Surveys of Lower Wisconsin River Floodplain Lakes
Sauk County, Wisconsin

Lakes Planning Grant Study

Sauk County Land Conservation Department

Prepared by

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Summary

As part of a Lakes Planning Grant Study, 17 sites on 14 Lower Wisconsin River floodplain lakes were sampled during the summer of 2008. Information collected during the surveys included water chemistry, water transparency, nearshore fish species, and aquatic plants. Fourteen fish species were identified in the floodplain lakes including the State Endangered starhead topminnow. The rare fish was found at 16 of the sampling sites and in all 14 floodplain lakes. While the rare fish species accounts reflect a dearth of sampling efforts in the past, additional sources of information suggest that the water quality had improved in recent years and their habitats expanded. The oxbows also supported numerous popular sport fishes include bluegill sunfish and largemouth bass. Sixty pressed aquatic plant specimens were submitted to the University of Wisconsin Madison Herbarium.

Three key factors were identified that influenced the abundance or presence of fish populations in braided channel oxbows. First, river flooding and associated alluvial groundwater depths can affect dissolved oxygen levels but are largely uncontrollable. However, river water quality has greatly improved since the 1980s with implementation of the Clean Water Act. Second, upland groundwater flow into the oxbows is very important for sustaining sufficient dissolved oxygen, particularly during periods of stress such as late winter ice cover or warm season floods. Lakes that lacked significant sources of upland groundwater flow, such as Wood Slough, had the lowest dissolved oxygen levels. A continuum of floodplain lake habitat exists that vary with the relative contributions of upland groundwater flow and alluvial groundwater flow. Third, upland watershed land uses can affect groundwater quality and flow to the floodplain lakes. The floodplain lakes located adjacent to the uplands typically benefit from upland

groundwater flow. These lakes offer the best fisheries habitat but also are more threatened by upland land uses that affect nearshore habitat, groundwater flow and quality, and surface runoff. At a few sites, upland groundwater discharge appeared as springs but usually groundwater inputs were identified as sheet flow and detected when measuring vertical temperature profiles in the oxbows or sloughs. Specific springs were identified at two locations, a site along Cynthia Slough and another site along Jones Slough.

Estimating annual phosphorus loading is difficult since river flooding can result in either a net gain or loss depending on a given event. Flooding events are a force of nature, and not manageable, but an important function that sustains the oxbows. Strong floods can scour the braided channel oxbows since these linear flood channels can pass high water velocities. Upland land uses can be managed to reduce nutrient loads and protect groundwater, factors that can have significant direct and indirect effects on fisheries and water quality. In general, the study has demonstrated that the spring fed floodplain lakes are the most environmentally sensitive water resources within the State Riverway.

Recommendations

1. Sauk County Land Conservation Department should work with the Lower Wisconsin State Riverway Board and Department of Natural Resources to determine if the existing State Riverway Boundaries are adequately protecting the environmentally sensitive floodplain lakes. Environmentally sensitive floodplain lakes would benefit by expanding buffer zones to protect both upland groundwater and reduce surface runoff pollution.
2. The Lower Wisconsin River is currently classified an Exceptional Resource Water (ERW) and appears to encompass the floodplain waterbodies that are difficult to distinguish from a dynamic river channel. However, given the environmental sensitivity of the floodplain lakes, the Department of Natural Resources should classify these waterbodies as Outstanding Resource Waters (ORW).
3. The Sauk County Land Conservation Department should coordinate an investigation with the Department of Natural Resources to determine the cause for excessive filamentous algal growths in Jones Slough and to a lesser extent in Norton Slough, Hutter Slough, Hill Slough and Bakkens Pond. These algal forms of fertility may be linked to nutrient management or liquid manure applications on coarse soils that overly shallow groundwater table.
4. Conservation easements should be considered as a management option in areas where nutrient management problems can be linked to high nitrate levels in wells and suspected high nutrient levels in oxbow springs.
5. This study certainly doesn’t finalize floodplain lake research needs or provide a complete floodplain lake dataset. Additional floodplain lake surveys are recommended, not just in Sauk County but along the entire State Riverway.

Introduction

While most glacial lakes and impoundments in southern Wisconsin have been the focus of lake monitoring, planning and management, another entire class of lakes has been largely ignored. Scores of braided channel oxbow and other floodplain lakes provide necessary habitats for numerous aquatic communities within a transitional area linking the Lower Wisconsin River with small tributaries and extensive wetlands. Based on a small sampling of oxbows that WDNR completed between 1999 and 2004 and more recently during a 2007-2008 Rivers Planning Grant Study, the Lower Wisconsin State Riverway floodplain lakes support a unique blend of riverine and lake fish populations and perhaps the most abundant populations of rare and endangered species in southern Wisconsin. Many of the oxbows are also locally popular sportfish destinations. Despite the preliminary information suggesting a wealth of biodiversity, very little is known about these mysterious lakes.

Prior to some preliminary baseline fish surveys conducted by WDNR from 1999 to 2004, information on floodplain lakes was limited to brief descriptions in “Surface Water Resources of Sauk County” (1971). In that publication, there is no discussion of Trophic State Indices (TSI) conditions, specific management recommendations or identification of nongame or rare populations. Yet much of the information in that report has not been updated. The primary focus of the Lower Wisconsin State Riverway has been to protect the view shed from the main river channel even though development activities has degraded habitat in some of the lakes. When the Lower Wisconsin River was designated Exceptional Resource Water (ERW) because of the natural floodplain conditions, scenic beauty and rare fish and aquatic life populations, the floodplain lakes were ignored as part of the designation even though they support outstanding populations of sport and rare nongame fishes. These important resources are vulnerable to both floodplain and upland land management.

In response to the dearth of information on these ecologically important oxbows, the Sauk County Land Conservation Department applied for and received a State Lakes Planning Grant to collect information needed to better understand these unique ecosystems and develop management recommendations. The surveys were designed to collect the following information: TSI and other water chemical parameters, nearshore fish populations, habitats including aquatic plants, local watershed areas and upland land uses that may affect water quality.

Methods

At each lake, surface water samples were collected for total phosphorus, color and chlorophyll a at the deepest location of each lake. A Garmin 76 was used to log all sampling locations. A YSI Model 52 meter was used to measure dissolved oxygen and temperature profiles vertically. A Yellow Springs Instrument Model 63 meter was used to measure pH and specific conductivity profiles vertically. Calibration of the instruments followed manufacturer recommendations including the 2 point calibration for pH. Back-up systems for pH included a LaMotte meter and ExStik conductivity probe. The water quality sampling was performed in July or August 2008 and included both secchi and secchi transparency tube measurements. Water samples were analyzed at the State Lab of Hygiene (SLOH). Parameters tested at the state lab included total phosphorus, chlorophyll and color.

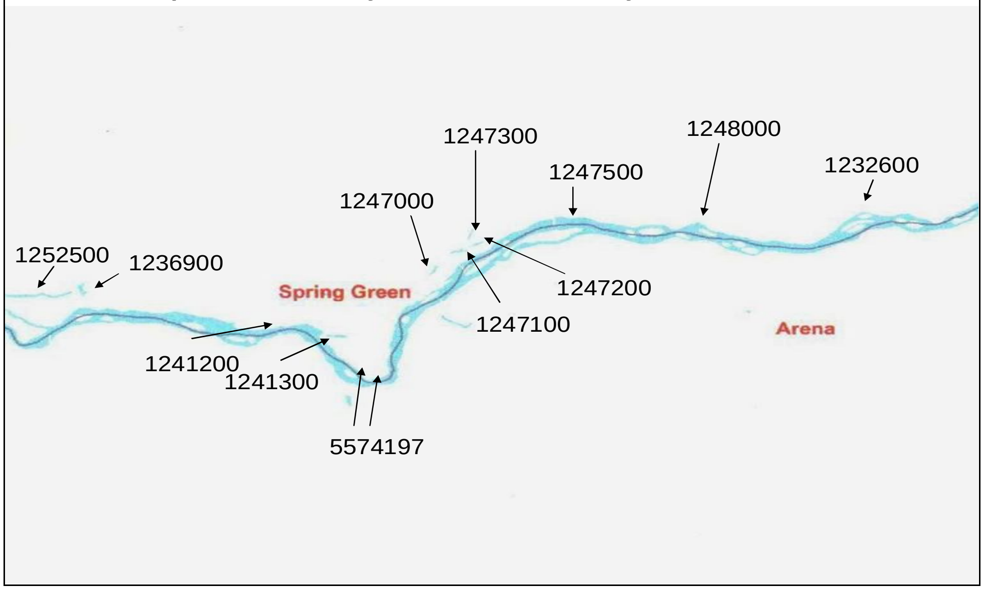
Notes on habitat quality were compiled for each floodplain lake. Aquatic plant specimens were collected and submitted to the University of Wisconsin Madison Herbarium. Photographs routinely captured aquatic plant and shoreline habitat conditions linked to GPS locations.

Nearshore fish population sampling included small mesh dipnetting and small mesh seining. WDNR Water Resources Biologist Jean Unmuth provided electro-shocking equipment for a site where filamentous algae undermined effective net sampling and during a demonstration for the Lower Wisconsin State Riverway Board. All specimens were immediately released after field identification and enumeration. Figure 1 displays the entire 2008 Sauk County surveys area.

Upland land uses and upland watersheds were estimated using Map Tech Terrain Navigator and WDNR WebView. WILMS watershed phosphorus loading module will be applied to the land use data. This information represented only an initial screening and does not account for alluvial groundwater inputs during floods or event related scour and deposition. The WILMS Trophic State Index (TSI) model was used to transform total phosphorus, chlorophyll-a and secchi water clarity measurements to TSI water quality values. The range is 0-100 with values higher values reflecting eutrophic conditions. The TSI values did not account for rooted plant suppression of planktonic algae.

Figure 1: Map of Surveys Area

Floodplain lakes surveys area with Waterbody Identification Codes



Findings

Deacon Thomas Lake (1232600) is an 11.4 acre oxbow that was formed when one of the former braided channels was cut off from the river. It has a reported maximum depth of 12 feet (WDNR 1971) but the deep hole was not sampled due to limited access. Two separate bays of the lake were sampled in early September 2008. Like most oxbows along the Lower Wisconsin River, Deacon Thomas Lake is long and narrow, reflecting the former braided river channel. Common with other former braided channel oxbows, basin narrowing due to beaver dams and other features create chains of smaller bays or lakes. These lake chains provide diverse habitats. Within Deacon Thomas Lake, water chemistry within the two bays we sampled was significantly different. Within the east bay (longitude 89 degrees 51.329), dissolved oxygen was 8 mg/l compared to 12.1 mg/l in the bay to the west (longitude 89 degrees 51.528). Specific conductivity (Figure 3) was lower in the east bay (168 uS/cm compared to 218 uS/cm) while both total phosphorus (26 ug/l) and chlorophyll-a (3.4 ug/l) were higher. These collective results suggested less upland groundwater input to the east bay than in the west bay, resulting in softer water (lower specific conductance) and greater fertility. Total phosphorus and chlorophyll-a in the west bay were 18 ug/l and 0.96 ug/l respectively, and are displayed in Figures 4 and 5. No discernible springs were detected around the perimeter of Deacon Thomas Lake.

Habitat conditions were similar for both bodies of water, reflecting near wilderness conditions and an abundance of native aquatic plants including slender naiad, large-leaf pondweed, white water lily, common water weed, coontail and native milfoil. Fallen timber that provide coarse woody debris habitat were evident everywhere. These conditions provide ideal habitat for basking turtles, starhead topminnows and other fish (Appendix A). Water clarity was very good (> 120 cm transparency tube) but water depths were too shallow for secchi readings (Figure 6). Our estimated secchi depth was greater than 6'. The satellite image suggested that water clarity in the lake ranged from 3' to 6.6' or a Trophic State Index range from 50 to 60 (http://www.ersc.wisc.edu/cgi-bin/mapserv). The phosphorus TSI values for the east and west bays were 53 and 51 respectively. The chlorophyll-a TSI values for the east and west bays were 44 and 34. While the phosphorus TSI values indicated moderate fertility, the very low chlorophyll measurements suggested rooted plant suppression of planktonic algae. Color levels (Figure 7) in both bays were moderately low at 15 s.u. and reflected low concentrations of organic compounds in the water. Low water color was another indication of clear upland groundwater inputs.

As mentioned above, Deacon Thomas Lake consists of a long chain of bays and is also connected to Long Lake (WBIC 1236600). These lakes are unconnected to the river except during flood events. The collective watershed area for this chain of lakes is about 2,019 acres. The predominant wooded/agricultural land uses contributed an estimated annual phosphorus loading of 2019 pounds (Figure 8). While these floodplain lake systems are complex and total loading linked to river flooding is currently unknown, the upland sources of phosphorus are more manageable for these and other oxbows along the river. It is uncertain whether a given flooding event results in a net gain or loss of nutrients but high velocities in the former channels can results in significant scouring and interrupted succession (Amoros and Bornette 2002).

Figure 2 displays a cross section of the elevation from the river to uplands. Both the relatively flat alluvial plain (with shallow groundwater table) and steep ridges (with shallow bedrock) farther from the river are susceptible to groundwater contamination, an issue that is just as important for the health of oxbows than surface runoff. The relatively low elevation of Deacon Thomas Lake (728 feet above sea level) compared with the river (725 ft) explains how annual flooding plays an important role in fertility and also dispersal of fish to new habitats.

Figure 2: Elevation cross section including the river, Deacon Thomas Lake and uplands.

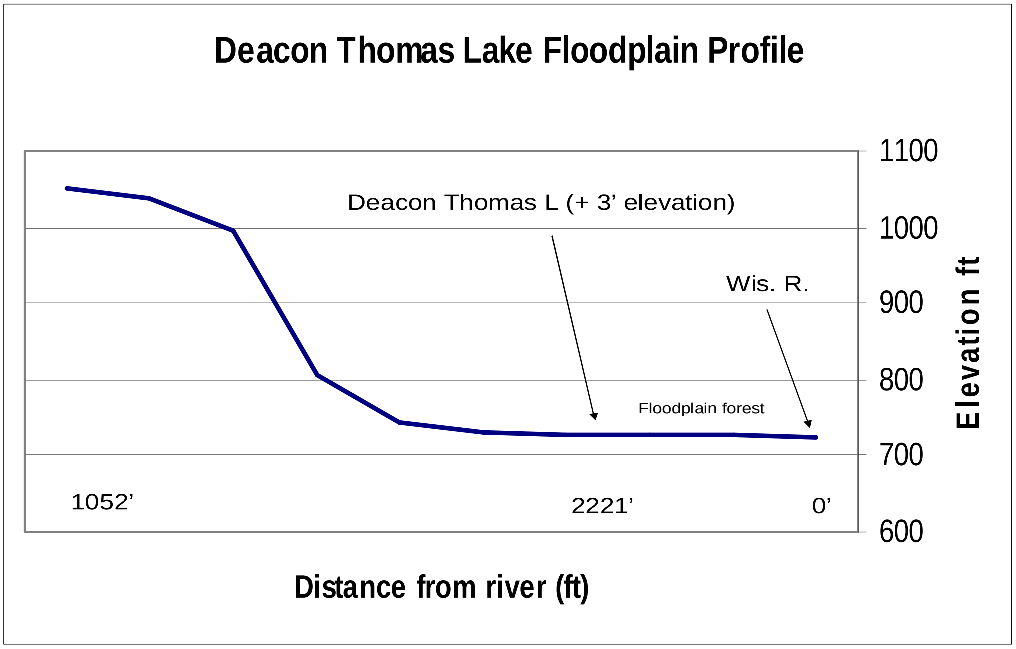


Figure 3: Specific conductance levels (uS/cm - 0.5 m depths) are a measure of dissolved solids in water.

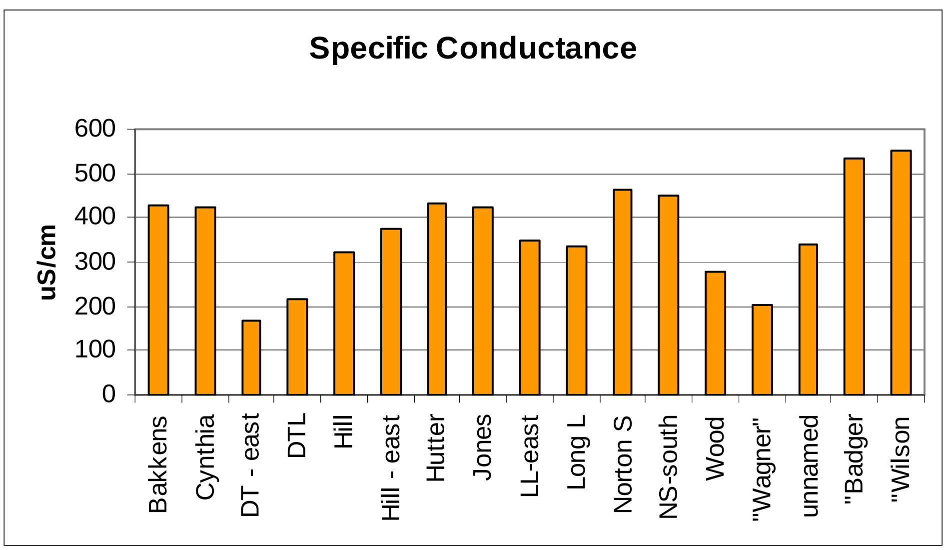


Figure 4: Total phosphorus concentrations (ug/l - 0.5 m depths).

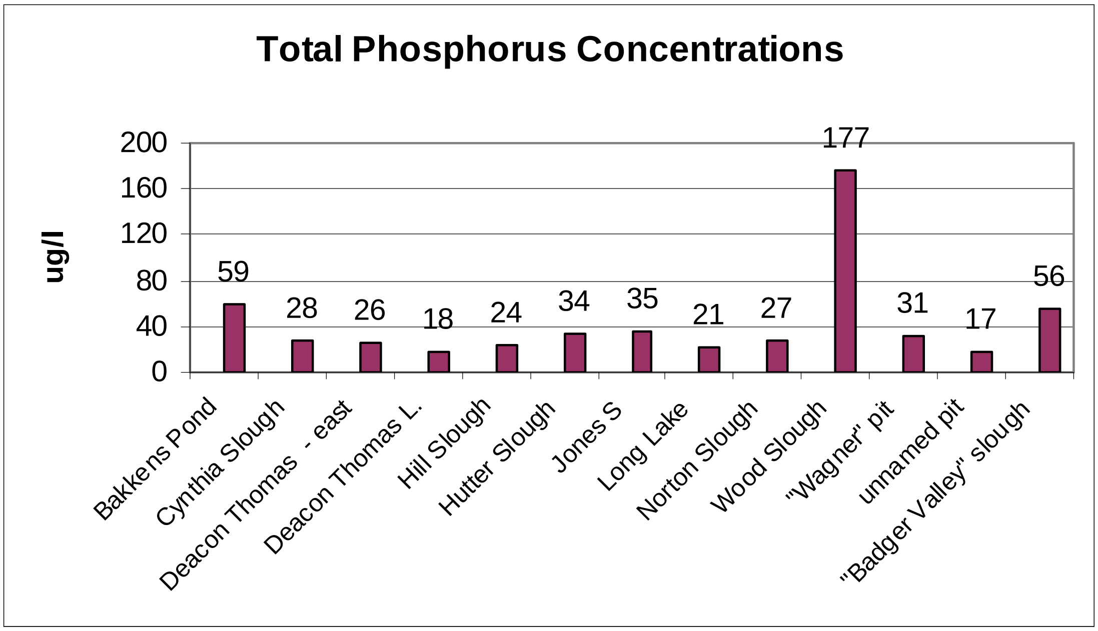


Figure 5: Chlorophyll-a concentrations (ug/l – 0.5 m depths)

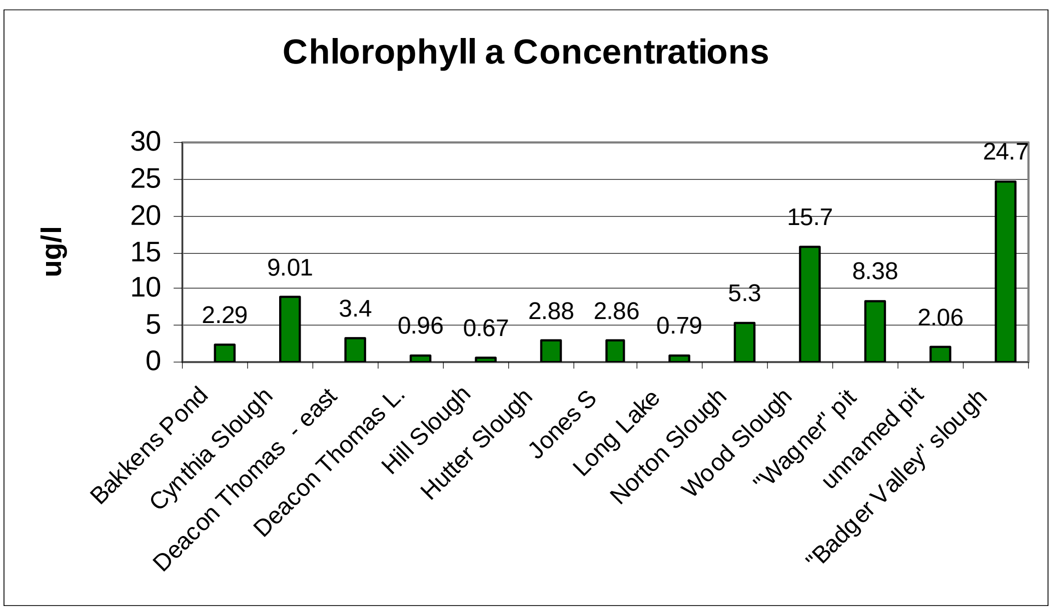


Figure 6: Floodplain lake water clarity measurements (max. trans. Tube = 1.2 m).

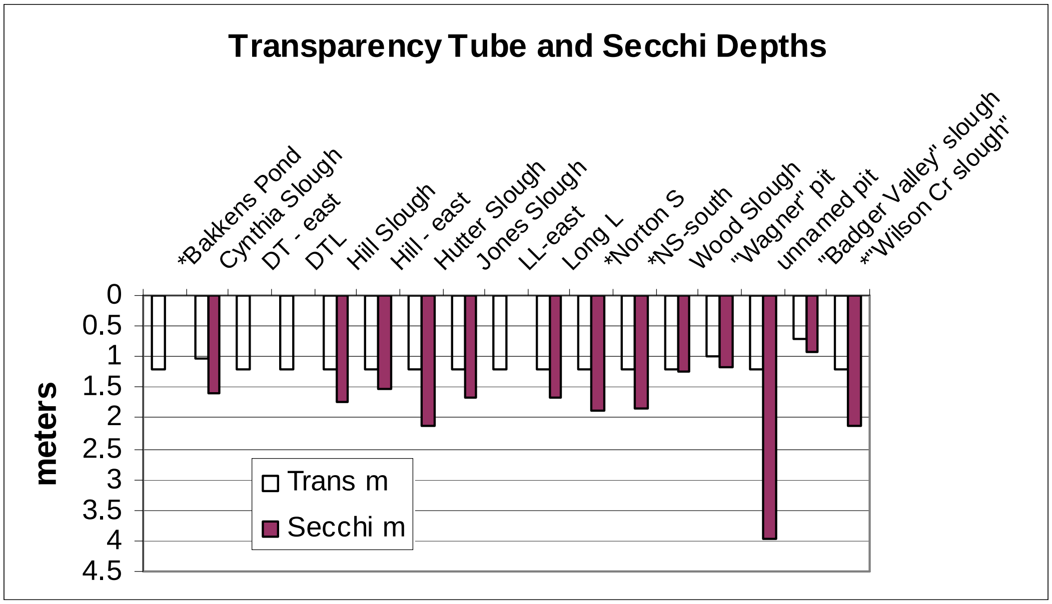


Figure 7: Color levels – measure of organic compounds when alluvial groundwater and wetland drainage are high.

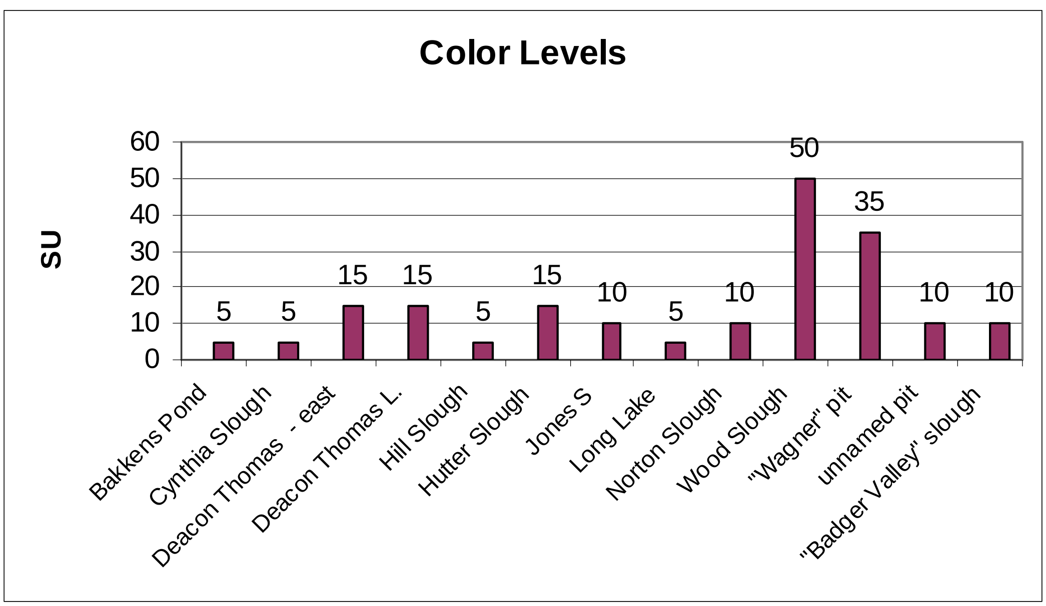
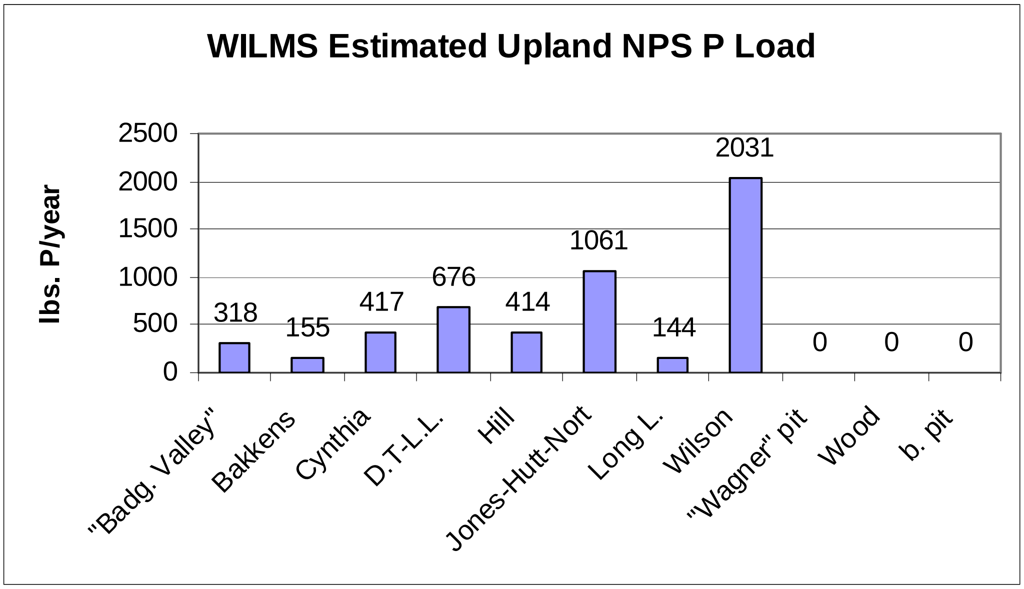


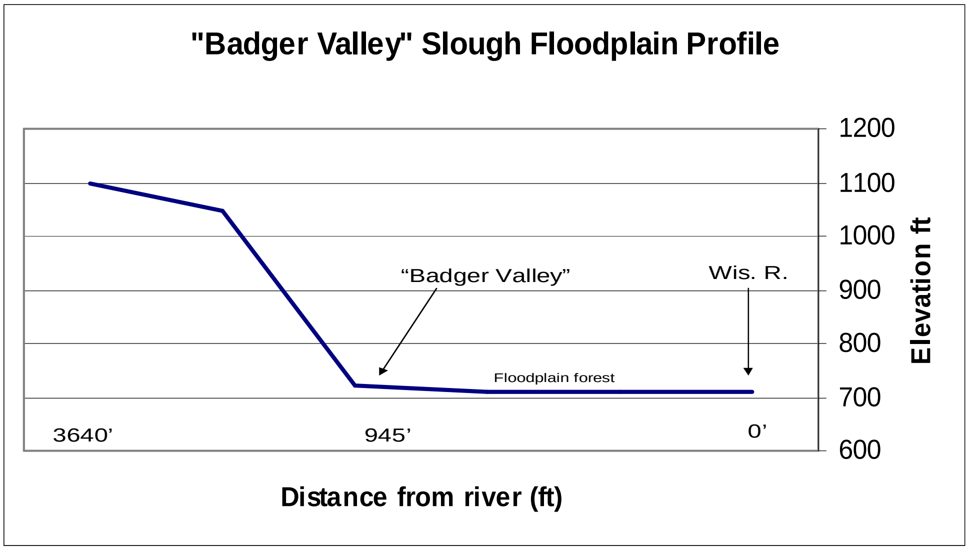
Figure 8: Estimated upland annual phosphorus loads (WILMS)



"Badger Valley" slough (1248000) is a floodplain lake that was formed when the river bank dammed a small tributary. The lake is 5 acres in surface area with a maximum depth of about 5 feet. It lies much closer to the surrounding ridges than most other lakes and drains a small but very steep watershed. Figure 9 illustrates the relatively close proximity of both the Wisconsin River and slough with the steep ridge along Highway 60. Even though the small slough drains a relatively small watershed, water fertility was higher than expected. Both total phosphorus (56 ug/l – Figure 4) and chlorophyll-a (24.7 ug/l – Figure 5) reflected high fertility. The TSI was 59 for both parameters. The water clarity (Figure 6) also reflected eutrophic conditions with a TSI value of 62. Reasons for the high fertility are unknown since estimated annual phosphorus loading is only 318 lbs. The 1404 acre watershed is only about 22% agricultural and mostly wooded (~70%). However, steep slopes have the potential to deliver sediment loads and organic matter. The tributary elevation change was very high at 125 ft/mile. This slough had the second highest specific conductance level (538 uS/cm – Figure 3) but not above normal background levels. The higher level likely reflected high mineral content in ridge top groundwater flow into the small tributary.

Rooted submersed and floating aquatic plants provided good habitat for fish and turtles. Bluegills were very abundant and also grass pickerel, starhead topminnows, mudminnows and brook silversides were collected. Numerous painted turtles basked on logs. The downstream end of the slough is connected with the river so there is potential for river fish migrations. Springs were not evident around the slough however a small cool stream appeared to be the primary water source for the lake.

Figure 9: Elevation cross section encompassing the river, “Badger Valley” slough and uplands.



Wilson Creek slough (1247500) could be described as a high quality deep water marsh with a maximum water depth of 7 feet. The open water area is roughly 30 acres of very clear water. The secchi was observed resting at the bottom in 7 feet of water.
SLOH water samples were not collected since this slough was an add-on without laboratory funding. However, the field measurements reflected a high quality resource. The primary habitat issue was the deposition of fine sediment at the head of the marsh. Beyond that point, the marsh supported an abundance of native submersed, floating-leaf and emergent plants. The plants provided ideal habitat for State Endangered starhead topminnows. Other species examined included bluegills, grass pickerel, golden shiners and johnny darters. Wilson Creek appeared to represent the dominant upland water source but springs are difficult to detect within the large marsh.

Wilson Creek drains a relatively large watershed at 5886 acres. The watershed is a mix of woods, cropland and mixed agriculture with an estimated annual phosphorus loading of 2031 lbs. Agriculture on steep slopes likely contributed to sediment at the mouth of the creek and head of the marsh. The gradient change in Wilson Creek is moderately high at 36 ft/mile. Within the floodplain, another branch of Wilson Creek connects the marsh with the river and river fish migrations can occur.

Jones (1247300), Norton (1247100), Wood (1247200) and Hutter (1247000) chain of lakes drains a watershed area of approximately1667 acres. This watershed lies west of Wilson Creek where the low gradient river valley widens and renders watershed divisions more nebulous. Figure 10 displays a much more broad and flat cross section compared to river landscapes to the east. In this area, cropland areas and intensive agriculture increase substantially. Jones Slough is 5 acres in size and the first in this chain of oxbow lakes. It receives substantial upland groundwater flow with very cold summer water temperatures in the slough. A defined upland spring was identified as well as indications of substantial sheet groundwater flow. Nutrient loading appears to be high based on very dense filamentous algal mats across the lake. Total phosphorus was moderately high (35 ug/l = 56 TSI) but chlorophyll-a (2.86 ug/l = TSI 43) was much lower on the TSI scale. The low chlorophyll level indicated suppression of planktonic algae by rooted macrophytes and filamentous algae. Secchi water clarity suggested an intermediate TSI ranking of 53.

Groundwater inputs may be the most significant source of nutrients in the groundwater fed lake with minor surface runoff. We observed heavy applications of liquid manure across the highway while local nitrate levels in wells have increased substantially. Phosphorus isn’t the only nutrient of concern for aquatic environments. Just as high nitrates are human health issue, recent research has determined similar negative physiological effects of high nitrates on aquatic organisms (Camargo et al. 2005). Nitrates can migrate rapidly in coarse sandy soils and where the groundwater table is shallow.

Norton Slough at 9.2 acres is the next lake west in the chain that lies just downstream of Jones Slough. Water chemical conditions and habitat were more variable in Norton Slough in part due to the various bays that project to the southeast. Some of these bays are partially isolated by beaver dams. Total phosphorus concentration (27 ug/l = TSI 54) reflected moderately eutrophic conditions while again the chlorophyll-a concentration was very low (5.3 ug/l = TSI 47). The water was clear with a secchi measurement greater than the maximum depth of 5.2 feet (TSI = <51). The Norton Slough response to phosphorus is similar to most other floodplain lakes where macrophytes and filamentous algae suppress planktonic algae. Specific springs were not detected along Norton Slough but the residents (Doug and Sheryl Jones) mentioned areas of the oxbow that rarely freeze.

The next oxbow west of Norton Slough is 10 acre Hutter Slough. Phosphorus levels in Hutter Slough were also relatively higher than either chlorophyll or secchi measures reflected macrophytes and filamentous algae suppression of planktonic algae. The TSI measures were typical for most of the floodplain lake: phosphorus = 34 ug/l or TSI 56, chlorophyll-a = 2.88 or TSI 43 and secchi = 6’ or TSI 49. The conditions in all three oxbows reflect clear water conditions compared with the more turbid river that is phytoplankton dominated. No discernible springs were detected around Hutter Slough but groundwater was evident from the vertical profile data.

Dissolved oxygen and temperature profiles for the three oxbows are compared in Figures 10 and 11. Cold water temperatures, particularly in Jones Slough, reflect strong upland groundwater flow. While dissolved oxygen levels were favorable for fish in both Norton and Hutter sloughs, extreme high and low levels in Jones Slough suggest high fertility that is likely linked to the groundwater.

Figure 10: Dissolved oxygen profiles for Jones, Norton and Hutter sloughs

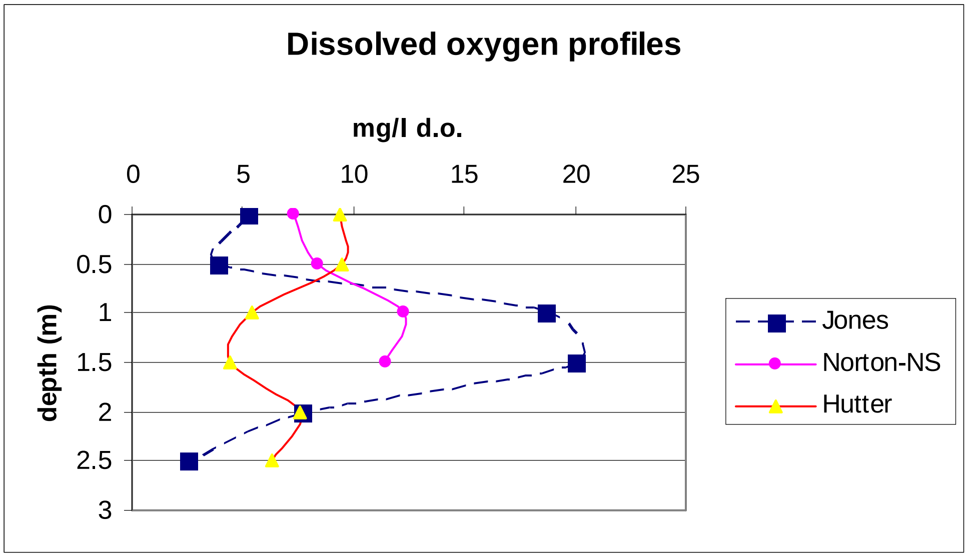
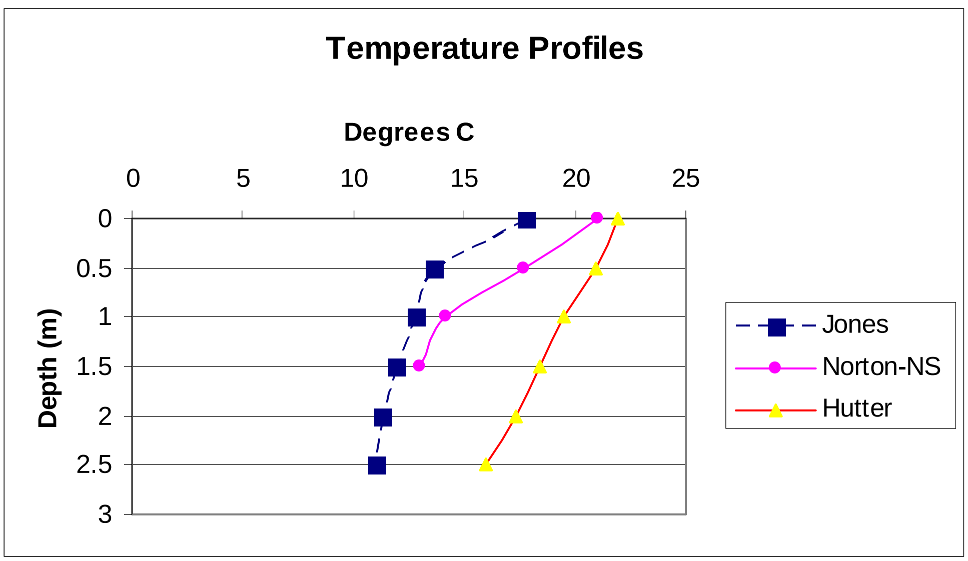


Figure 11: Temperature profiles for Jones, Norton and Hutter sloughs



Lying just south of Jones Slough and east of Norton Slough is 3.6 acre Wood Slough. Wood Slough is significantly different from the other three oxbows since it is isolated from upland landscapes and is influenced more by alluvial river groundwater. As a result, it differs substantially from the other oxbows based on a number of chemical parameters. First, dissolved oxygen levels were very low in Wood Slough with a maximum concentration of only 3.1 mg/l. The State Water Quality Criterion for dissolved oxygen in warm water environments is 5 mg/l. The dissolved oxygen levels within the other oxbows were generally much higher and these sloughs receive upland groundwater. Color, total phosphorus and chlorophyll concentrations were much higher in Wood Slough and reflected organically enriched alluvial groundwater. In the Jones-Norton-Hutter chain, color measurements ranged from 10-15 s.u. while the color level in Wood Slough was 50 s.u. The average color level for Wisconsin lakes is 39 s.u. The high color content in Wood Slough reflected organic compounds dissolved in alluvial groundwater. Total phosphorus was extremely high at 117 ug/l or TSI 65 and chlorophyll was also high at 15.7 ug/l or TSI 55. Consistent with the higher chlorophyll-a concentration, water clarity was lower than most oxbows with a secchi of 4.1’ or TSI 57. The water clarity and chlorophyll concentration were not consistent with the very high phosphorus concentration and reflected rooted plant suppression of planktonic algae. A combination of high phosphorus and areas of rust colored iron-rich water suggested that reduced conditions in Wood Slough lacked upland groundwater inputs.

The temperature profiles of the east-west oriented Jones, Norton and Hutter sloughs suggest strong exposure to upland groundwater. In Figures 12 and 13, dissolved oxygen and temperature profiles are plotted for Norton (EW) east-west bay, Norton (NS) north-south bay that is more isolated from upland groundwater sources, and Wood Slough that receives almost no upland groundwater. The dissolved oxygen levels were lower and temperatures higher in the waterbodies (Norton NS and Wood) that were strongly influenced by alluvial groundwater rather than upland groundwater.

Figure 12: Dissolved oxygen profiles for upland adjacent Norton Slough (EW), floodplain surrounded Norton Slough (NW) and floodplain surrounded Wood Slough.

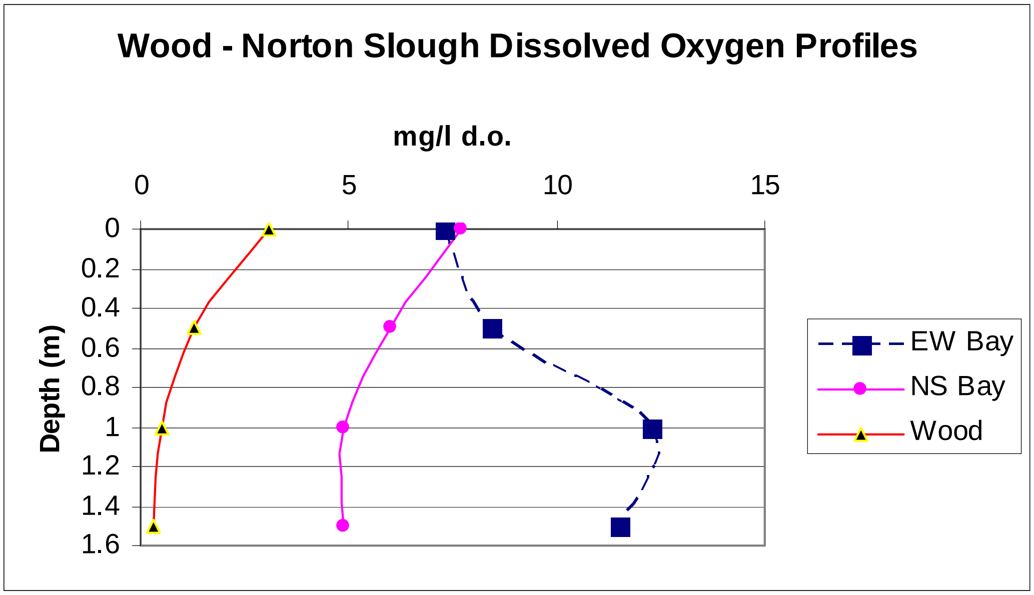
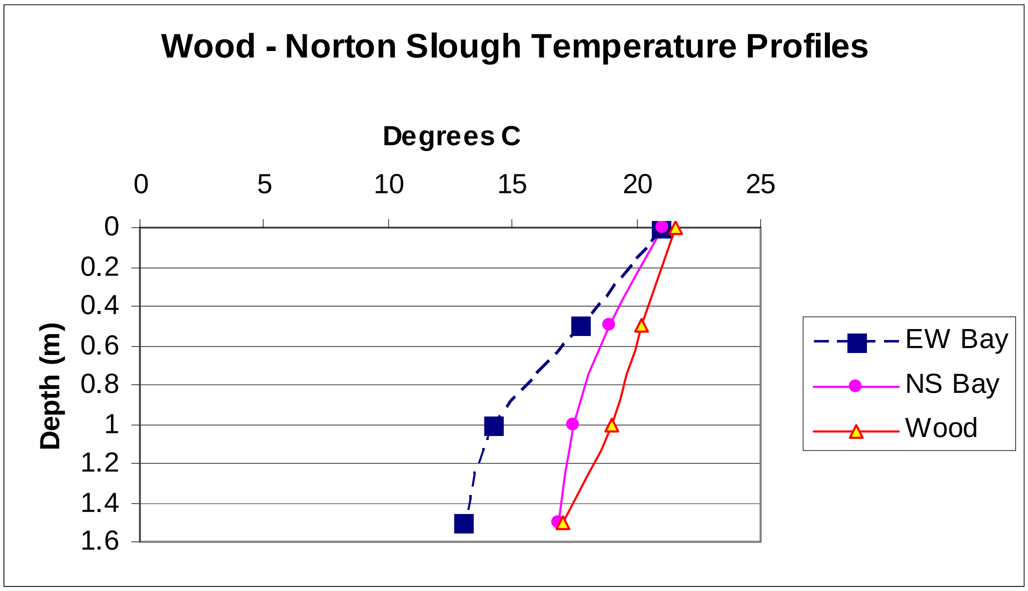
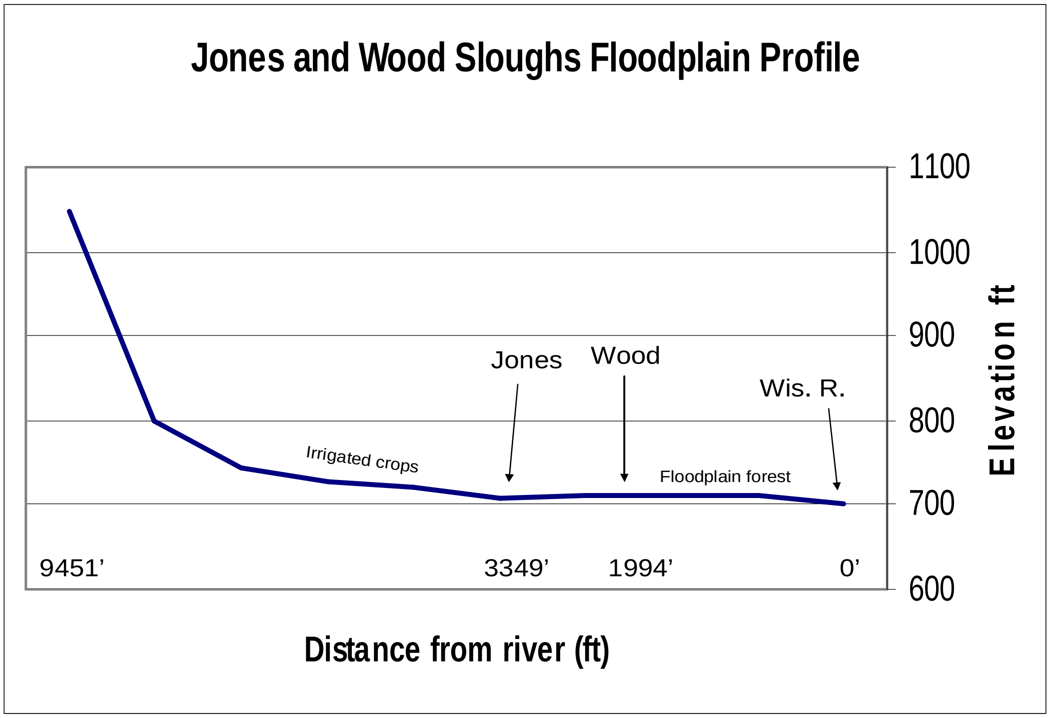


Figure 13: Temperature profiles for upland adjacent Norton Slough (EW), floodplain surrounded Norton Slough (NW) and floodplain surrounded Wood Slough.



While water quality was more favorable for fish populations in Jones, Norton and Hutter sloughs compared with Wood Slough, watershed assessment and observations suggest greater upland threats to these three oxbows. The broad upland valley supports intensive agriculture on sandy nutrient-poor soils. Applications of both liquid manure and commercial fertilizers can rapidly leach in the shallow groundwater table that is important to these lakes. The heavy filamentous algal growths in these oxbows suggest external nitrogen and phosphorus sources. Irrigated cropland is the dominant land use in the broad upland valley at about 70% of the watershed. Most of the remaining watershed land use is woodland and the estimated annual phosphorus loading is 1061 lbs (Figure 8). Nitrate loading is not known but can be high in the coarse sandy soils, as local well testing has demonstrated.

Figure 14: Cross section encompassing the river, Wood and Jones Sloughs and upland elevations.



Aside from chemical and temperature differences among the four oxbows, a combination of fallen trees, submersed aquatic plants, floating-leaf aquatic plants and emergent aquatic plants provided excellent fish and aquatic life habitat. Starhead topminnows were found in all four oxbows along with grass pickerel, northern pike, lake chubsucker, mudminnow, brook silversides, johnny darters, bluegills, and largemouth bass. The low dissolved oxygen conditions within Wood Slough would likely prevent survival of bottom dwelling darter species. These oxbows are typically not connected to the river except during periods of high flow.

Norton Slough. Similar scenes can be found in many braided channel oxbows.

“Wagner” borrow pit and an unnamed borrow pit (5574197) are located just north of the Highway 23 bridge. Both waterbodies were either expanded or entirely created when they were dredged for construction sand. Both ponds are deeper than the other floodplain lakes sampled. While they lie just 650’ apart, they are significantly different chemically and in habitat quality. “Wagner” pond was constructed in the shape of a rectangle with very little nearshore habitat due to steeply sloped contours. Aquatic plant habitat was limited to small patches of white water lilies and submersed plants and those were the locations where nearshore fish were collected. Among abundant bluegills and a few of other Sunfish Family species, a few starhead topminnows were collected within the plants. The pond is managed as a park setting so that coarse woody habitat is also limited. “Wagner” pond is reported to be a locally popular fishing destination, primarily due to easy access and diversity of lake and river species that can be caught there. An upland watershed could not be described for Wagner borrow pit since it lies entirely within the river floodway. There was no evidence of upland spring flow yet an outlet suggested that the small lake was influenced by alluvial groundwater.

Just across Highway 23 is the other borrow pit that is apparently much older than “Wagner”. This small lake also lies within the floodway with no discernible upland watershed. Access is limited to a rustic foot path and the surrounding woods suggest a more naturalized environment with dense riparian shrubs and trees. Submersed and floating-leaf plants were found around the perimeter but shallow depths were also limited in this pond. The fishery included starhead topminnows, bluegills and largemouth bass.

Water clarity was much better in the unnamed borrow pit, 13.1' or TSI 40 versus 3.9' or TSI 57. The good water clarity in the unnamed borrow pit may have reflected abundant rooted aquatic plants that grew across the bottom that was at least 4 meters (13.1') deep.

"Wagner" pond was more eutrophic than the unnamed borrow pit based on total phosphorus (31 ug/l or TSI 55 versus 17 ug/l or TSI 50 and chlorophyll-a (8.38 ug/l or TSI 51 versus 2.06 ug/l or TSI 40 in the unnamed pond. "Wagner" had a fairly high color value (35 s.u.) that contributed to the poor water clarity along with planktonic algae. The unnamed pond had a color measurement of just 10 s.u. The low color value, combined with a higher specific conductance level (341 uS/cm versus 203 uS/cm in "Wagner"), suggested that the unnamed pond may have had greater influence from upland groundwater even though springs were not detected. The question whether or not upland groundwater reaches the unnamed borrow pit is further complicated since chemically reduced alluvial floodplain lakes lie between the borrow pit and uplands. Both ponds lie close to the river and neither have identifiable watersheds beyond the riparian banks. Figures 15 and 16 compare dissolved oxygen and temperature profiles for the relative deep two borrow pit lakes.

Figure 15: Dissolved oxygen profiles for "Wagner" and unnamed borrow pits.

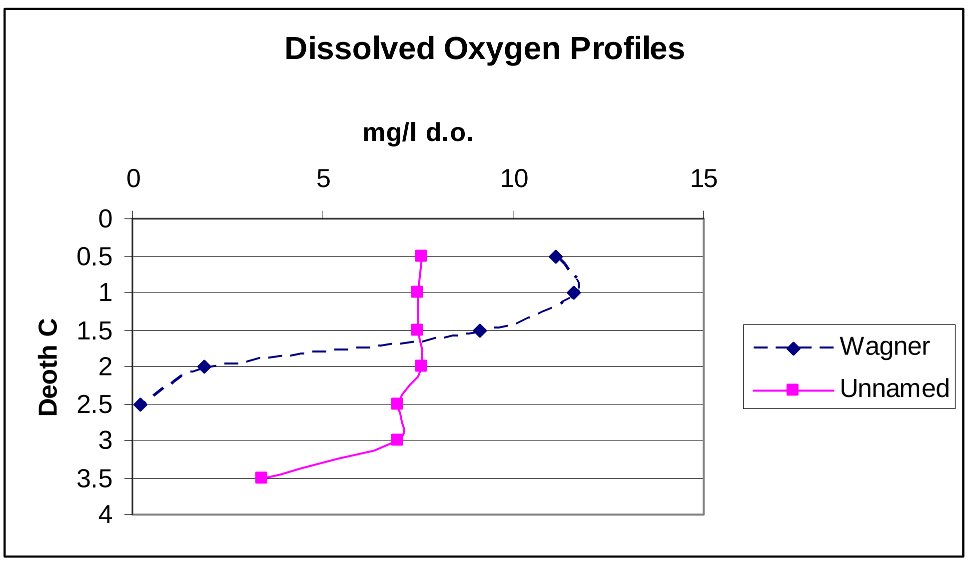
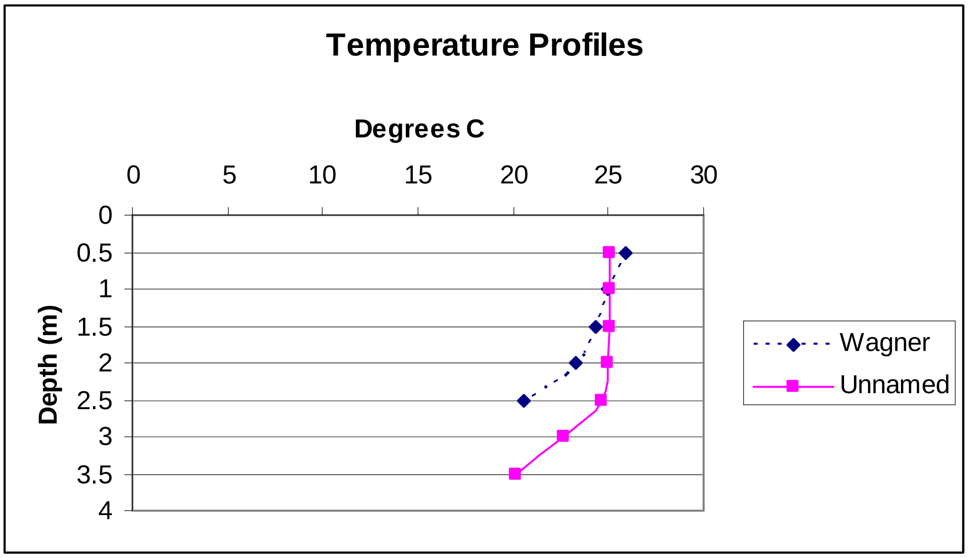


Figure 16: Temperature profiles for "Wagner" and unnamed borrow pits.



Cynthia Slough (1241300- cover photo) is located directly south of the Village of Spring Green and is the site of a private trailer park and canoe rental. The slough is closely connected to the river and supports both lake and river fish populations. This connection and same elevation with the river has a negative impact since the regulated flow pulse causes daily nearshore drawdown and desiccation of aquatic plants. Aquatic vegetation was less dense compared to unconnected oxbows. Large numbers of carpsuckers were observed during the August 2008 survey. In 2007, massive schools of gizzard shad created moving clouds in the slightly turbid water.

Despite the large areas devoid of aquatic vegetation, juvenile bluegills and brook silversides and four starhead topminnows were collected near shore. Painted turtles were observed on logs and one individual was dip netted. Aquatic vegetation was dense in relatively small patches of either Eurasian watermilfoil or Chara. The presence of Chara reflected upland hardwater seepage. Figures 17 and 18 present dissolved oxygen and temperature profiles near the upper end of the slough (where groundwater seepage and Chara were evident) and near the river connection. Dissolved oxygen levels were very high at both locations and reflected a moderate phytoplankton bloom. Water temperatures were cold near the bottom at both sites and reflected upland groundwater flow. Secchi measures were 5.2' and 4.8' reflected moderate eutrophic conditions (TSI 53 and 55). Both total phosphorus (28 ug/l) and chlorophyll also indicated moderate eutrophic conditions with TSI values of 54 and 51 respectively. A low color value of 5 s.u. indicated minimal wetland drainage or alluvial groundwater flow into the slough.

Figure 17: Dissolved oxygen profiles at two locations in Cynthia Slough.

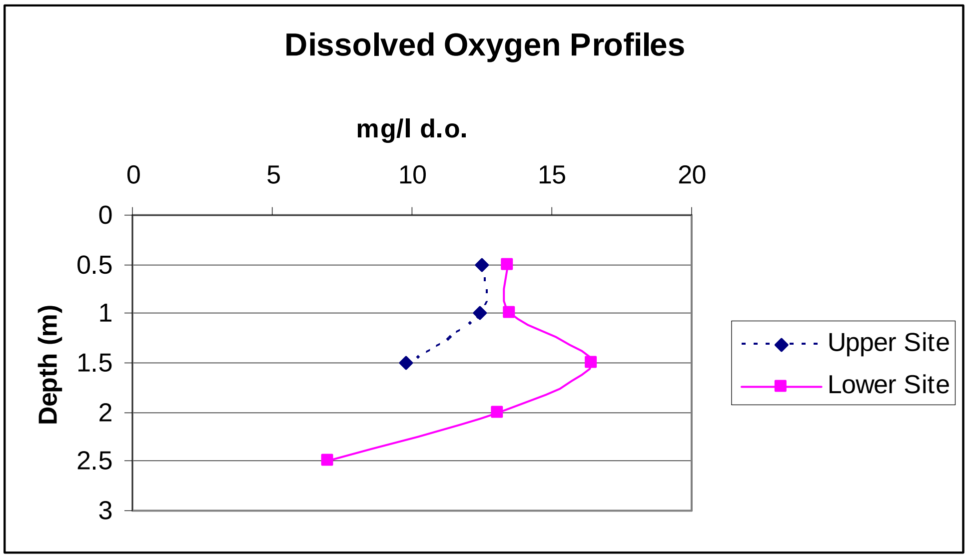
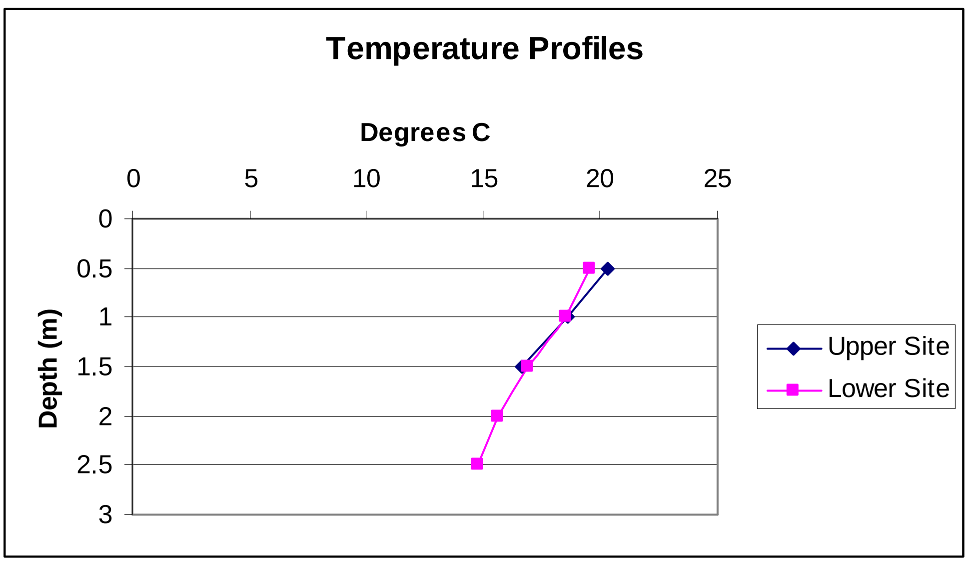
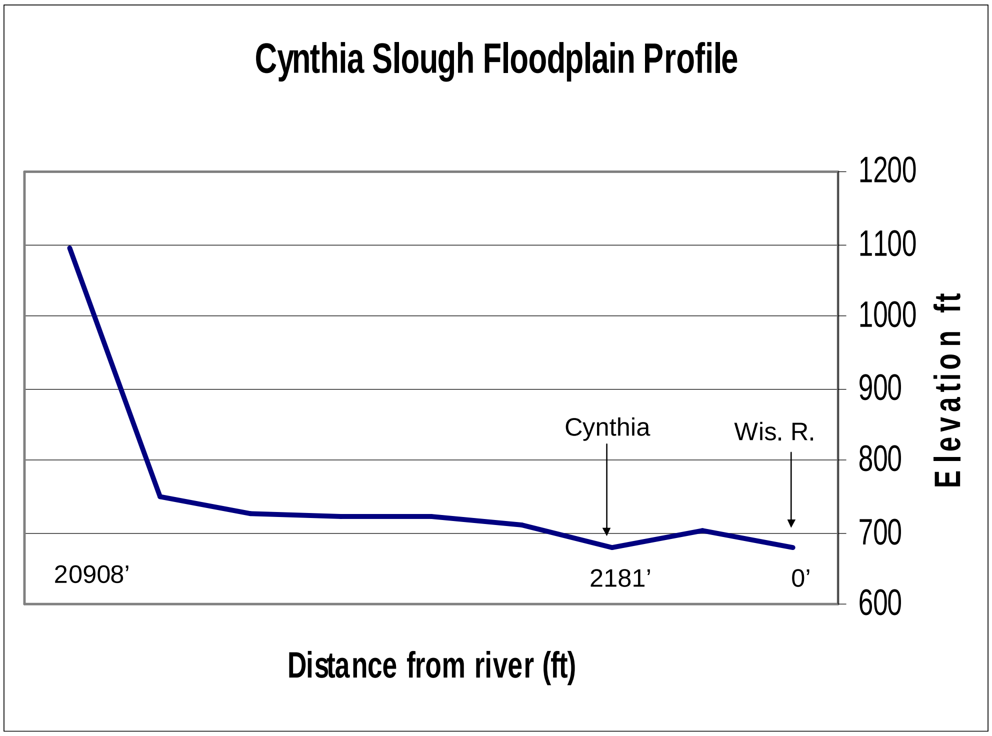


Figure 18: Temperature profiles at two locations in Cynthia Slough.



The valley plain on the north side of the river is considerably more expansive around Spring Green compared with areas to the east (Figure 19). Watershed boundaries are less discernable within this broad flat valley. For purposes of estimating phosphorus loading, the watershed extended to the north side of Spring Green. The estimated 708 acre watershed is considerably more developed than the other watersheds including about 80% moderate urban density and 17% cropland. The estimated annual phosphorous loading is about 417 lbs. Direct sources of runoff were not evident and potential groundwater contamination may be a greater concern, an issue identified in the Lower Wisconsin River State of the Basin Report (WDNR).

Figure 19: Cross section encompassing river, Cynthia Slough and upland elevations.



Hill Slough (1241200) is located about a mile west of Cynthia Slough and consists of a series of separate connected basins over 2 miles long. The far west bay appears to drain into the river however this part of the lake chain was not sampled. During the 2008 surveys, the two eastern bays were sampled. Another bay further west was sampled in 2007 as part of a River Planning Grant Study. While the bay to the west supported abundant floating-leaf plants in 2007, the bays to the east supported patches of dense Eurasian watermilfoil, filamentous algae and duckweed. The eutrophic conditions may have reflected surrounding land uses, including a barnyard, and a few common carp that were observed. However, water chemical sampling from the first bay suggested moderate fertility with a total phosphorus concentration of 24 ug/l or TSI 53 and 0.67 ug/l chlorophyll-a or TSI 32. The low planktonic chlorophyll reflected productivity in the form of filamentous algae, duckweed and Eurasian watermilfoil. Water clarity was greater than 5', the maximum depth found. The color value was only 5 s.u. and reflected minimal wetland drainage or alluvial groundwater inputs. Dissolved oxygen levels (Figure 20) were generally above minimum criterion (5 mg/l) and bottom temperatures

Figure 20: Dissolved oxygen profiles from two locations in Hill Slough.

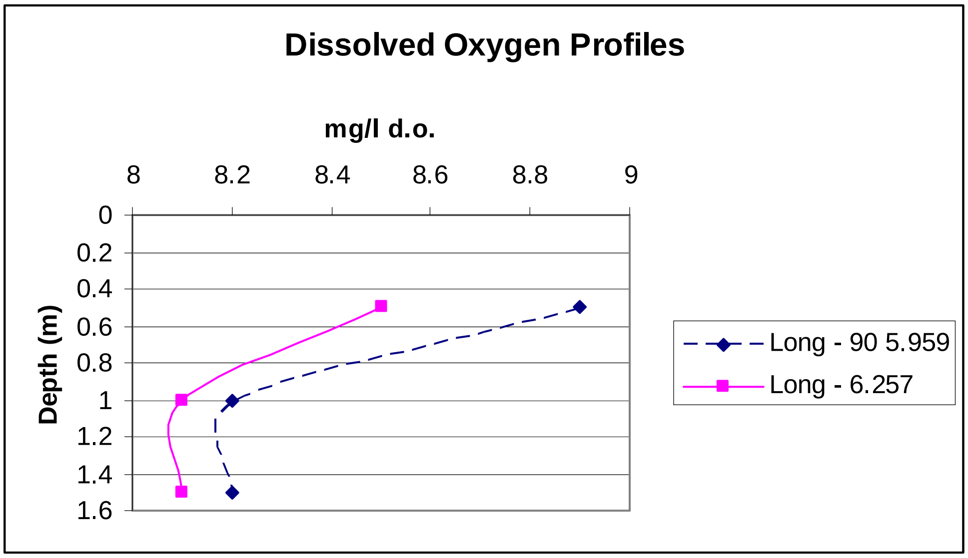
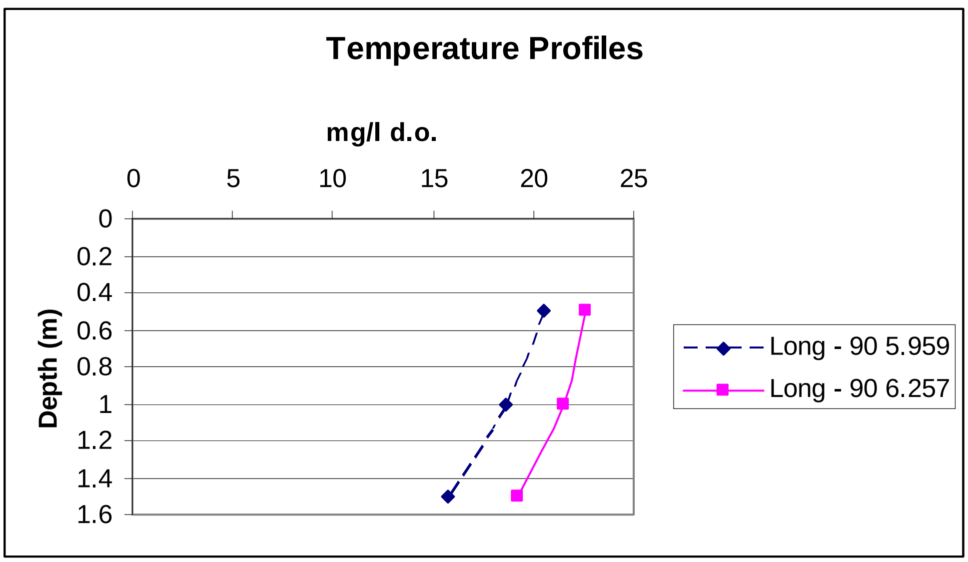


Figure 21: Temperature profiles from two locations in Hill Slough.



(Figure 21) in the first bay suggested upland groundwater inputs. Specific sources of groundwater or springs were not found along either bay.

Watershed boundaries were again difficult to define within the broad level valley and groundwater quality may be a more important environmental issue than surface runoff. The estimated annual phosphorus loading from the 1220 acre watershed is 414 lbs.

Irrigated croplands comprise about 25% of the watershed and woodlands comprise roughly 70%.

The far eastern bay was sampled with a small mesh seine yielding bluegills, grass pickerel, largemouth bass, mudminnow, lake chubsucker and brook silversides Starhead topminnows were also dip netted in the other bay. Tree falls provided good fish habitat in both bays. Starhead topminnows were found in greater abundance in the more westerly bay in 2007 where floating leaf plants and other aquatic vegetation appeared presented more favorable habitat.

Bakkens Pond (1236900) and Long Lake (1252500) are linked to a common clear water stream that ultimately empties into the river. Bakkens Pond is a flowage system upstream of Long Lake and manipulated using an earthen dam and tin-whistle discharge structure. Bakkens Pond displays marshy habitat with clear water and abundant submersed, floating leaf and emergent plants. Habitat conditions change substantially below the dam since Long Lake appears more typical of narrow long channel oxbows. However, unlike most of the other braided channel oxbows the north shore is heavily developed. Habitat conditions were not favorable to most nearshore fishes along the north shore due to removal of fallen tree and aquatic plant habitat. Woody habitat on the south side of the lake provided good habitat but shading limited aquatic plants. Some of the more sensitive fishes such as starhead topminnows and mud darters were only found near a few undeveloped sites with adequate cover.

Mats of filamentous algae in Bakkens Pond created a navigational challenge and deeper water could not be sampled. Numerous species of high quality native plants were also observed including Chara, sago pondweed, elodea, leafy pondweed, and buttercup. Fish species collected included starhead topminnow, brook silverside and golden shiner.

Cool clear water in the stream (18 degrees C) and low color content (5 s.u.) reflected substantial upland groundwater flow and minimal alluvial groundwater. Upland springs aside from the cold water creek were not observed. Total phosphorus concentration was quite high at 59 ug/l (TSI 60) but heavy growths of rooted and floating plants had suppressed planktonic algae (chlorophyll-a = 2.26 ug/l or TSI 41).

Aquatic plants in Long Lake were patchier and less diverse. Dominant species included Eurasian watermilfoil, coontail and filamentous algae. Small duckweed and white water lily were less common. Water was relatively clear with a secchi depth of 5.5’ or TSI 53. Total phosphorus concentration indicated low level eutrophic conditions at 21 ug/l or TSI 52. Planktonic algae suppression was expressed with a chlorophyll concentration of only 0.79 ug/l or TSI 33. Typical for most of the Lower Wisconsin River floodplain lakes, the chlorophyll concentrations did not reflect actual fertility. Dissolved oxygen (Figure 22) and temperature profiles (Figure 23) indicated favorable fish habitat and upland groundwater inflow.

Fish species collected at the inlet below the dam included bluegills, largemouth bass, brook silverside, starhead topminnow and mud darter. South of the tin-whistle, alluvial groundwater entered from below the earthen dam. The water was stained orange from the high iron content and dissolved oxygen 1.9 mg/l. Subsurface discharges from this and other tin-whistle structures had caused water quality problems in the past.

Figure 22: Dissolved oxygen profiles at two Long Lake locations.

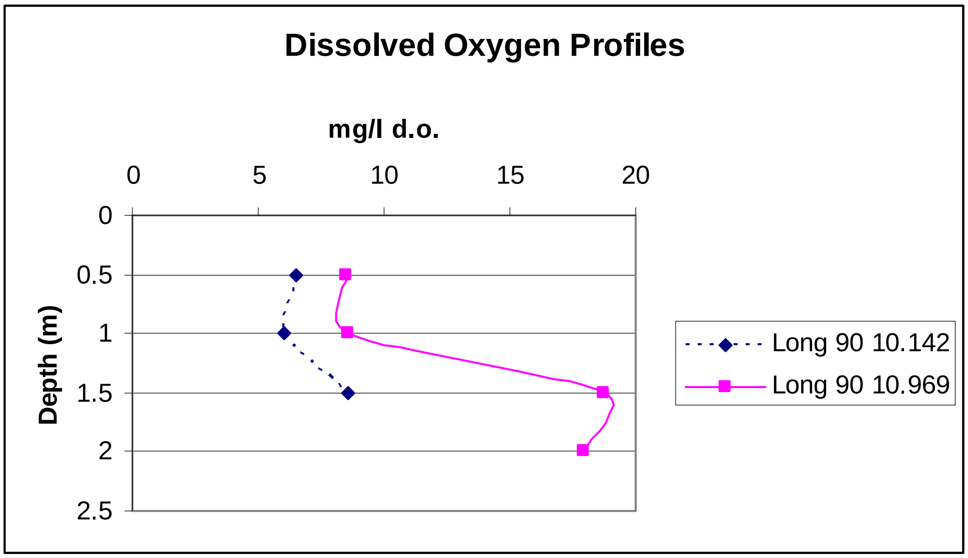


Figure 23: Temperature profiles at two Long Lake locations.

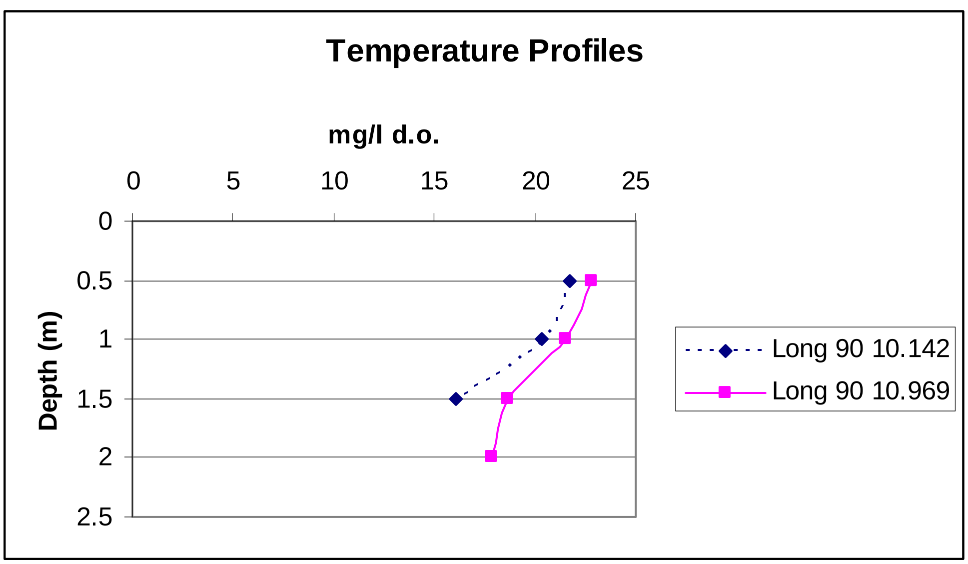
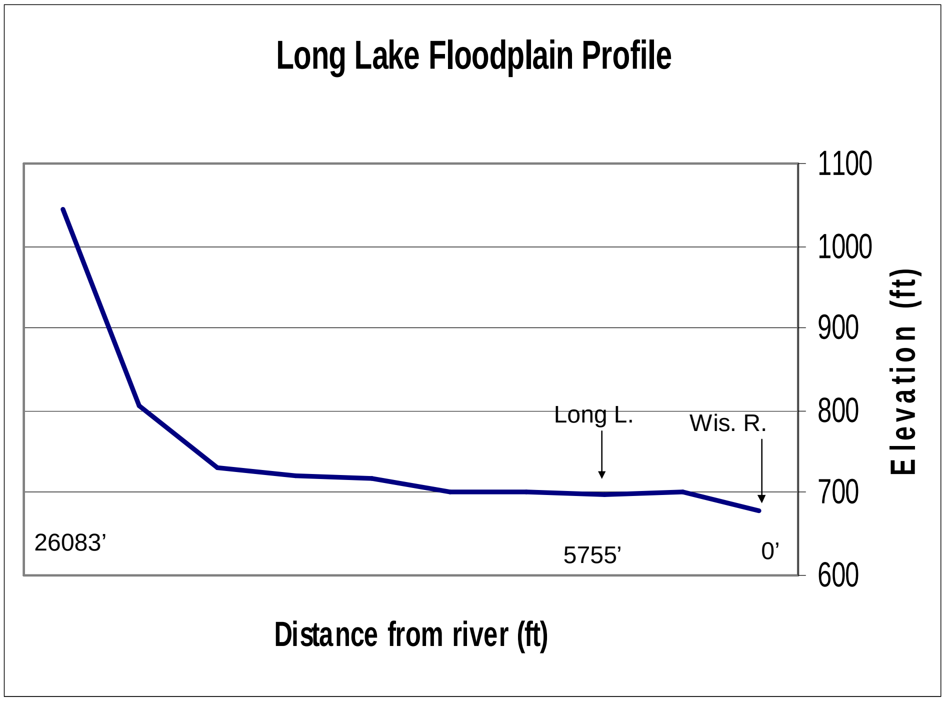


Figure 24: Cross section encompassing river, Long Lake and upland elevations.



Bakkens Pond and Long Lake lie adjacent to the broad valley plain that originated near Spring Green (Figure 24). The watershed again is level in this area with coarse soils that drain quickly. The estimated Bakkens Pond watershed is 640 acres with woodlands comprising about 60% and croplands about 30% of the area. The estimated annual phosphorus load is 155 lbs. The high fertility in Bakkens Pond suggests greater phosphorus loading than this estimate indicated but the amount does not reflect potential groundwater inputs or other factors. River flooding can be a significant nutrient source. Unlike the more linear braided channel oxbows that exhibit higher flood velocities, the Bakkens Pond impoundment may trap more nutrients and sediment than the channel oxbows. The Long Lake watershed area is about 448 acres with low level residential as the dominant land use. Estimated annual phosphorus load is about 144 lbs. Septic systems in the area may be a contributing factor but were not part of this estimate.

Discussion

The planning grant study revealed diverse floodplain lakes in Sauk County, a reflection of a natural river floodplain. These habitats sustain the high biodiversity and provide important ecological functions linked to the main river channel. Some of the braided channel oxbows and other lakes are continuously connected to the main river channel and support a blend of riverine and lake fish populations. These habitats also provide important nursery habitat for immature river fish (Amoros 2001, Killgore and Miller 1995). Other oxbows are isolated from the river channel except under floodwater conditions. In many other river systems, these unique habitats had been destroyed by dams as the diverse oxbows become permanently flooded.

In the past, floodplain lakes had been rarely sampled for either fish populations or water quality parameters. Some of the waterbodies we sampled are described in “Surface Water Resources of Sauk County”, a document that DNR had prepared in 1971 but lacks significant fisheries or water quality information. Lyons et al. (2000) indicated that State Endangered starhead topminnows were more widespread along the Lower Wisconsin State Riverway than previously reported. More recently, the oxbows along the river had been described as important habitats for starhead topminnows and other rare species (Marshall and Lyons 2008). The 2008 Lake Planning Grant Study surveys revealed high numbers of State Endangered starhead topminnows in all of the habitats we sampled. The starhead topminnow is now more common than previous distribution maps found in “Fishes of Wisconsin” (Becker 1983) or “Distribution and Relative Abundance of Fishes in Wisconsin” (Fago 1992). The Sauk County floodplain lakes may be the “topminnow sanctuary” that Becker (1983) had envisioned for the survival of this rare species.

Upland groundwater plays an important role in the survival of starhead topminnows and other fish species. There are some indications that habitat linked to water quality and upland groundwater may have improved over the years. Long term United States Geological Survey data indicate rising groundwater levels and increasing tributary lowflow rates in the Driftless Area (Figure 25) (Giebert and Krug 1996, Potter 1991). These changes were linked to improved agricultural land use practices. Increased tributary lowflow rates to the floodplain lakes may have improved habitat for starhead topminnows and other species in recent years. Flooding would then be the likely dispersal mechanism for fish to become established in favorable habitats.

Other factors likely contributed to improved floodplain lake and stream habitats. First, thanks to the Clean Water Act upper river pollutant loads declined precipitously since the early 1980’s. Implementation of the Clean Water Act and the Wisconsin Pollutant Discharge Elimination System resulted in a 95% reduction in Biochemical Oxygen Demand from point sources by the early 1980s (Figure 26). Floodplain habitats are now exposed to cleaner water during seasonal flood events. Secondly, land uses in the counties surrounding the Lower Wisconsin River have changed dramatically over the years, affecting nutrient loads. Just as baseflows have increased and peak flows have declined, watershed pollution loads had decreased. The numbers of dairy farms has declined by roughly 50% since the 1970s and animal unit numbers (and manure production) declined even though average farm sizes increased (Figure 27). Coinciding with reduced numbers of dairy farms was participation in the federal Conservation Reserve Program (CRP) since 1986 (Figure 28). Improved farming practices and implementation of CRP had greatly improved trout streams within the Driftless Area (Marshall et al. 2008). The same land use practices that had benefited trout streams may have benefited floodplain habitats but more research is needed to support this hypothesis. Of concern is the more recent decline in CRP participation as the value of corn for ethanol production increased.

The dissolved oxygen and temperature profile data that we collected demonstrated significant sources of upland groundwater occur in most of the lakes we sampled. Alternatively, Wood Slough is an example of a floodplain lake that is influenced by alluvial groundwater and water quality conditions that are marginal for fish species. Other lakes with even lower dissolved oxygen levels and higher dissolved organic matter were sampled as part of the recent River Planning Grant Study. A continuum exists ranging from upland adjacent lakes to highly organic and stained lakes influenced by alluvial groundwater. These diverse habitats expand biodiversity within the floodplain. While alluvial groundwater lakes such as Wood Slough are more isolated from upland land uses, the upland adjacent braided channel oxbows and other lakes are more vulnerable to nearshore habitat loss, runoff pollution and groundwater pollution and reduction in flow. Upland watershed management can have a greater influence on the conditions in these lakes than the river. Sustaining strong and clean upland groundwater flow is necessary for sustaining these oxbows during stressful periods such as late winter ice cover or during flooding when the alluvial groundwater table rises and enters the upland adjacent lakes.

Figure 25: USGS Stream Flow Data – example of increase tributary flows.

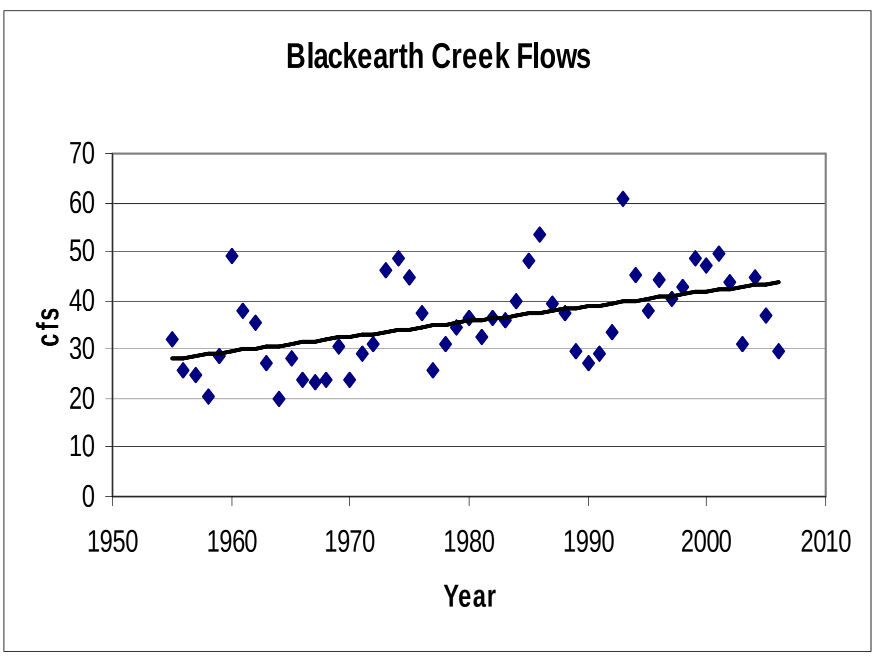


Figure 26: Decline in upper river point source pollution

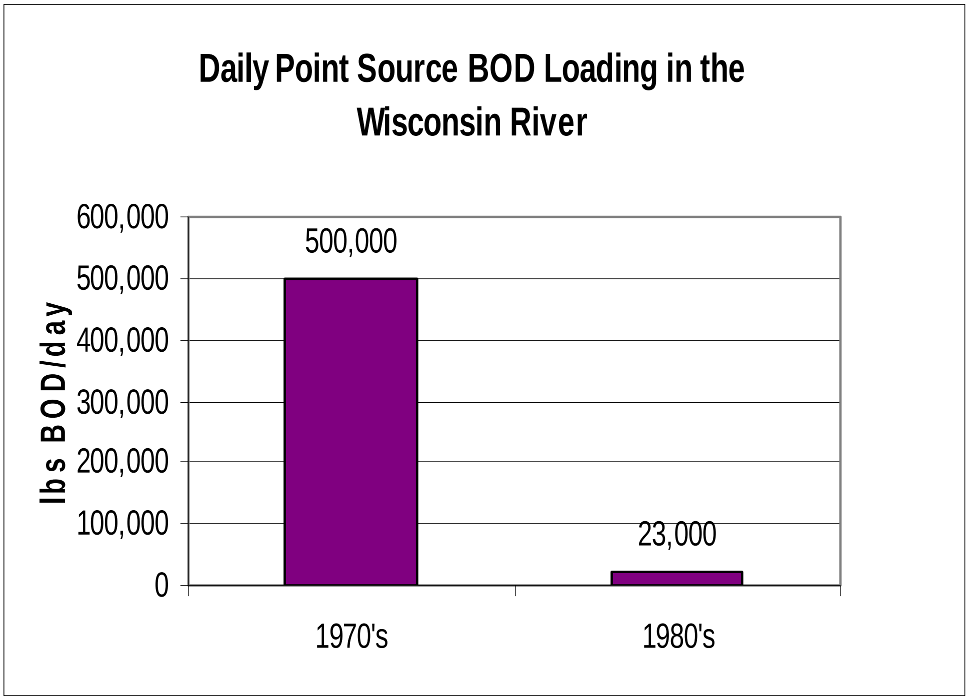


Figure 27: Change in Driftless Area farming

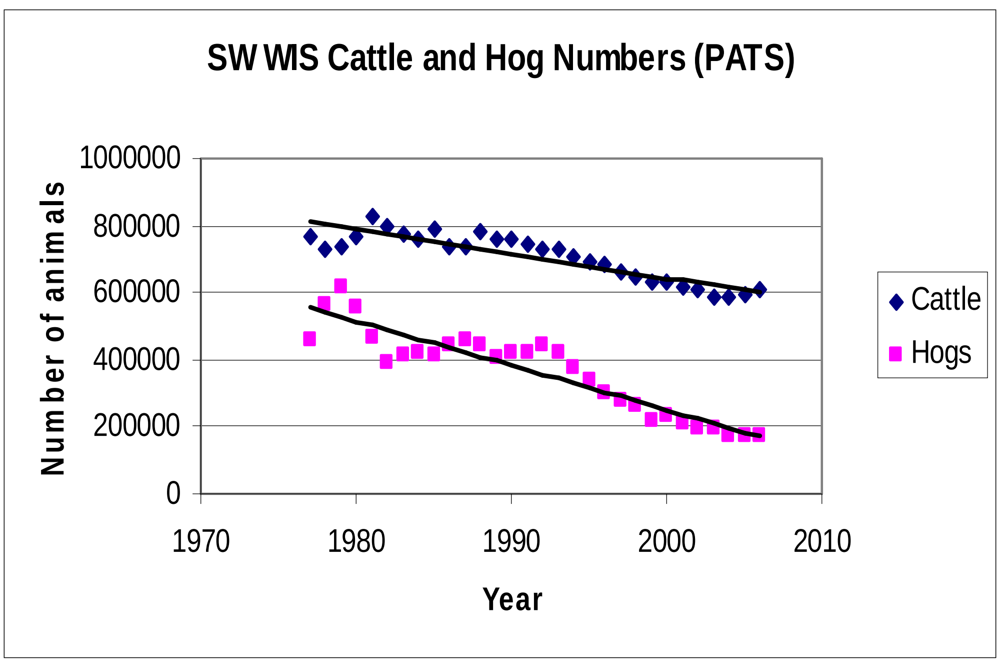
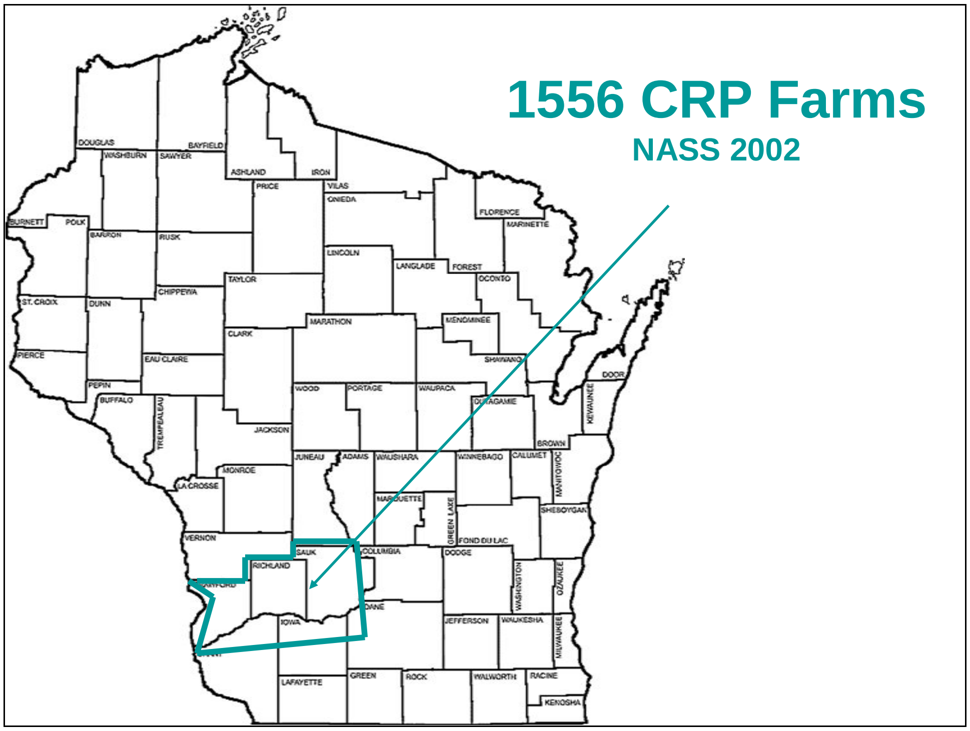


Figure 28: CRP participation within the Lower Wisconsin River watershed (2002)



Acknowledgements

We wish to thank Executive Director Mark Cupp and the Lower Wisconsin State Riverway Board for their continued support for floodplain habitat studies. We also thank Doug and Sheryl Jones for providing access and local knowledge about the Jones-Norton-Wood-Hutter chain of lakes. And Ted Cochrane for accepting and correcting misidentified plant species that we submitted for the UW Madison Herbarium.

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Appendix A

Waterbody	WBIC	Date	Fish Species and Number
Bakkens	1236900	8/6/08	Golden shiners 3, brook silversides 29, starhead topminnow 1
Cynthia	1241300	8/11/08	Brook silversides, bluegills, starhead topminnows 5
Deacon Thomas	1232600	9/5/08	Golden shiners 19, g. pickerel 1, starhead topminnows 20, bluegill 2, warmouth sunfish 1
Hill	1241200	8/7/08	Brook silversides, lake chubsucker 1, starhead topminnows 6, bluegills 10, largemouth bass 2
Hutter	1247000	8/14/08	g. pickerel 1, brk. silversides 2, starhead topminnows 30, bluegills 10, largemouth bass 1, johnny darter 1
Jones	1247300	8/14&21/08	Mudminnows 13, g. pickerels 7, lake chubsucker 6, starhead topminnows 20, warmouth sunfish 1
Long	1252500	8/6/08	Brook silversides 2, starhead topminnows 6, bluegills 8, largemouth bass 2, mud darter 1
Norton	1247100	8/13/08	Mudminnow 1, g. pickerel 1, golden shiners 2, starhead topminnows 10, bluegill 2, largemouth bass 1
Wood	1247200	8/13/08	Mudminnows 3, g. pickerel 1, n. pike 1, starhead topminnows 4, bluegills 12
“Wagner”	5574197	8/7/08	Starhead topminnows 2, bluegills 148, pumpkinseed 1, largemouth bass 1
unnamed	5574197	8/21/08	Mudminnow 1, black bullhead 1, starhead topminnows 5
“Badger Val.”	1248000	8/26/08	Mudminnow 1, g. pickerel 4, brk. silversides 2, starhead topminnows 6, bluegills 121
Wilson Cr.	1247500	9/12/08	Golden shiners 2, g. pickerel 1, starhead topminnow 103, bluegills 16, johnny darters 4

Appendix B: Plants submitted to UW Madison Herbarium

Waterbody	WBIC	Common Name	Scientific Name
Bakkens	1236900	Curly-leaf pondweed	*Potamogeton crispus*
Bakkens	1236900	Leafy pondweed	*Potamogeton foliosus*
Bakkens	1236900	Muskgrass	*Chara*
Bakkens	1236900	Buttercup	*Ranunculus longirostris*
Bakkens	1236900	Common waterweed	*Elodea canadensis*
Bakkens	1236900	Eurasian watermilfoil	*Myriophyllum spicatum*
Bakkens	1236900	Clasping-leaf pondweed	*Potamogeton richardsonii*
Bakkens	1236900	Coontail	*Ceratophyllum demersum*
Bakkens	1236900	White water lily	*Nymphaea odorata*
Cynthia	1241300	Eurasian watermilfoil	*Myriophyllum spicatum*
Cynthia	1241300	Sago pondweed	*Struckenia pectinatus*
Cynthia	1241300	Muskgrass	*Chara*
Hill	1241200	Eurasian watermilfoil	*Myriophyllum spicatum*
Hill	1241200	Coontail	*Ceratophyllum demersum*
Norton	1247100	Slender naiad	*Najas flexilis*
Norton	1247100	Fries pondweed	*Potamogeton friesii*
Norton	1247100	Coontail	*Ceratophyllum demersum*
Norton	1247100	Common waterweed	*Elodea canadensis*
Norton	1247100	Long-leaf pondweed	*Potamogeton nodosus*
Norton	1247100	Sago pondweed	*Struckenia pectinatus*
Norton	1247100		*Ludwigia palustris*
Norton	1247100	Bur-reed	*Sparganium sp.*
Norton	1247100	Water stargrass	*Heteranthera dubia*
Norton	1247100	Eurasian watermilfoil	*Myriophyllum spicatum*
Norton	1247100	Bladderwort	*Utricularia dubia*
Long L.	1252500	Coontail	*Ceratophyllum demersum*
Long L.	1252500	Eurasian watermilfoil	*Myriophyllum spicatum*
Long L.	1252500	White water lily	*Nymphaea odorata*
“Badger Val”	1248000	Eurasian watermilfoil	*Myriophyllum spicatum*
“Badger Val”	1248000	Coontail	*Ceratophyllum demersum*
“Badger Val”	1248000	Sago pondweed	*Struckenia pectinatus*
“Badger Val”	1248000	Common waterweed	*Elodea canadensis*

Appendix B continued			
“Badger Val”	1248000	Water stargrass	*Heteranthera dubia*
Wilson Cr	1247500	Water stargrass	*Heteranthera dubia*
Wilson Cr	1247500	Eurasian watermilfoil	*Myriophyllum spicatum*
Wilson Cr	1247500	Large-leaf pondweed	*Potamogeton amplifolius*
Wilson Cr	1247500	Curly-leaf pondweed	*Potamogeton crispus*
Wilson Cr	1247500	Sender arrowhead	*Sagittaria graminea*
Wilson Cr	1247500	Horned pondweed	*Zannichellia palustris*
Wilson Cr	1247500	Leafy pondweed	*Potamogeton foliosus*
Wilson Cr	1247500	Muskgrass	*Chara*
Wilson Cr	1247500	N. watermilfoil	*Myriophyllum sibiricum*
Un. Borrow pit	5573400	Long-leaf pondweed	*Potamogeton nodosus*
Un. Borrow pit	5573400	Buttercup	*Ranunculus longirostris*
Un. Borrow pit	5573400	Slender naiad	*Najas flexilis*
Un. Borrow pit	5573400	N. watermilfoil	*Myriophyllum sibiricum*
Un. Borrow pit	5573400	Coontail	*Ceratophyllum demersum*
Un. Borrow pit	5573400	Sago pondweed	*Struckenia pectinatus*
Un. Borrow pit	5573400	Long-leaf pondweed	*Potamogeton nodosus*
Un. Borrow pit	5573400	Large-leaf pondweed	*Potamogeton amplifolius*

Appendix C: SLOH Water Chemistry Results

Waterbody	WBIC	Date	T.P. - ug/l	Chl a - ug/l	Color - su
Bakkens	1236900	8/6/08	59	2.29	5
Cynthia	1241300	8/11/08	28	9.01	5
D. Thomas east	1232600	9/5/08	26	3.4	15
D. Thomas west	1232600	9/5/08	18	0.96	15
Hill	1241200	8/7/08	24	0.67	5
Hutter	1247000	8/14/08	34	2.88	15
Jones	1247300	8/14&21/08	35	2.86	10
Long	1252500	8/6/08	21	0.79	5
Norton	1247100	8/13/08	27	5.2	10
Wood	1247200	8/13/08	177	15.7	50
“Wagner”	5574197	8/7/08	31	8.38	35
unnamed	5574197	8/21/08	17	2.06	10
“Badger Val.”	1248000	8/26/08	56	24.7	10

Apendix D: Field Profiles and Water Clarity

	8/6/2008	Bakkens Pond		43 10.734 - 90 9.297		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
	>120 cm	0.5	8.37	13.2	18.4	429
	8/11/2008	Cynthia Slough		43 9.631 - 90 4.548		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
5.2'	90 cm	0.5	8.49	13.4	19.5	423
		1	8.4	13.5	18.5	339
		1.5	8.07	16.4	16.9	453
	8/11/2008	Cynthia Slough		43 9.631 - 90 4.548		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
4.8'	90 cm	0.5		13.4	19.5	
		1		13.5	18.5	
		1.5		16.4	16.9	
		2		13.1	15.6	
		2.5		7	14.8	
	9/5/2008	Deacon Thomas L.		43 12.161 - 89 51.329		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
	>120 cm	0.5	9.24?	12.1	20.2	168
	9/5/2008	Deacon Thomas L.		43 12.191 - 89 51.528		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
	>120 cm	0.5	8.7	8	20	218
	8/7/2008	Hill Slough		43 10.021 - 90 5.959		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
5'	>120 cm	0.5	8.65	8.9	20.5	348
		1	8.64	8.2	18.6	373
		1.5	8.81	8.2	15.7	373
	8/7/2008	Hill Slough		43 10.0567 - 90 6.257		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
>5'	>120 cm	0.5	8.52	8.3	22.6	321
		1	8.1	6.8	21.5	330
		1.5	8.1	4.4	19.2	337

	8/14/2008	Hutter Slough		43 10.885 - 90 2.228		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
7'	>120 cm	0	8.01	9.4	21.9	405
		0.5	7.96	9.6	20.9	419
		1	7.62	5.4	19.5	416
		1.5	7.65	4.4	18.4	416
		2	7.79	7.6	17.3	412
		2.5	7.71	6.3	16	405
	8/21/2008	Jones Slough		43 11.516 - 90 1.494		
Secchi	Trans. Tube	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
5.5'	>120 cm	0	7.46	5.2	17.8	423
		0.5	7.24	3.9	13.6	517
		1	7.6	18.7	12.8	567
		1.5	7.54	20	11.9	532
		2	7.2	7.7	11.3	532
		2.5	7.28	2.5	11	569
		Long Lake		43 10.402 - 90 10.142		
	8/6/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0.5	7.98	6.5	21.7	349
	>120 cm	1	7.93	6	20.3	353
		1.5	8.02	8.6	16.1	342
		Long Lake		43 10.367 - 90 10.969		
	8/6/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0.5	8.3	8.5	22.8	336
5.5'	>120 cm	1	8.25	8.6	21.5	335
		1.5	8.04	7.5	18.7	332
		2	7.9	6	17.9	336
		Norton Slough		43 11.239 - 90 1.7082		
	8/13/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0	7.68	7.7	21.1	462
6.2'	>120 cm	0.5	7.57	6	18.9	461
		1	7.45	4.9	17.5	476
		1.5	7.45	4.9	16.9	471

		Norton Slough		43 11.215 - 90 2.005		
	8/13/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0	7.65	7.3	21	450
>6'	>120 cm	0.5	7.72	8.4	17.7	425
		1	7.96	12.3	14.2	430
		1.5	7.94	11.5	13	434
		"Badger Valley"		43 11.866 - 89 56.544		
	8/26/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0	7.95	10	18.2	533
>3'	72	0.5	7.97	10	16.5	522
		Wood Slough		43 11.372 - 90 1.357		
	8/13/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0		3	22.7	
4.1'	>120 cm	0.5	7.06	2	22.1	277
		1	7.03	0.36	21	279
		1.5	7.07	0.4	21	272
		Wood Slough		43 11.332 - 90 1.501		
	8/13/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0	7.17	3.1	21.6	325
3	115 cm	0.5	7.11	1.3	20.2	327
		1	6.93	0.5	19	371
		1.5	7.03	0.3	17	415
		"Wagner" borrow pit		43 8.918 - 90 3.058		
	8/7/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0.5	8.98	11.1	25.9	203
3.8'	100 cm	1	9.02	11.6	25	203
		1.5	8.77	9.1	24.3	205
		2	7.29	1.9	23.3	212
		2.5	7.12	0.2	20.6	232
		unnamed borrow pit		43 9.047 - 90 3.628		
	8/21/2008	Depth m	pH su	D.O. mg/l	Temp. C	Sp Cond.
Secchi	Trans. Tube	0.5	7.96	7.6	25.1	340
>13'	>120	1	7.95	7.5	25.1	341
		1.5	7.93	7.5	25.1	341
		2	7.81	7.6	25	341
		2.5	7.19	7	24.6	341
		3	7.05	7	22.7	343
		3.5	7.02	3.4	20.1	347