrophytes commonly are caused by increased nutrients, invasion of exotic species, or accumulation of organic sediment. The improvement of water clarity resulting from management actions designed to control algal production can provide better conditions for growth of rooted plants.

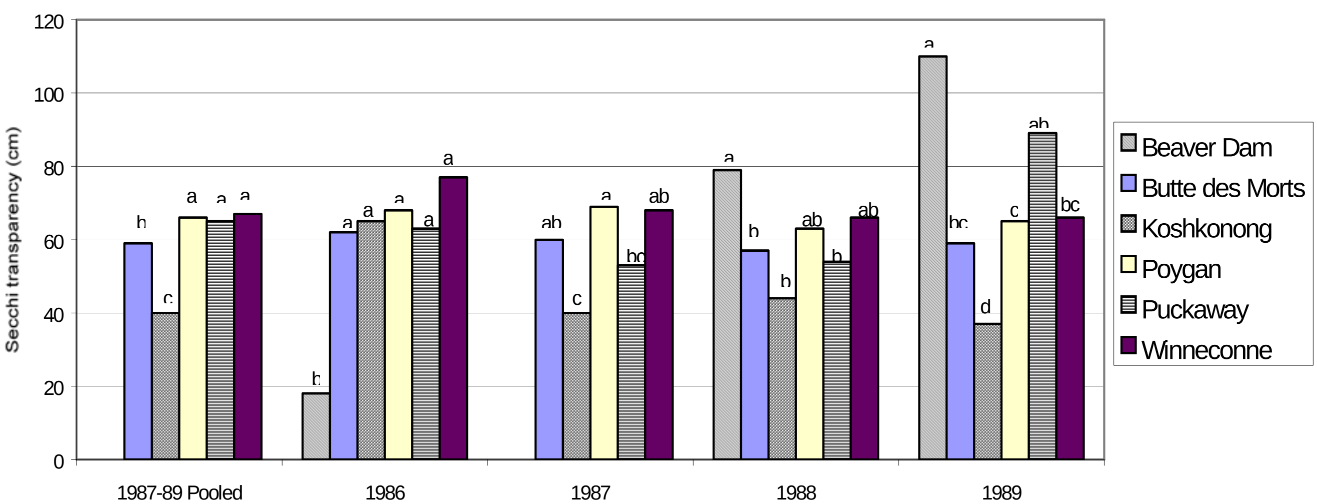
Species shifts – Populations of desirable animal and plant species might decline sharply or disappear, to be replaced by other species. Usually, the new dominant species will become a nuisance and degrade some or all desirable qualities of the lake. Species shifts can be caused by introduction of invasive species that may have little or no natural controls on their population growth, or are stimulated by changes in environmental conditions (for example, climate changes, acidification from “acid rain” or other changes in water chemistry, or physical changes.

Eutrophication diminishes water quality by promoting the excessive growth of algae, and increasing suspended organic material. When degraded, unpleasant odors and tastes can result from the excessive amounts of algae. Furthermore, microorganisms associated with eutrophication may pose health risks to consumers. Increases in water quality parameters such as chlorophyll *a*, turbidity, total suspended solids (TSS), and nutrients are symptomatic of eutrophic conditions. Concentrations of these parameters can provide insight on the extent of eutrophication and the potential impact on aquatic biota and overall water quality.

Secchi Depth- Water clarity has two main components: true color (materials *dissolved* in the water) and turbidity (materials *suspended* in the water such as algae and silt). The algae population is usually the largest and most variable component. Water clarity often indicates a lake's overall water quality, especially the amount of algae present. Algae are natural and essential, but too much of the wrong kind can cause problems. Secchi disc (Secchi disk) readings are taken using an 8-inch diameter weighted disc painted black and white. The disc is lowered over the downwind, shaded side of the boat until it just disappears from sight, then raised until it is just visible. The average of the two depths is recorded. Secchi disc values vary throughout the summer as algal populations increase and decrease. Measuring several sites may be useful in some lakes, depending upon the uniformity of the lake. Year to year changes result from weather and nutrient accumulation. Weekly or biweekly Secchi records (April-November) over a number of years provide an excellent and inexpensive way to document long-term changes in water clarity.

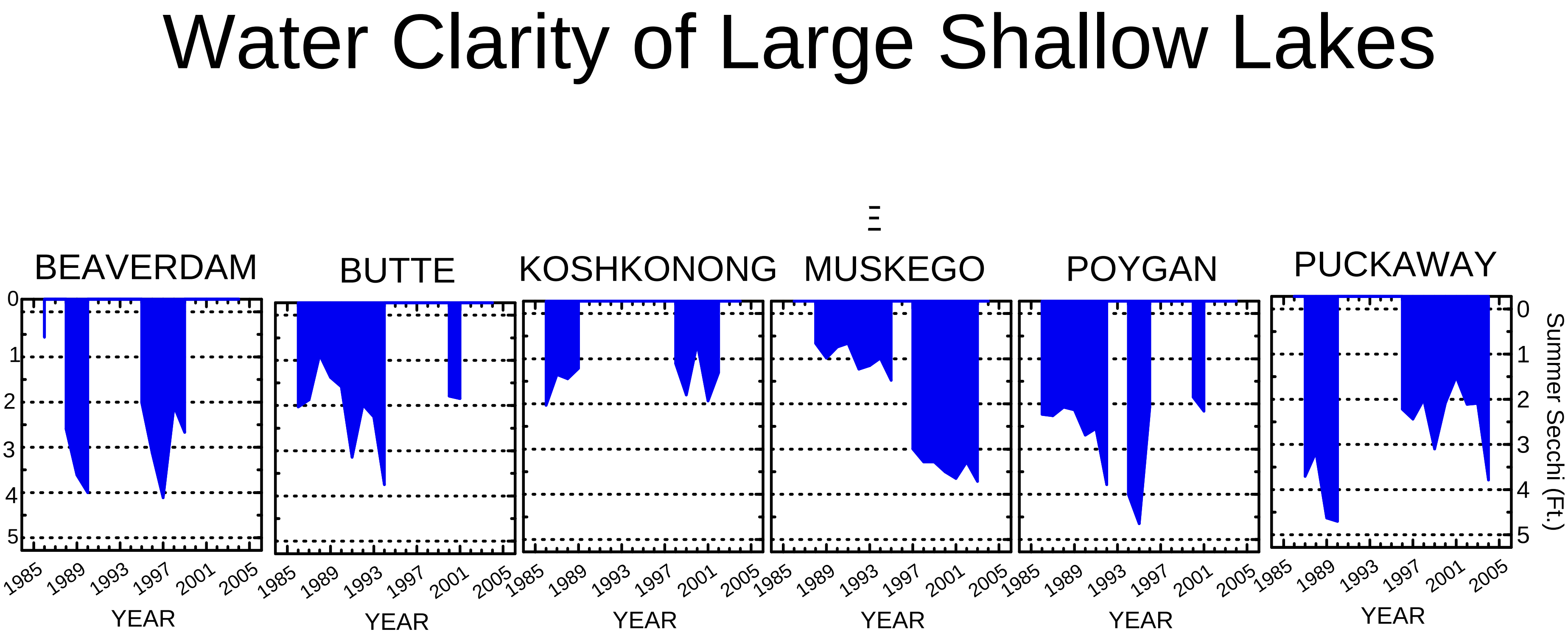
Secchi depths reported for Lake Koshkonong average 40 cm (1.3 ft.; Figure 26 and 27) and are significantly less than values reported for other large shallow lakes of Wisconsin's Southeast Glacial Plains (Figure 27).

Figure 26 *Mean Secchi transparency depth for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=87-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=27-30; for 1988-89 N=30).**



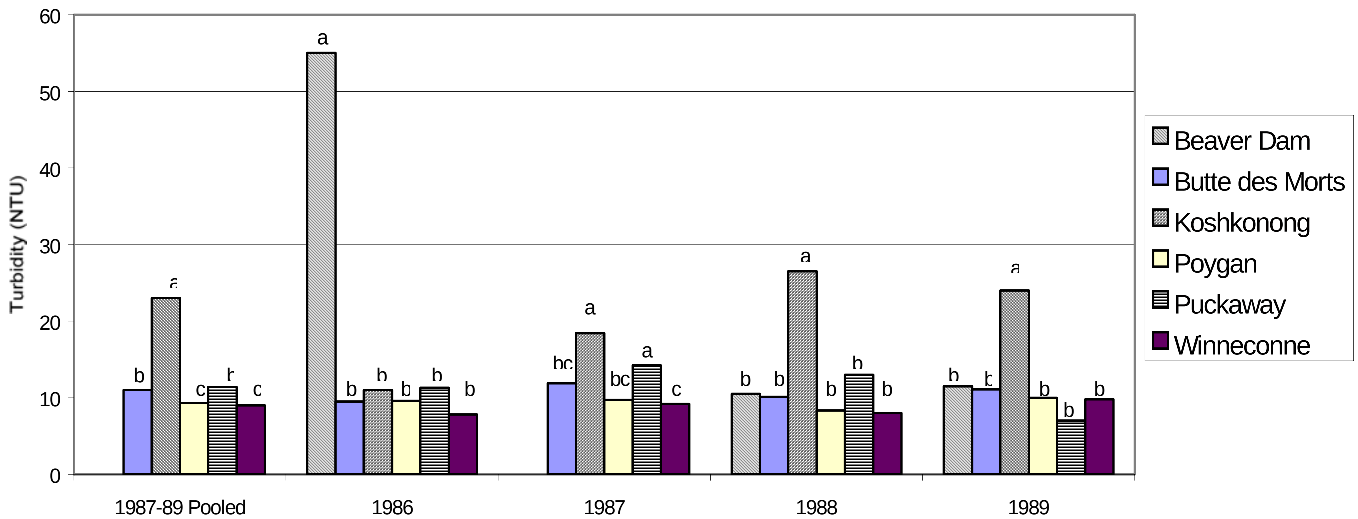
*Among lakes, means with the same letters are not different, Tukey's Studentized Range Test (*P*>0.05); 1986 excluded from overall analysis due to too many missing observations, and Beaver Dam excluded from overall and 1987 analyses due to a drawdown in 1987 for a rough fish eradication project.

Figure 27. Water clarity for six large shallow lakes as measured by secchi depth (ft) for the years 1986 - 2004. Lakes respectively shown are Beaver Dam Lake (Dodge Co.), Lake Butte Des Mortes (Winnebago Co.), Lake Koshkonong (Jefferson Co.), Big Muskego Lake (Waukesha Co.), Lake Poygan (Winnebago Co.), and Lake Puckaway (Green Lake County). Values shown represent annual mean estimates from all values reported during the months of May through September.



Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity is the result of suspended solids in the water, rather than dissolved organic compounds. Suspended particles dissipate light, which affects the depth at which plants can grow. Suspended solids are variable, ranging from clay, silt, and plankton, to industrial wastes and sewage. Lakes receiving runoff from silt or clay soils often possess high turbidities. These values vary widely with the nature of the seasonal runoff. Suspended plants and animals also produce turbidity. Many small organisms have a greater effect than a few large ones. A rough measure of turbidity can be made with a Secchi Disk, but more accurate measurements need to be taken with a turbidimeter, Turbidity is measured in **NTU**s, the abbreviation for nephelometric turbidity unit. A normal range for turbidity in river water has not been established. High turbidity water will appear to be murky or muddy. Turbidity in excess of five NTUs can be easily detected. Lake Koshkonong is significantly more turbid than other large shallow lakes of the Southeast Glacial Plains. Turbidity values for Lake Koshkonong average 23 NTU's, which is 2 fold higher than other shallow lakes (Figure 28).

Figure 28 *Mean turbidity for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=89-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=29-30; for 1988 N=29-30; for 1989 N=30).**



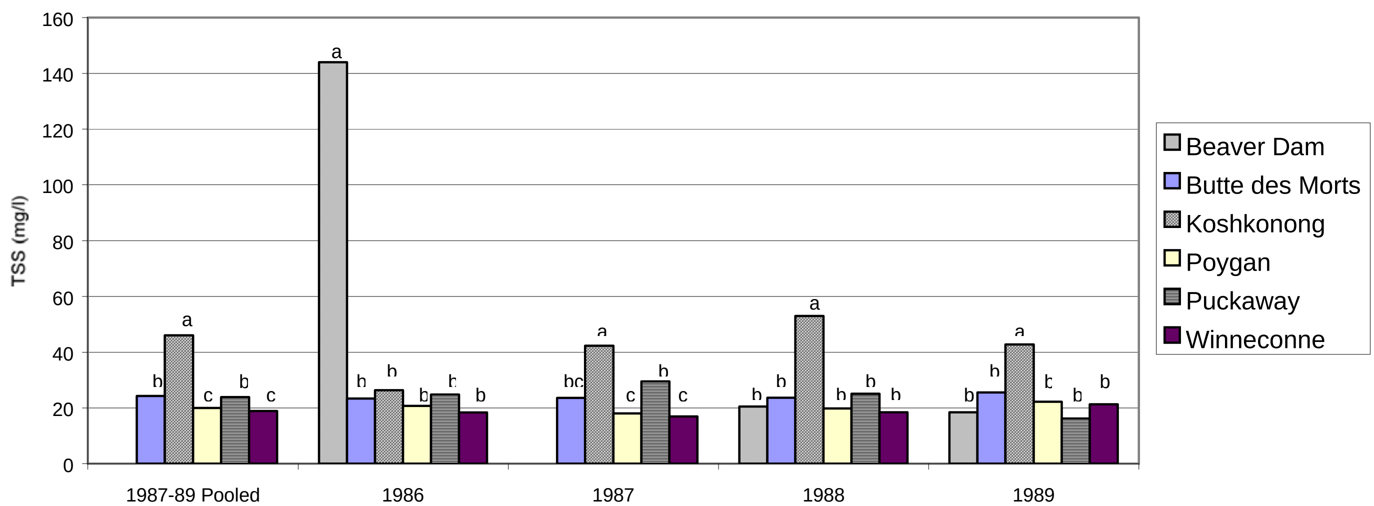
*Among lakes, means with the same letters are not different, Tukey's Studentized Range Test (*P*>0.05); 1986 excluded from overall analysis due to too many missing observations, and Beaver Dam excluded from overall and 1987 analyses due to a drawdown in 1987 for a rough fish eradication project.

Total suspended solids (TSS) consist of an inorganic fraction (ISS-silts, clays, etc.) and an organic fraction (OSS-algae, zooplankton, bacteria, and detritus) that are carried along by water as it runs off the land. The inorganic portion is usually considerably higher than the organic. Both contribute to turbidity, or cloudiness of the water. Waters with high sediment loads are very obvious because of their "muddy" appearance. This is especially evident in rivers, where the force of moving water keeps the sediment particles suspended.

The geology and vegetation of a watershed affect the amount of suspended solids. If the watershed has steep slopes and is rocky with little plant life, top soil will wash into the waterway with every rain. On the other hand, if the watershed has lots of firmly rooted vegetation, it will act as a sponge to trap water and soil and thereby eliminate most erosion. Most suspended solids come from accelerated erosion from agricultural land, logging operations (especially where clear-cutting is practiced), surface mining, and construction sites.

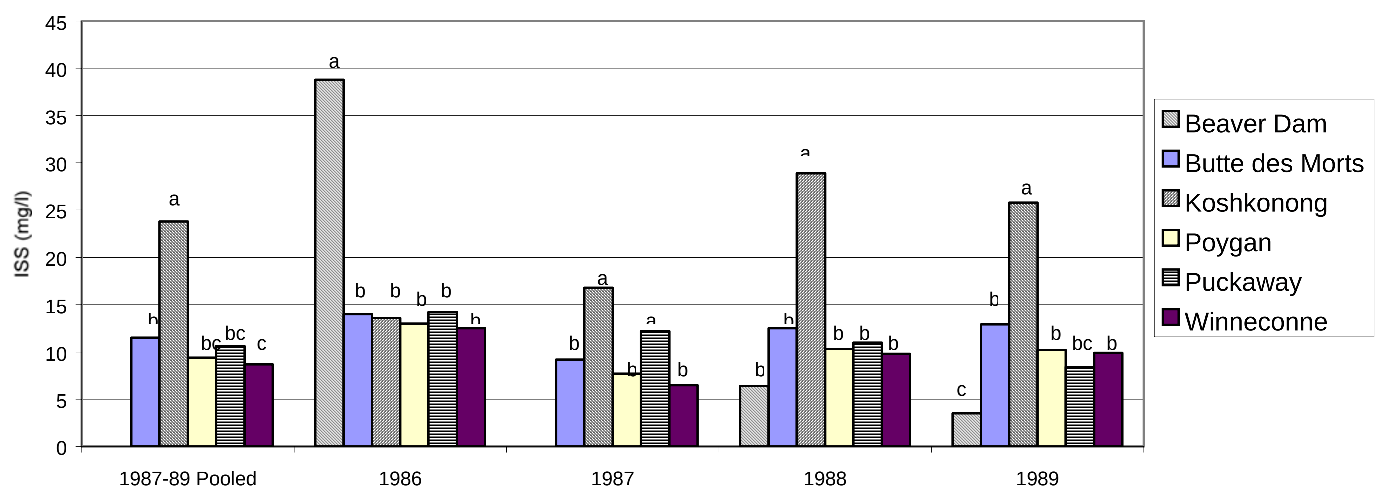
Suspended solids can clog fish gills, either killing them or reducing their growth rate. They also reduce light penetration. This reduces the ability of algae to produce food and oxygen. When the water slows down, as when it enters a reservoir, the suspended sediment settles out and drops to the bottom, a process called siltation. This causes the water to clear, but as the silt or sediment settles it may change the bottom. The silt may smother bottom-dwelling organisms, cover breeding areas, and smother eggs. Indirectly, the suspended solids affect other parameters such as temperature and dissolved oxygen. Because of the greater heat absorbency of the particulate matter, the surface water becomes warmer and this tends to stabilize the stratification (layering) in stream pools, embayments, and reservoirs. This, in turn, interferes with mixing, decreasing the dispersion of oxygen and nutrients to deeper layers. Mean total suspended solids (TSS) average 46 mg/l and are approximately two-fold higher than other large shallow lakes (Figure 29). Approximately equal fractions derived from organic and organic origins (inorganic fraction=24mg/l and organic fraction=22 mg/l) comprise Lake Koshkonong's TSS (Figs. 30 and 31).

Figure 29 *Mean total suspended solids (TSS) for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=87-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=30; for 1988 N=30; for 1989 N=27-30).**



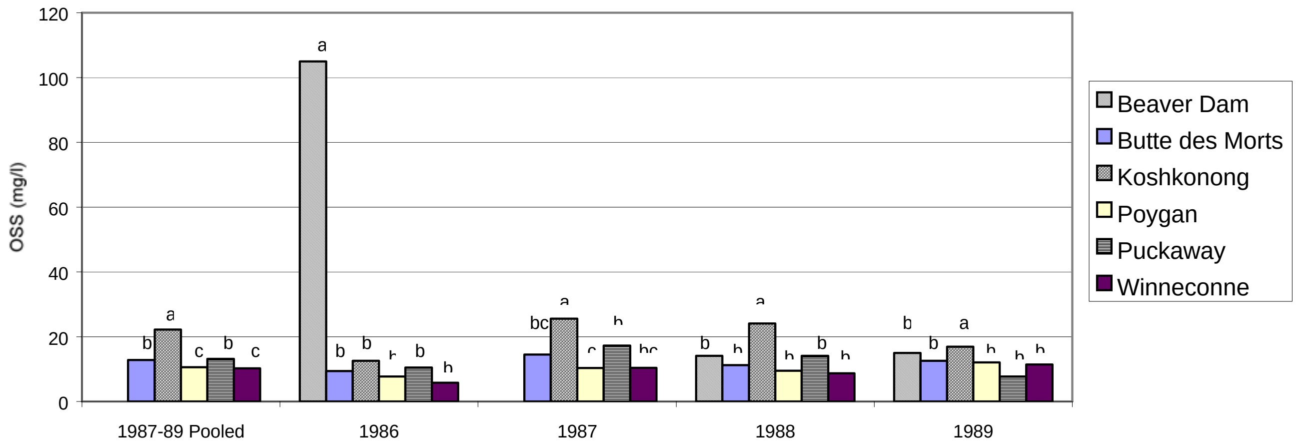
*Among lakes, means with the same letters are not different, Tukey's Studentized Range Test (*P*>0.05); 1986 excluded from overall analysis due to too many missing observations, and Beaver Dam excluded from overall and 1987 analyses due to a drawdown in 1987 for a rough fish eradication project.

Figure 30 *Mean inorganic suspended solids (ISS) for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=87-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=30; for 1988 N=30; for 1989 N=27-30).**



*Among lakes, means with the same letters are not different, Tukey's Studentized Range Test (*P*>0.05); 1986 excluded from overall analysis due to too many missing observations, and Beaver Dam excluded from overall and 1987 analyses due to a drawdown in 1987 for a rough fish eradication project.

Figure 31. *Mean organic suspended solids (OSS) for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=87-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=30; for 1988 N=30; for 1989 N=27-30).**



*Among lakes, means with the same letters are not different, Tukey's Studentized Range Test (*P*>0.05); 1986 excluded from overall analysis due to too many missing observations, and Beaver Dam excluded from overall and 1987 analyses due to a drawdown in 1987 for a rough fish eradication project.

Chorophyll A. One adverse effect of nutrient enrichment in surface water bodies is the occurrence of nuisance “algal” blooms (see example; Figure 32). Chlorophyll *a* (Chl *a*) is often used as an estimate of algal biomass, with blooms being estimated to occur when Chl *a* concentrations exceed 30-40 µg L -1. Investigators have shown that there is often a strong correlation between total phosphorus (TP) and algal biomass. Mean chlorophyll a (chla) concentrations for Lake Koshkonong average 180 ug/l and are more than 3-fold greater than other large shallow lakes (Figure 33).

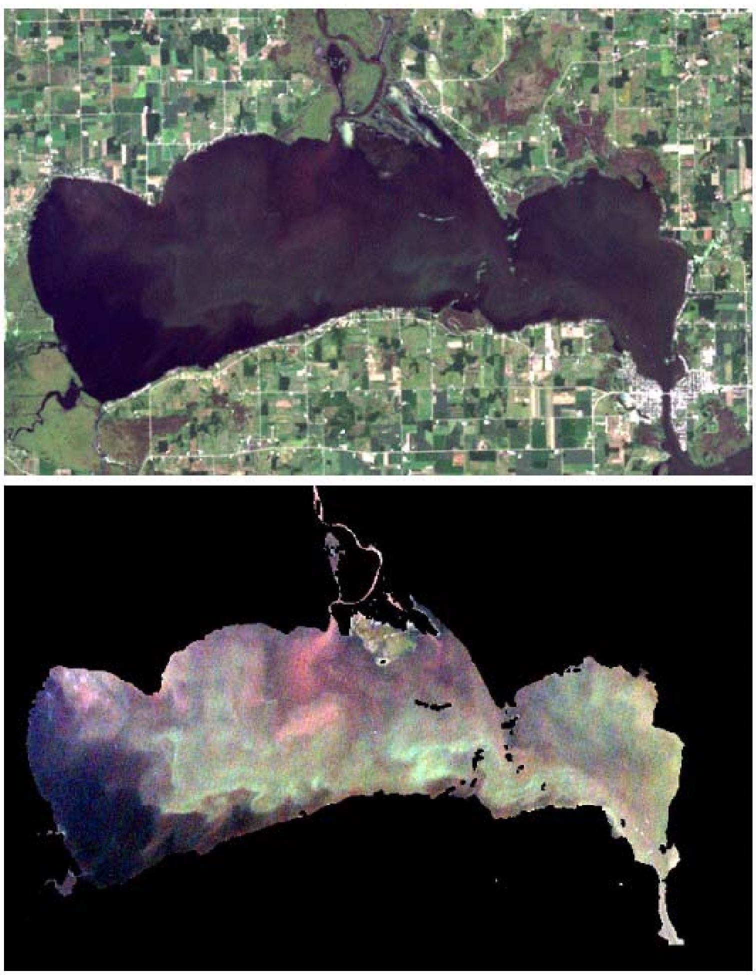
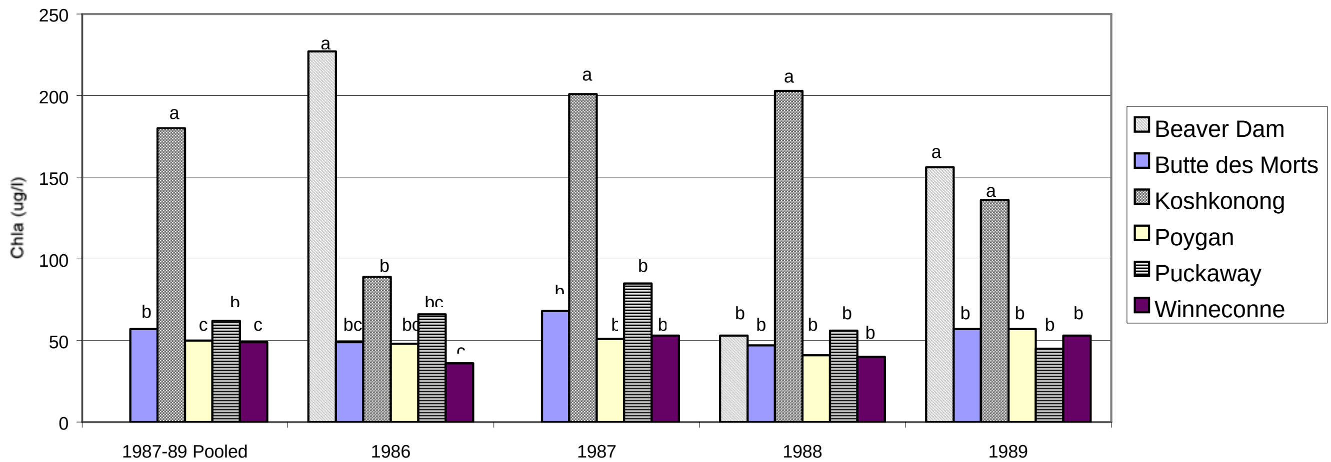


Figure 32. This Landsat-7 image, acquired on July 27, 1999, shows Lakes Poygan and Winneconne. Two versions of the satellite imagery are compared. The first, "raw," image shows the lake in the context of its surrounding landscape. Extensive wetlands can be seen at the western and northern edges of Lake Poygan. In the second image, digital image processing techniques have been used to "mask out" all land areas, and to enhance the variability within the lakes. The results clearly show even the most subtle variations in lake color, with green colors representing the effects of chlorophyll-rich algae and red-brown colors representing suspended materials stirred up by wave action or carried into the lake from sources upstream.

Figure 33 *Mean chlorophyll a (chla) concentrations for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=89-90; for 1986 N=22-27; for 1987 excluding Beaver Dam N=29-30; for 1988-89 N=30).**



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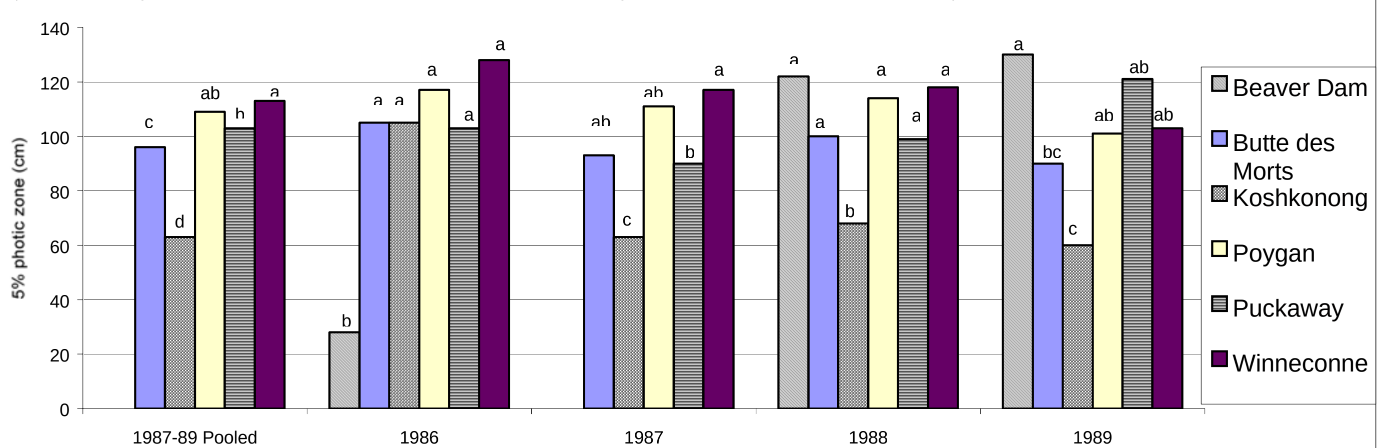
Photic Zone Depth (5%). The photic zone is the uppermost part of the water column, where the intensity of solar radiation is sufficient for net photosynthetic production to occur. Photic Zone depth is often defined as the depth where the irradiance is reduced to 1% of its value in the surface. Effective management and restoration of submerged macrophyte communities often depends on an accurate and meaningful estimate of water clarity. Most studies report water clarity as light attenuation coefficients (AC's) derived from measuring light availability at a single depth or as Secchi transparencies. A few studies use these parameters to indirectly estimate the 1% photic zone based on previously documented relationships between these parameters. Yet submerged macrophytes may require 5-10% of surface light (i.e., the 5% or 10% photic zone). Photic zone depth (5%) for Lake Koshkonong averaged 63 cm (2.1 ft.) for years 1987-1989, while lakes Butte des Morts, Puckaway, Poygan, and Winneconne, averaged 96, 103, 109, and 113 cm., respectively (Figure 34).

Figure 34 *Mean 5% photic zone depth for 3 mid-lake sampling sites in each of 6 lakes in south and east central Wisconsin, late April-late August, 1986-89 (for 1987-89 pooled excluding Beaver Dam N=87-90; for 1986 N=22-25; for 1987 excluding Beaver Dam N=27-30; for 1988-89 N=30).**



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Phosphorus Loading- One of the major factors influencing the trophic state of Lake Koshkonong is the annual nutrient load to the Lake. Of particular concern is the phosphorus, which is the limited nutrient for plant growth within the Lake. In 2000, the Rock River Watershed Partnership (RRWP) finished its report, culminating two years of modeling and monitoring of the Rock River Basin. That report predicted an average annual load of just over 1 million pounds of phosphorus to the lake. Of that load 56 % (574,725) was estimated from non-point runoff and 44% (456,434 lbs) was estimated from point source loads. Table 7 shows the total phosphorus load by basin.

Table 7. Phosphorus Load to Lake Koshkonong

Basin	Non-Point Total P (lb/yr)	Point Source Total P (lb/yr)			
	Non-Point	Point	% of Non-point Watershed load	% of point Watershed load	% of point loads
Lower Koshkonong Creek (LR11)	19,293	48,206	1.87%	4.67%	11%
Upper Koshkonong Creek (LR12)	41,940	31,412	4.07%	3.05%	7%
Bark River (LR13)	19,596	17,497	1.90%	1.70%	4%
Whitewater Creek (LR14)	10,496	14,816	1.02%	1.44%	3%
Scuppernong River (LR15)	13,166	2,905	1.28%	0.28%	1%
Middle Rock River (UR01)	21,545	81,767	2.09%	7.93%	18%
Lower Crawfish River (UR02)	27,543	63,616	2.67%	6.17%	14%
Beaver Dam River (UR03)	42,920	67,944	4.16%	6.59%	15%
Calamus Creek (UR04)	3,868	0	0.38%	0.00%	0%
Maunesha River (UR05)	54,798	8,189	5.31%	0.79%	2%
Upper Crawfish River (UR06)	35,234	848	3.42%	0.08%	0%
Johnson Creek (UR07)	6,188	3,673	0.60%	0.36%	1%
Sinissippi Lake Watershed (UR08)	66,899	45,279	6.49%	4.39%	10%
Oconomowoc River (UR09)	27,986	16,599	2.71%	1.61%	4%
Ashippun River (UR10)	28,368	1,096	2.75%	0.11%	0%
Rubicon River (UR11)	46,960	14,884	4.55%	1.44%	3%
Upper Rock River (UR12)	26,516	17,105	2.57%	1.66%	4%
East Branch Rock River (UR13)	81,410	20,598	7.90%	2.00%	5%
Total	574,725	456,434	55.74%	44.26%	100%

Implementation of NR 217 (point source phosphorus limits) and NR 151 (non-point performance standards) will have some affect on both point and non-point loads to the Lake. The RRWP study indicated that full implementation of NR 217 would reduce P loads by almost 24% basin wide. The RRWP further concluded that fully implementing NR 217 and shifting to agricultural best management practices would result in a P load reduction of about 40%. While this reduction is significant it is unlikely to have a significant affect on the water clarity of the Lake.

During non-runoff times we estimate that STP contribute about 26 MGD (40 CFS) to the base flow. It is possible that NR 217 reductions could cause significant reductions in P levels during low flow, however, it is not possible to predict improved water clarity during these low flow periods. There have been several recent winter fish kills on the Lake that are thought to be related to super saturation of oxygen. These conditions appear to be the result of photo synthesis caused by clear ice conditions and nutrient loads. While it is possible that reduced low flow P levels caused by the implementation of NR 217 could relieve this situation it is not possible to predict through conventional modeling.