Hey and Associates, Inc.

ALTO CREEK MONITORING PROJECT
FINAL REPORT

FOX LAKE, DODGE COUNTY, WISCONSIN

Prepared for:

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INTRODUCTION

Fox Lake is a 1,022-hectare (2,625-acre) lake located in northwestern Dodge County. In the 1980's and 1990's, Fox Lake experienced a rapid shift in water quality from a clear-water lake to one characterized by poor-water transparency, increased algae populations, loss of aquatic macrophytes, loss of wetland fringe, and declining sports fishery. In the mid 1990's, the Fox Lake Inland Lake Protection and Rehabilitation District (FLILPRD), in partnership with the Wisconsin Department of Natural Resources (WDNR) began implementation of a long-range management project to shift the lake back into a clear-water state. In 1995 a long-range management strategy for Fox Lake was developed by an advisory committee that included FLILPRD, WDNR, Dodge County, University of Wisconsin-Extension, Town of Fox Lake, City of Fox Lake, and civic and sportsman groups. The project management strategy is outlined in a report tilted, *Long Range Planning Strategy for the Rehabilitation of Fox Lake, Dodge County* (R. A. Smith and Associates, Inc. 1998).

To deal with the complex water quality problems at Fox Lake, the planning and rehabilitation process was broken down into the following components:

1. Watershed management to reduce sediment and nutrient inputs
2. Shoreline stabilization to reduce erosion
3. Aquatic plant management to restore rooted aquatic vegetation
4. Fishery Management (bio-manipulation to reduce rough fish and increase top predators)
5. Lake use management to protect sensitive areas
6. Public education

In 2005 and 2006 the University of Wisconsin and Hey and Associates, Inc. conducted an intensive lake and watershed monitoring program to evaluate the success of the above management strategy. The results of the monitoring are summarized in a report titled: *Fox Lake Management Strategy Evaluation and Recommendations for Future Action – 2008*, (Hey and Associates, Inc. and UW-Milwaukee, 2008). The monitoring documented that high levels of nitrogen and phosphorus were entering the lake from the lake's three tributaries.

The purpose of this project was to collect additional data on sources of nitrogen, phosphorus and sediment entering Fox Lake from the Alto Creek watershed. The work is a follow-up to sampling in 2005 and 2006 conducted by the University of Wisconsin-Milwaukee. The goal of the project is to narrow down which watershed activities, such as feedlots, animal waste storage and spreading, wastewater treatment, and tillage practices on specific properties are contributing to the high concentration of nitrogen and phosphorus being experienced in the previous sampling.

SAMPLING METHODS

Sampling was conducted at six sites illustrated on Figure 1. Samples were collected on four dates in the fall of 2009 and summer of 2010. Samples were analyzed for the following parameters:

- TOTAL KJELDAHL NITROGEN
- NITRATE PLUS NITRITE-NITROGEN
- TOTAL PHOSPHORUS
- DISSOLVED PHOSPHORUS
- TOTAL SUSPENDED SOLIDS (SEDIMENT)
- FECAL COLIFORM (MFFCC) (BACTERIA)
- STREAM FLOW

All sampling was conducted using the methods outlined in:

- Edwards, T.K., and G.D. Glysson. 1999. *Field Methods for Measurement of Fluvial Sediment, Book 3, Chapter C2*. Techniques of Water-Resources Investigations of the United States Geological Survey, U.S. Government Printing Office, Washington, DC.

- Shelton, L. R., 1994. *Field Guide for Collecting and Processing Stream Water Samples for the National Water-Quality Assessment Program*, Open-File Report 94-455, United States Geological Survey, Sacramento, California.

- United States Geological Survey (USGS). 2005. *Techniques of Water Resources Investigations Reports. Book 3: Applications of hydraulics, Section A: Surface-water techniques.* (21 chapters). United States Department of Interior, U.S. Geological Survey. Washington D.C. http://water.usgs.gov/pubs/twri/.

All water quality and bacterial samples were iced upon collection and transported by cooler to the Wisconsin State Laboratory of Hygiene in Madison Wisconsin for analysis.

Flow velocities were measured using a Marsh McBerny FlowMate® flow meter.

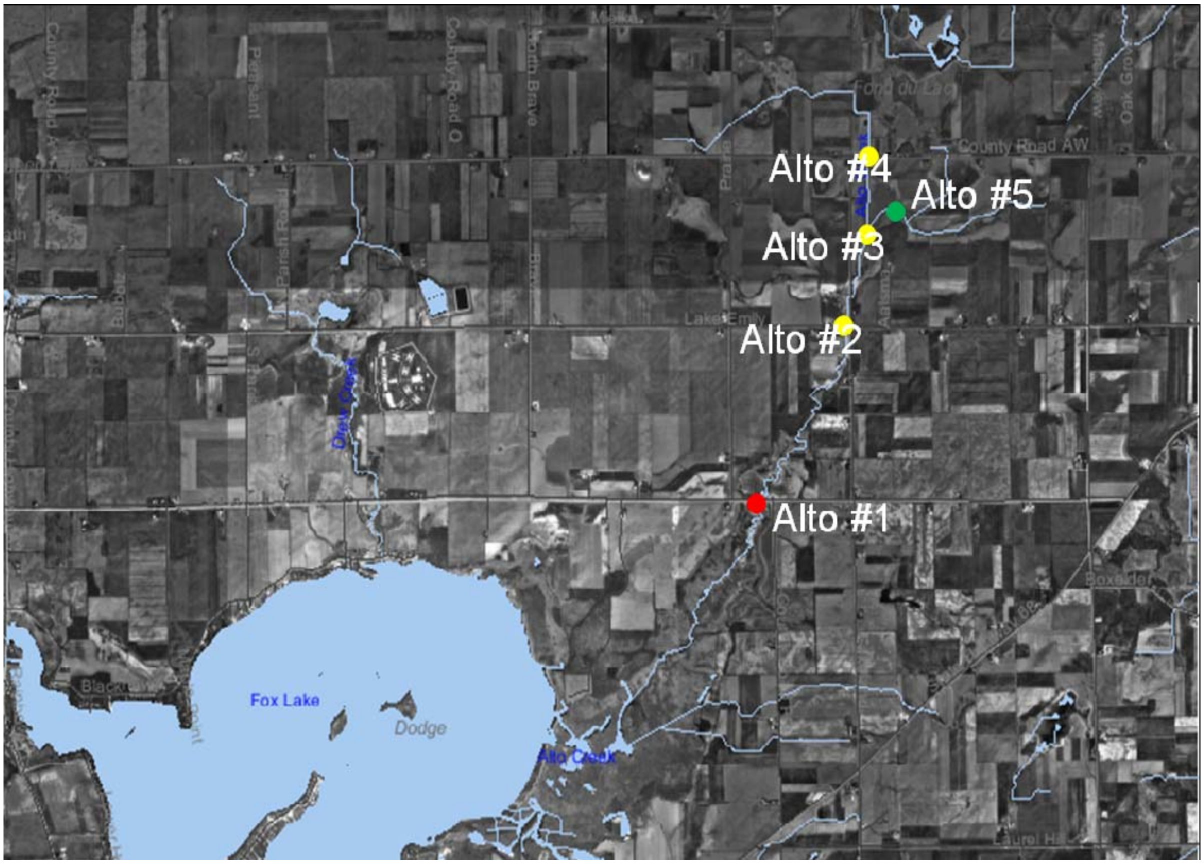

Figure 1
Location of Sampling Points

SUMMARY OF UW-MILWAUKEE 2006 SAMPLING

As discussed above, the University of Wisconsin-Milwaukee (UWM) conducted tributary monitoring of Alto, Drew and Cambra Creeks in spring and summer of 2006. In the Alto Creek watershed samples were collected at four sites. The sites were No. AC-1 (CTH F), No. AC-2 (Lake Emily Road) and No. AC-3 (Snowmobile bridge WDNR property), and AC-4 (CTH W) illustrated on Figure 1. The mean values of the UWM sampling are summarized in Table 1. Included in the table for comparisons are statewide means and ranges for nitrogen and phosphorus based on data for 240 streams as part of the study, *Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin* (USGS, 2006). Values in bold text indicate mean concentrations above the state, ecoregion or environmental phosphorus zone averages as reported by USGS.

Table 1

Results of UWM Tributary Monitoring
Mean Values from Five Sampling Dates in 2006

Watershed and Station No.	Total Suspended Solids (mg/l)	Organic Nitrogen (TKN) (mg/l)	Nitrate/Nitrite (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Dissolved Phosphorus (SRP) (mg/l)
Alto No. AC-1	9.878	0.654	*12.893*		0.070	0.043
Alto No. AC-2	31.600	*1.040*	*8.830*		*0.117*	0.067
Alto No. AC-3	18.520	*1.216*	*7.770*		*0.129*	0.074
Alto No. AC-4	25.720	*1.472*	*8.536*		*0.129*	0.065
	Statewide Means (USGS, 2006)					
Mean	-	0.675	2.086	2.807	0.116	0.079
Median		0.563	1.048	1.695	0.085	0.050
Minimum	-	0.070	0.005	0.131	0.012	0.004
Maximum	-	2,350	20.550	21.260	1.641	1.495
Standard deviation	-	0.414	2.865	2.860	0.144	0.122
	Eco-region Means (USGS, 2006)					
Median	-	-	-	0.811	0.025	-
0% percentile	-	-	-	0.777	0.023	-
100 percentile	-	-	-	21.260	1.641	-
	Environmental Phosphorus Zone Means (USGS, 2006)					
Median	-	-	-	0.632	0.042	-
0% percentile	-	-	-	0.298	0.016	-
100 percentile	-	-	-	21.260	0.304	-

Source: University of Wisconsin-Milwaukee and Wisconsin Laboratory of Hygiene and USGS (2006)

As can be seen Alto Creek has concentrations of organic nitrogen (TKN), and nitrate/nitrite that far exceed the statewide means (bold text). Total phosphorus concentrations slightly exceed statewide mean and median levels.

RESULTS OF HEY SAMPLING

The results of the 2009-2010 sampling by Hey and Associates are summarized in Table 2 (field parameters) and Table 3 (laboratory parameters).

Table 2

Results of Alto Creek Tributary Monitoring 2009 -2010
Field Parameters

Site Location	Site No.	Date	Flow (cfs)	Flow (MGD)	Temp (^{0}F)	Dissolved Oxygen (mg/l)	Conductivity
HWY F	AC-1	12/8/2009	2.81	1.82	1.90	13.86	1012
		5/5/2010	12.15	7.85	11.60	10.73	777
		8/2/2010	32.50	21.00	15.60	4.28	NA
		8/22/2010	18.33	11.84	13.10	6.25	NA
		Mean	**16.45**	**10.63**	**10.55**	**8.78**	**894.50**
Lake Emily Road	AC-2	12/8/2009	2.23	1.44	3.00	13.00	1064
		5/5/2010	6.33	4.09	11.70	8.66	825
		8/2/2010	13.25	8.56	17.50	5.97	NA
		8/22/2010	9.47	6.12	14.80	7.10	NA
		Mean	**7.82**	**5.05**	**11.75**	**8.68**	**944.50**
Snow-mobile Crossing WDNR Property	AC-3	12/8/2009	1.36	0.88	3.70	11.86	950
		5/5/2010	5.515	3.56	11.60	9.32	805
		8/2/2010	9.72	6.28	18.20	3.81	NA
		8/22/2010	1.057	0.68	15.10	5.61	NA
		Mean	**4.41**	**2.85**	**12.15**	**7.65**	**877.50**
CTH-W	AC-4	12/8/2009	0.91	0.59	2.40	12.41	936
		5/5/2010	1.671	1.08	13.90	10.85	782
		8/2/2010	5.314	3.43	18.00	4.48	NA
		8/22/2010	1.545	1.00	16.40	3.75	NA
		Mean	**2.36**	**1.53**	**12.68**	**7.87**	**859.00**
Unnamed Tributary from East	AC-5	12/8/2009	0.10	0.06	4.80	10.81	926
		5/5/2010	3.21	2.08	12.30	8.22	787
		8/2/2010	TDTM	TDTM	18.20	4.08	NA
		8/22/2010	TDTM	TDTM	14.80	6.24	NA
		Mean	**1.66**	**1.07**	**12.53**	**7.34**	**856.50**

Table 3

Results of Alto Creek Tributary Monitoring 2009 -2010
Laboratory Parameters

Site Location	Site No.	Date	TP (mg/l)	SRP (mg/l)	TSS (mg/l)	TKN (mg/l)	NO2 NO3 (mg/l)	E-Coli (Counts per 100 ml)
HWY F	AC-1	12/8/2009	0.087	0.028	30	ND	**11.9**	12
		5/5/2010	0.069	0.041	18	0.48	**11.7**	108
		8/2/2010	**0.128**	**0.120**	4	0.53	**9.28**	140
		8/22/2010	0.116	**0.072**	13	0.58	**12.5**	162
		Mean	**0.100**	**0.065**	**16**	**0.53**	**11.3**	**106**
Lake Emily Road	AC-2	12/8/2009	0.050	0.022	10	0.40	**11.2**	15
		5/5/2010	0.078	0.051	12	**0.91**	**7.88**	86
		8/2/2010	**0.237**	**0.217**	20	**1.16**	**7.29**	**270**
		8/22/2010	**0.149**	**0.107**	14	**0.62**	**9.56**	166
		Mean	**0.129**	**0.099**	**14**	**0.77**	**9.0**	**134**
Snow-mobile Crossing WDNR Propertyt	AC-3	12/8/2009	0.051	0.024	11	0.51	**9.11**	10
		5/5/2010	0.095	0.063	15	**0.94**	**6.56**	49
		8/2/2010	**0.272**	**0.240**	24	**1.33**	**6.23**	130
		8/22/2010	**0.170**	**0.119**	18	**0.97**	**8.6**	111
		Mean	**0.147**	**0.112**	**17**	**0.94**	**7.6**	**75**
CTH-W	AC-4	12/8/2009	NA	NA	NA	NA	NA	NA
		5/5/2010	NA	NA	NA	NA	NA	NA
		8/2/2010	NA	NA	NA	NA	NA	NA
		8/22/2010	**0.186**	**0.137**	18	0.97	**9.05**	NA
		Mean	**-**	**-**	**-**	**-**	**-**	**-**
Unnamed Tributary from East	AC-5	12/8/2009	0.049	0.022	2	0.26	**1.42**	4
		5/5/2010	0.104	0.071	9	**0.82**	**6.31**	50
		8/2/2010	**0.331**	**0.286**	23	**1.6**	**5.73**	230
		8/22/2010	**0.129**	**0.098**	3	**0.70**	**8.62**	102
		Mean	**0.153**	**0.119**	**9**	**0.85**	**5.5**	**97**

- NA = sample lost at State Laboratory of Hygiene

Concentrations highlighted in Table 3 are levels above statewide means for nitrogen and phosphorus based on data for 240 streams as part of the study, *Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin* (USGS, 2006), or above state water quality standards for bacteria.

Stream Flow

Stream flow was measured on each of the sampling dates. Figure 2 illustrates the variability of flow from upstream to downstream. Generally flow increased as we moved downstream. The greatest increase in flow was seen between the two downstream stations AC-2 (Lake

Emily Road) and AC-1 (CTH F) where flows increases from 1.85 to 207 percent with a mean increase of 92 percent. At station AC-5, the eastern tributary flow on August 2 and August 22, 2010 was over the bank in a large marsh area and unable to be measured.

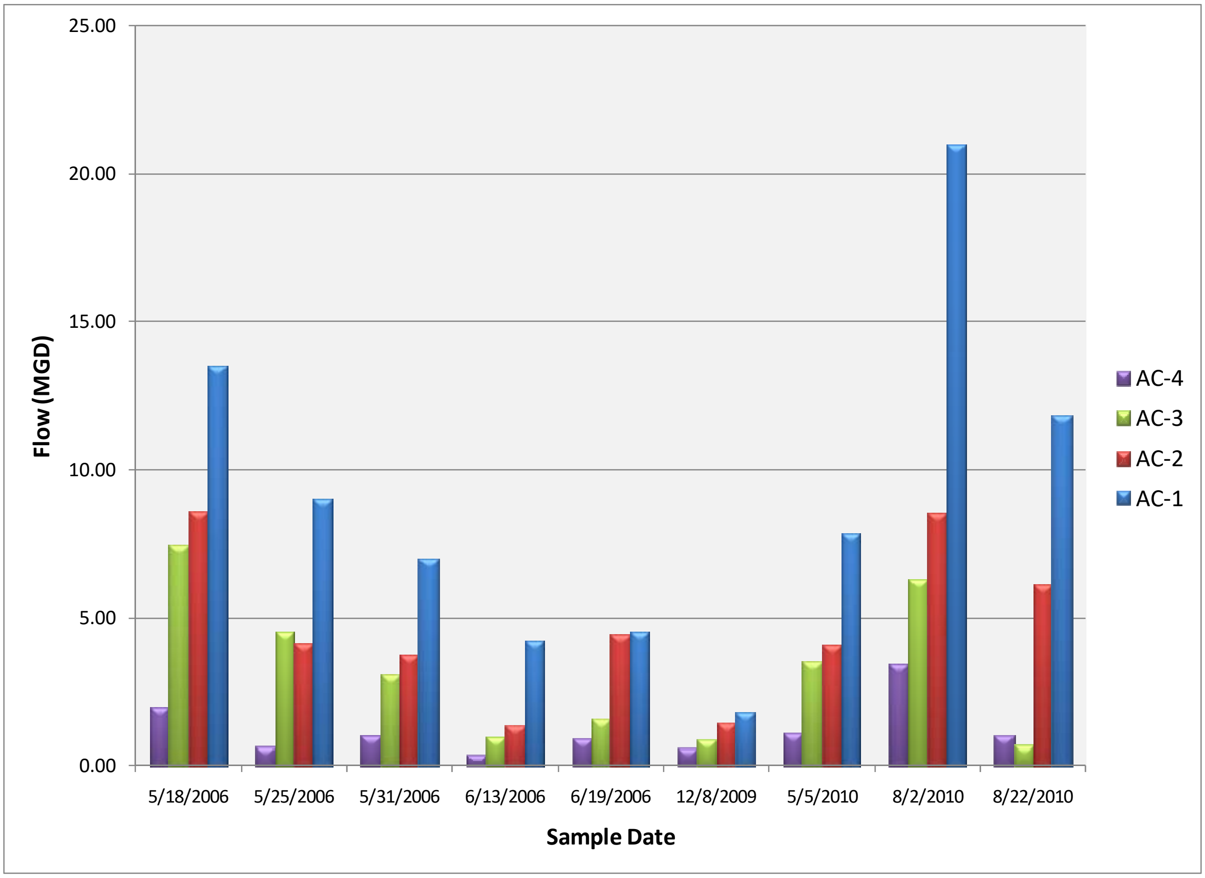

Figure 2
Relationship of Stream Flow from Upstream to Downstream by Sample Date

Total Suspended Solids

Total suspended solids (TSS) include all particles suspended in water which will not pass through glass-fiber filter disk. Suspended solids are associated with nonpoint source pollution, such as soil erosion from agricultural and construction sites. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. Suspended solids absorb heat from sunlight, which increases water temperature and subsequently decreases levels of dissolved oxygen. Warmer water holds less oxygen than cooler water. Photosynthesis also decreases, since less light penetrates the water causing less oxygen to be produced by plants and algae. TSS can also destroy fish habitat because suspended solids settle to the bottom and cover coarse bottom materials. Suspended solids can smother the eggs of fish and aquatic insects, and can suffocate newly-hatched insect larvae. Suspended solids can also harm fish by clogging gills, reducing growth rates, and lowering resistance to disease. As suspended solids settle in the calm waters of the lake, they fill in bays impacting recreational use. Levels above 40 mg/l cause water to become cloudy and above 100 mg/l begin to damage aquatic life.

In 2009-2010 sampling, TSS values ranged from 3 to 30 mg/l, indicating low levels of suspended sediment. The sampling indicates that surface erosion on the sampling dates was not a major problem. Figure 3 Illustrates the relationship of TSS concentrations from upstream to downstream by sample date. The data illustrates no relationships between upstream and downstream concentrations.

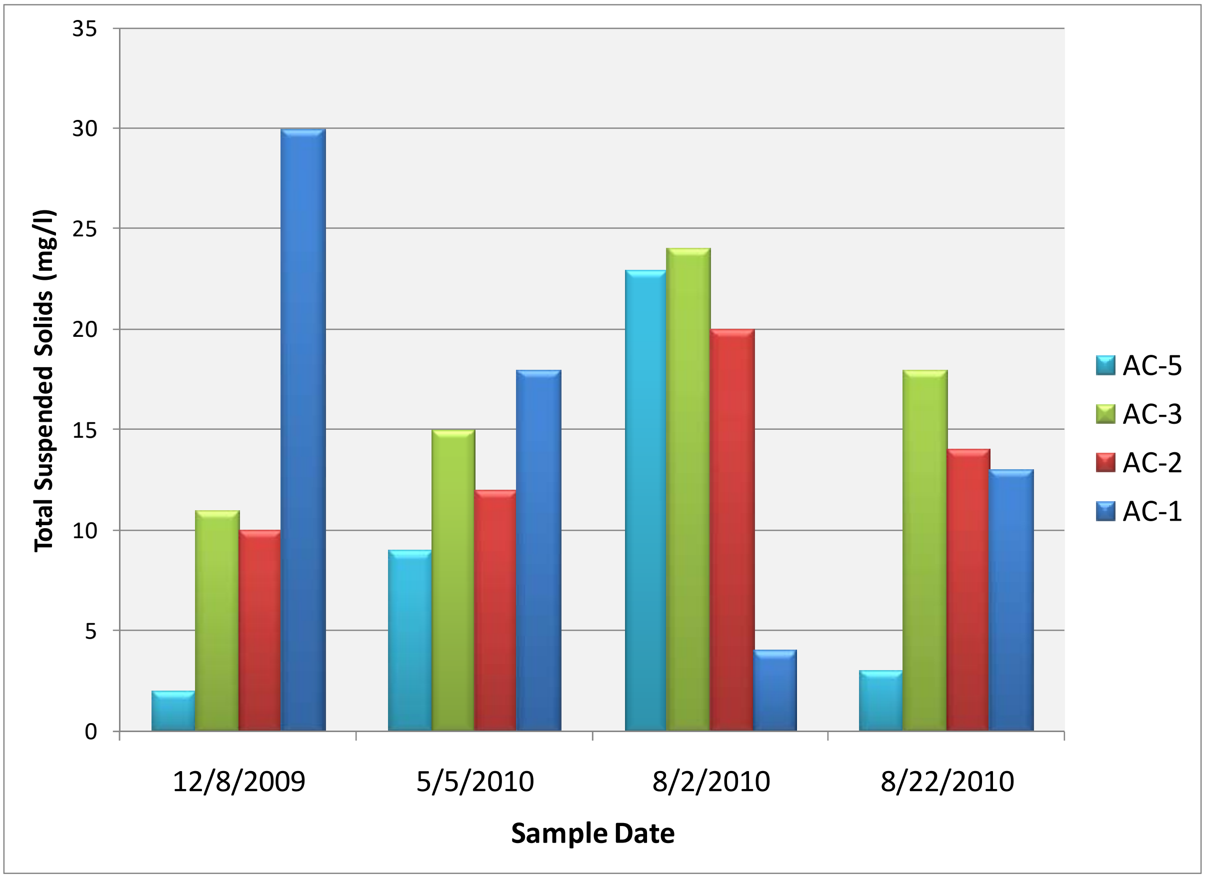

Figure 3
Relationship of Total Suspended Solids Concentrations from Upstream to Downstream by Sample Date

Table 3 summarizes the estimated loadings of TSS, nitrogen and phosphorus to Fox Lake at each of the Alto Creek sampling sites. Loading is the total mass in pounds that enters the lake per day or per year. Multiplying the measured stream flow times the pollutant concentration you can estimate daily pounds of a given pollutant that has entered the lake at that moment. Estimates of annual loading, as done in the 2005 -2006 UWM and Hey and Associates study would require additional flow and concentration data.

Table 3

Calculated Daily Pollutant Loadings in Pounds per day for the Alto Creek Tributary Monitoring by Sample Site 2009 -2010

Location	Site No.	Date	Flow (mgd)	TP (lbs/day)	SRP (lbs/day)	TSS (lbs/day)	TKN (lbs/day)	NO2 NO3 (lbs/day)
HWY F	AC-1	12/8/2009	1.82	1.32	0.43	455.36		180.63
		5/5/2010	7.85	1.05	0.62	273.22	7.29	177.59
		8/2/2010	21	1.94	1.82	60.72	8.04	140.86
		8/22/2010	11.84	1.76	1.09	197.32	8.80	189.74
		Mean	**10.63**	**1.52**	**0.99**	**246.66**	**8.04**	**172.20**
Lake Emily Road	AC-2	12/8/2009	1.44	0.76	0.33	151.79	6.07	170.00
		5/5/2010	4.09	1.18	0.77	182.15	13.81	119.61
		8/2/2010	8.56	3.60	3.29	303.58	17.61	110.65
		8/22/2010	6.12	2.26	1.62	212.50	9.41	145.11
		Mean	**5.05**	**1.95**	**1.51**	**212.50**	**11.73**	**136.34**
Snow-mobile Crossing WDNR Property	AC-3	12/8/2009	0.88	0.77	0.36	166.97	7.74	138.28
		5/5/2010	3.56	1.44	0.96	227.68	14.27	99.57
		8/2/2010	6.28	4.13	3.64	364.29	20.19	94.56
		8/22/2010	0.68	2.58	1.81	273.22	14.72	130.54
		Mean	**2.85**	**2.23**	**1.69**	**258.04**	**14.23**	**115.74**
CTH-W	AC-4	12/8/2009	0.59	NA	NA	NA	NA	NA
		5/5/2010	1.08	NA	NA	NA	NA	NA
		8/2/2010	3.43	NA	NA	NA	NA	NA
		8/22/2010	1	2.82	2.08	273.22	14.72	137.37
		Mean	**1.53**	**-**	**-**	**-**	**-**	**-**
Unnamed Tributary from East	AC-5	12/8/2009	0.06	0.74	0.33	30.36	3.95	21.55
		5/5/2010	2.08	1.58	1.08	136.61	12.45	95.78
		8/2/2010	TDTM	5.02	4.34	349.11	24.29	86.97
		8/22/2010	TDTM	1.96	1.49	45.54	10.63	130.84
		Mean	**1.07**	**2.33**	**1.81**	**140.40**	**12.83**	**83.79**

Phosphorus

Aquatic plants and algae require nutrients such as phosphorus, nitrogen, carbon, calcium, chlorides, iron, magnesium, sulfur, and silica for growth. In lakes where the supply of one or more of these nutrients is limited, plant and algae growth may also be limited. The two nutrients that most often limit and control the growth of plants are nitrogen and phosphorus. In nutrient limited lakes, if you add more nitrogen or phosphorus, you will get more plant or algae growth. The Southeastern Wisconsin Regional planning Commission (SEWRPC) has recommended that in-lake total phosphorus concentration be below 0.02 mg/l to prevent nuisance algae blooms. The State of Wisconsin has established under Wisconsin Administrative Code NR 102.06 a total phosphorus standard of 100 ug/L (0.10 mg/l) for unidirectional flowing waters (streams) and 30 ug/L (0.03 mg/l) for lakes that are both drainage and stratified lakes.

Two types of phosphorus were sampled; total phosphorus (TP) and soluble reactive phosphorus (SRP).

Phosphorus is found in natural environments in several forms including (Snoeyink and Jenkins, 1980):

- Orthophosphate (H_3PO_4, $H_2PO_4^-$, HPO_4^-, HPO_4^{2-}, HPO_4^{2-} complexes)
- Polyphosphates ($H_4P_2O_7$, $H4P_2O_7^-$, $H_4P_2O_7^{2-}$, $H_4P_2O_7^{3-}$, $H_4P_2O_7^{4-}$, $H_4P_2O_7^{3-}$complexes)
- Metaphosphate ($HP_3O_9^{2-}$, $HP_3O_9^{3-}$)
- Organic phosphates (phosphorus tied up in organic matter)

A test for total-phosphorus (TP) will identify the combined concentration of all of the above compounds. Orthophosphate and the other complexes of phosphorus found in the natural environment are generally not very soluble and typically bind with various cations such as calcium (Ca), magnesium (Mg), aluminum (Al) or iron (Fe). The most common complexes include the following:

- Calcium hydrogen phosphate $CaHPO4_{(s)}$ (pK_{so} +6.66)
- Calcium dihydrogen phosphate $Ca(H_2PO_4)_{2(s)}$ (pK_{so} +1.14)
- Hydroxyapatite $Ca_5(PO_4)_2OH_{(s)}$ (pK_{so} +55.9)
- Ferric phosphate $FePO_4$ (pK_{so} +21.9)
- Aluminum phosphate $AlPO_4$ (pK_{so} +21.0)

The solubility of these complexes in fresh water is defined by a solubility equilibrium constant (pK_{so}). The smaller the solubility constant the less soluble the compound is in water. Other complexes with sodium (Na), magnesium (Mg), manganese (Mn), and orthophosphate, pyrophosphate and tripophosphate also exist, making phosphorus equilibrium chemistry very complex.

The soluble reactive phosphorus (SRP) consists largely of the inorganic orthophosphate (PO_4) form of phosphorus. Orthophosphate is the phosphorus form that is directly taken up by algae, and the concentration of this fraction constitutes an index of the amount of phosphorus immediately available for algal growth. The presence of soluble phosphorus in high concentrations is unusual in areas with hard water and high calcium levels as found throughout Southern Wisconsin.

The test results show high concentration of total phosphorus on all of the sampling dates and at all of the sampling locations. The concentrations highest on August 2, 2010 right after a large rain storm. Figures 4 and 5 illustrate concentrations of total phosphorus and soluble reactive phosphorus by site respectively. It can be seen generally total phosphorus increased from upstream to downstream, while dissolved phosphorus generally decreases as we move downstream, likely due to the effects of the wetland restoration project at CTH F. Approximately 67% of the total phosphorus is in the form of soluble reactive phosphorus. As outlined above this is unusual in the hard water of Southern Wisconsin. This indicates that the source of the phosphorus is not soil erosion where most phosphorus is typically bound to the soil particles, but is due a soluble source of phosphorus such as contamination of groundwater by sources such as treated wastewater, septic system waste or animal manure.

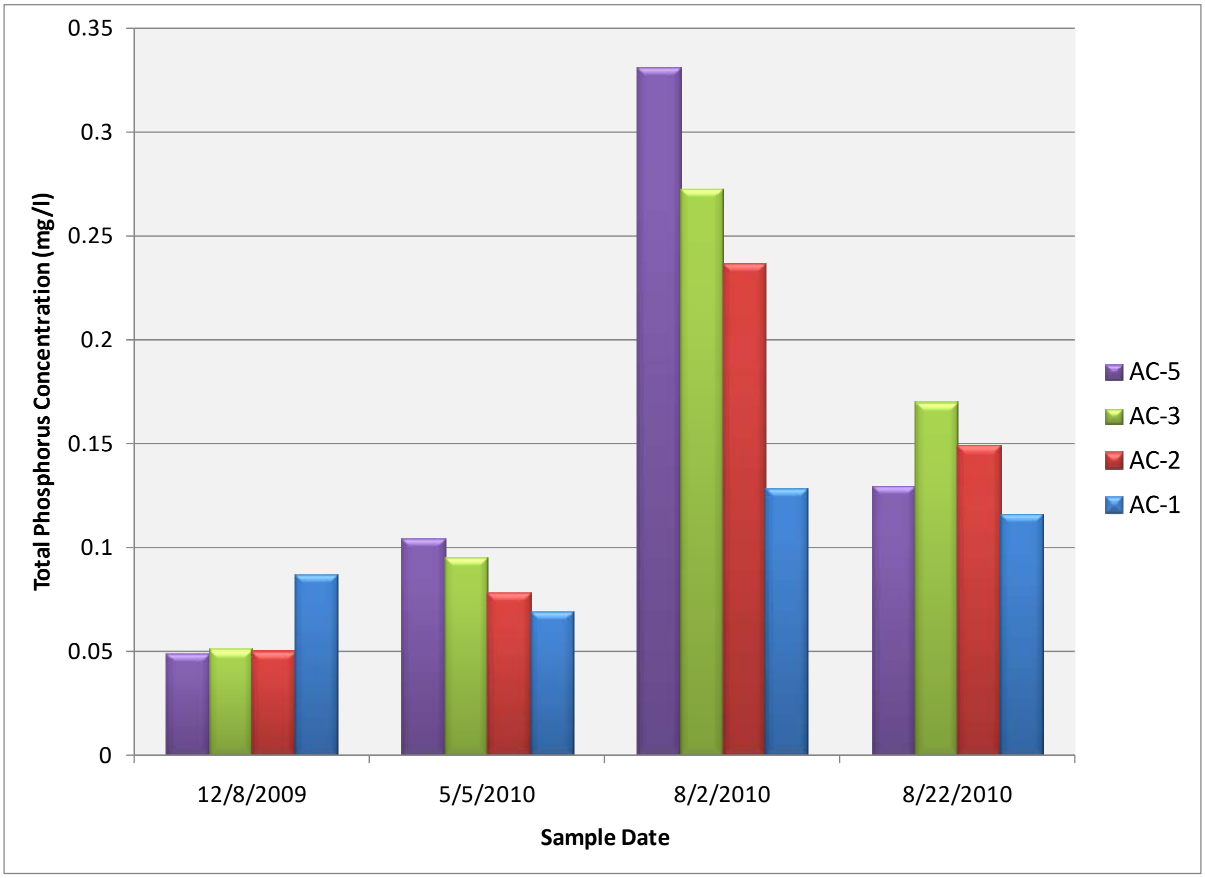

Figure 4
Relationship of Total Phosphorus Concentrations from Upstream to Downstream by Sample Date

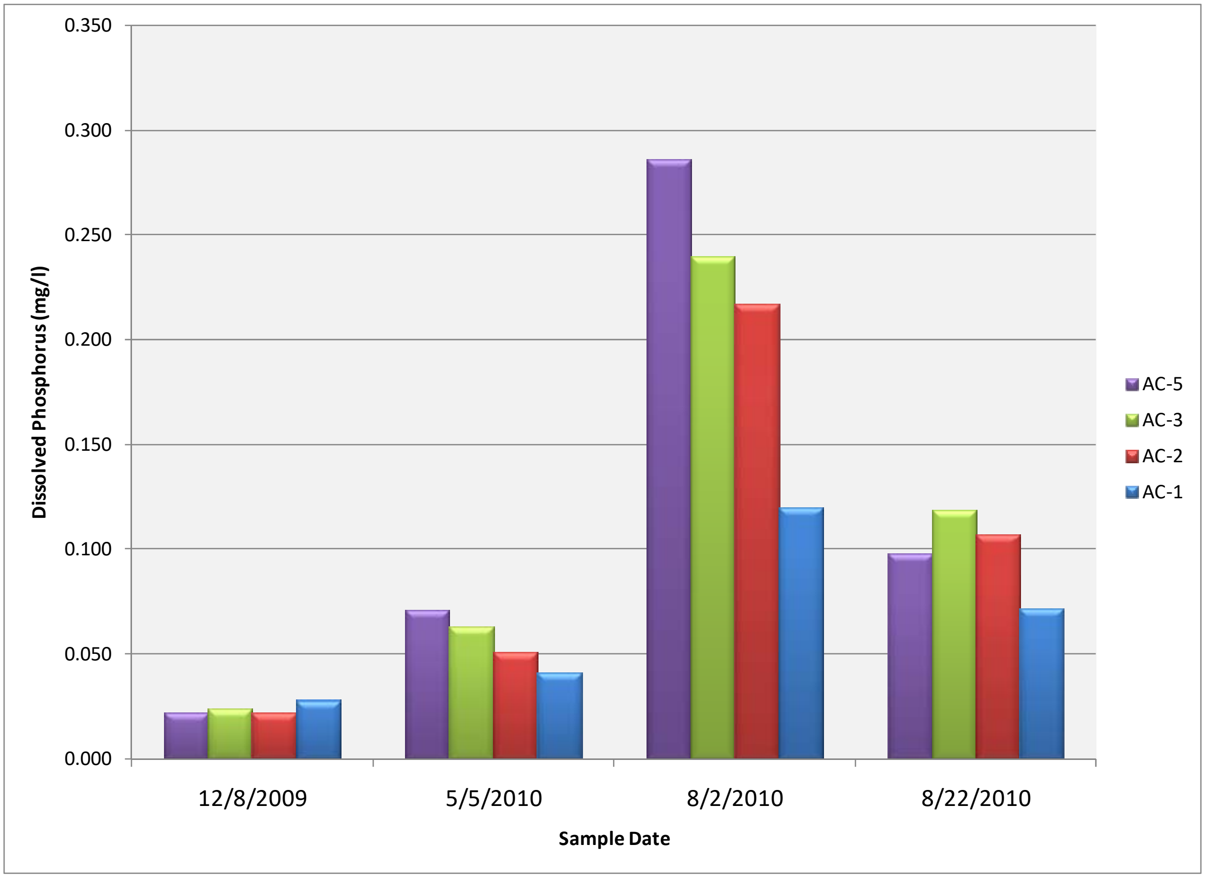

Figure 5
Relationship of Dissolved Phosphorus Concentrations from Upstream to Downstream by Sample Date

Nitrogen

Nitrogen can be found in many different organic and inorganic forms in our environment. The air we breathe is composed of 78 percent nitrogen. Nitrogen can also be found in many varied forms in the soil. Plants need nitrogen from the soil for proper growth and development but are only able to use very specific forms of nitrogen. Plants cannot use the form of nitrogen found in the atmosphere.

Natural biological process carried out by microorganisms in the soil convert organic nitrogen to inorganic forms, which plants are able to use. Organic nitrogen is a common component in plant residues and organic matter. Ultimately, organic nitrogen is converted to inorganic ammonium (NH-). Nitrate is the form of nitrogen that is most used by plants for growth and development. Where crops are grown, nitrates can also emanate from nitrogen fertilizers, and manure.

Nitrogen becomes a concern to water quality when nitrogen in the soil is converted to the nitrate (NO_3) form. This is because nitrate is very mobile and easily moves with water. The concern of nitrates and water quality is generally directed at groundwater. However, nitrates can also enter surface waters such as ponds, streams and rivers. Nitrates in the soil result from natural biological processes associated with the decomposition of plant residues and organic matter. Nitrates can also come from animal manure, treated human waste effluents and nitrogen fertilizers.

Whether nitrates actually enter groundwater depends on underlying soil and/or bedrock conditions, as well as depth to groundwater. If depth to groundwater is shallow and the underlying soil is sandy, the potential for nitrates to enter groundwater is relatively high.

Two of the major problems with excess levels of nitrogen in the environment are:

- Excess nitrogen can cause overstimulation of growth of aquatic plants and algae. Excessive growth of these organisms, in turn, can clog water intakes, use up dissolved oxygen as they decompose, and block light to deeper waters. This seriously affects the respiration of fish and aquatic invertebrates, leads to a decrease in animal and plant diversity, and affects our use of the water for fishing, swimming, and boating.
- Too much nitrate in drinking water can be harmful to young infants or young livestock.

The two forms of nitrogen measured as part of this study were:

- Total Kjeldahl Nitrogen (TKN), a measurement of organic nitrogen and ammonia, and
- Nitrite/nitrate nitrogen which measures nitrogen in the forms of NO_2 and NO_3.

Total Kjeldahl Nitrogen (TKN) concentration ranged from 0.26 to 1.60 mg/l and did not show any trends from upstream to downstream. The concentrations of TKN generally showed decreasing concentrations from upstream to downstream, possible due to wetland restoration project at CTH F.

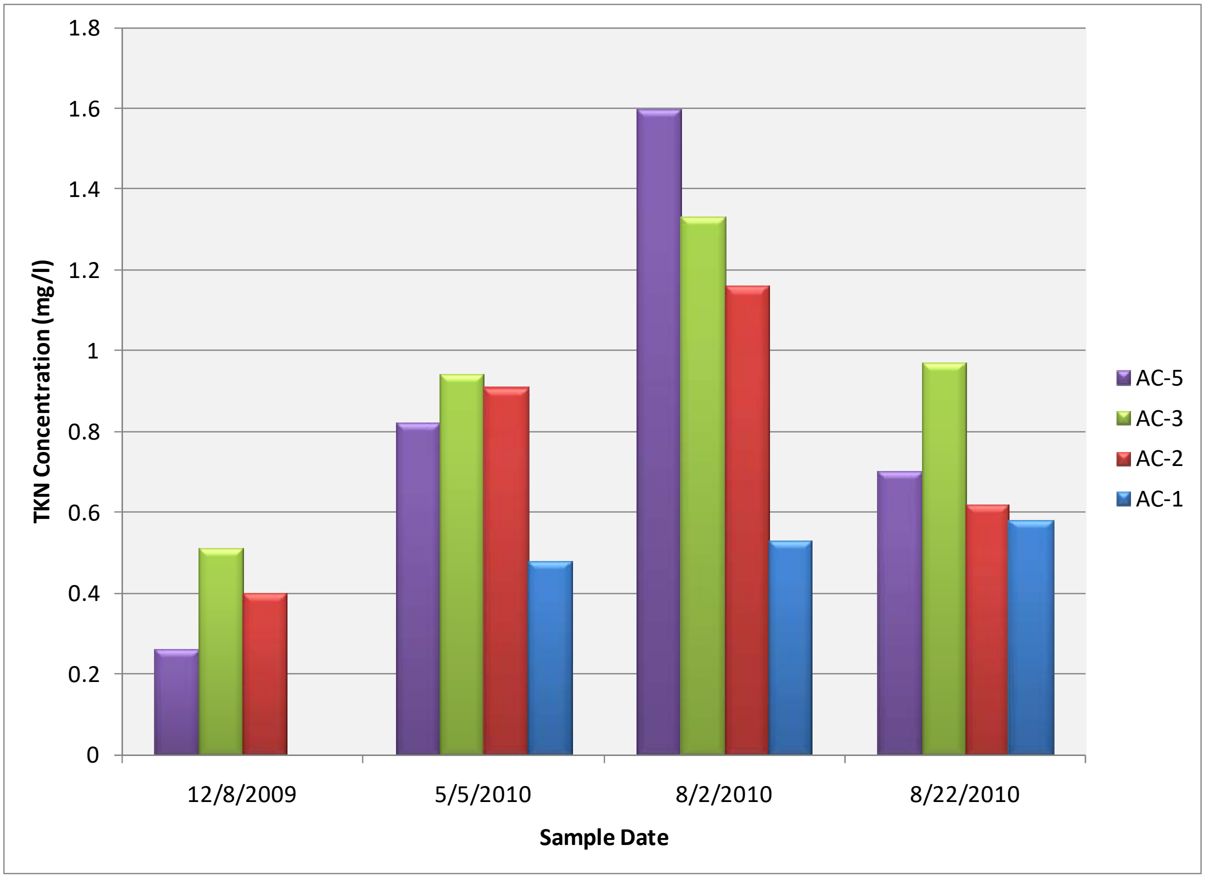

Figure 6
Relationship of Total Kjeldahl Nitrogen (TKN) Concentrations from Upstream to Downstream by Sample Date

Nitrite/nitrate nitrogen (NO2 & NO3) levels ranged from 1.42 to 12.5 mg/l. State and Federal laws set the maximum allowable level of nitrate-nitrogen in public drinking water at 10 milligrams per liter (10 parts per million). Nitrate-contaminated water should never be fed to an infant less than 6 months of age. In young infants, ingestion of nitrate can reduce the blood's ability to carry oxygen. In severe cases it can cause a condition that doctors call methemoglobinemia also called "blue baby syndrome" because the infant's skin appears blue-gray or lavender in color. This skin color change is caused by a lack of oxygen in the blood. An infant suffering from "blue baby syndrome" needs immediate medical care because the condition can lead to coma and death if it is not treated promptly. Some scientific studies have also found evidence suggesting that women who drink nitrate contaminated water during pregnancy are more likely to have babies with birth defects. People who have heart or lung disease, certain inherited enzyme defects or cancer may be more sensitive to the toxic effects of nitrate than healthy individuals. Some researchers also suspect that consuming nitrate-contaminated water may increase the risk of certain types of cancer (WDNR Publication: PUB-DG-001 2006).

Moderate levels of nitrate/nitrite nitrogen were found at all of the Alto Creek sampling sites. Approximately 85 to 96% of the total nitrogen is in the form of nitrate and nitrite. Alto Creek receives most of its water from groundwater seepage, indicating that the groundwater throughout the stream's watershed is contaminated. We notice a large increase in nitrate/nitrite nitrogen between sample site AC-2 and AC-1 indicating a nitrogen source between these two sample points, likely groundwater discharges into the marsh upstream of CTH F. Potential sources of the nitrate/nitrite nitrogen is the Fox Lake Correctional Institution wastewater treatment plant, animal feedlots and the excess spreading of manure and other organic waste. One theory for the increase in nitrite/nitrate nitrogen upstream of CTH-F is the potential leakage of groundwater from the Drew Creek area to the west which has documented very high concentrations of NO2 & NO3 in the groundwater.

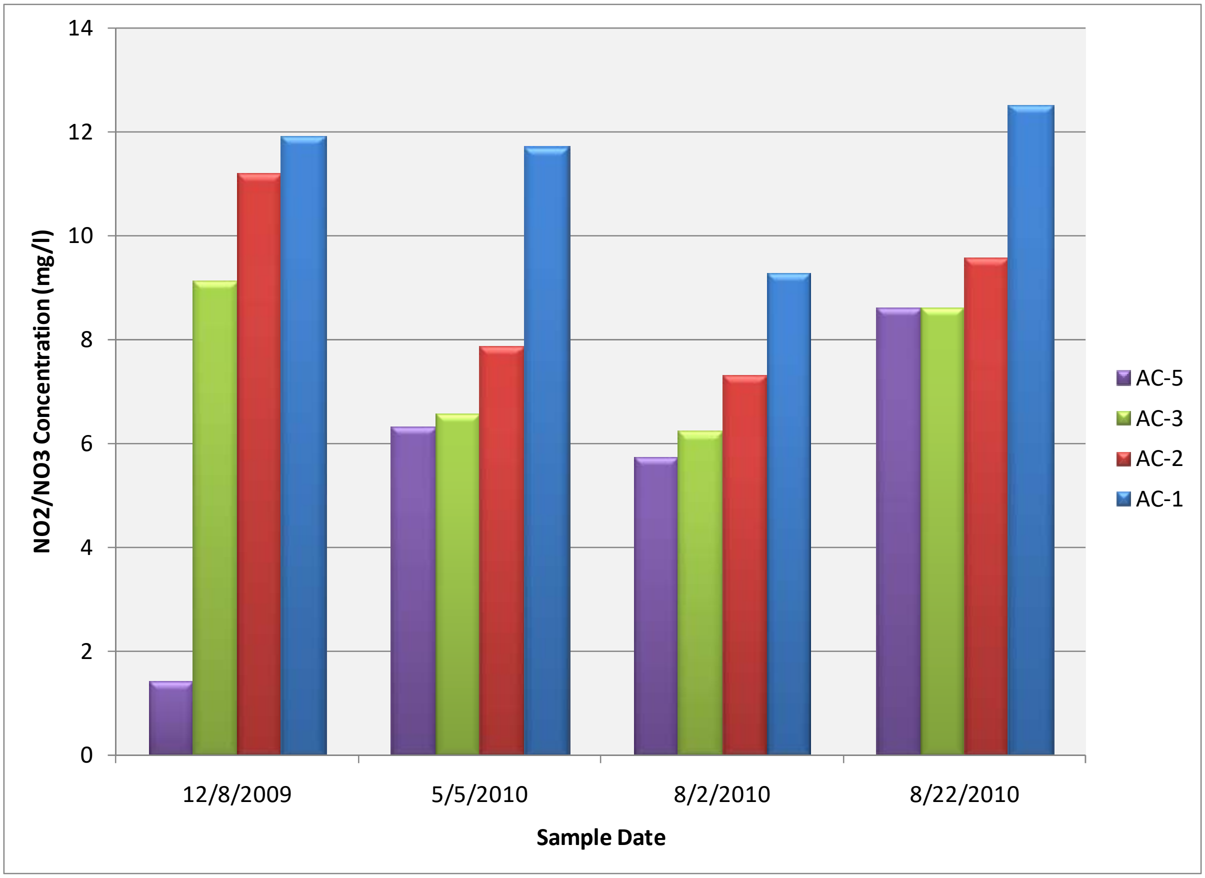

Figure 7
Relationship of NO_2/NO_3 Concentrations
from Upstream to Downstream by Sample Date

Fecal Bacteria

Fecal bacteria are bacteria that grow in the intestines of warm blooded animals and are found in fecal matter. E-coli (Escherichia coli) are a specific form of the fecal coliform group. E-coli have been associated with making humans sick through ingestion. The U. S. Environmental Protection Agency (USEPA) has recommended that E- coli be used to measure the safety of public beaches. The USEPA recommends that beaches be posted with an advisory sign informing the public of increased health risk when a water sample exceeds 235 colony-forming units of E. coli per 100 milliliters of water.

Generally E-coli counts were low to moderate at each sample site on each sample date, indicating that barnyard runoff and septic system leakage are not a major problem in the Alto Creek watershed.

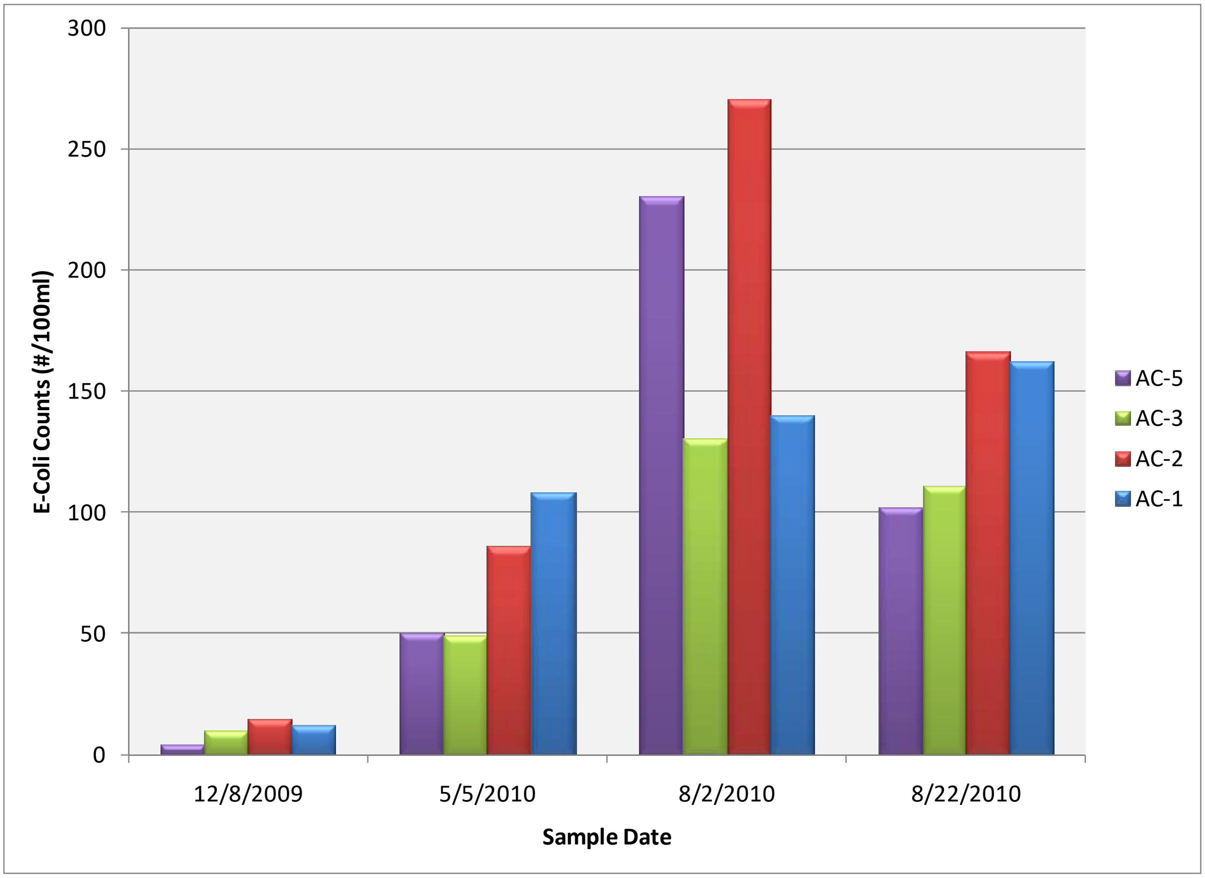

Figure 8
Relationship of Fecal E-Coli Bacteria Counts
from Upstream to Downstream by Sample Date

EFFECTS OF WETLAND CONTROL STRUCTURE AT CTH F

In 2002 a weir structure was installed upstream of CTH F with the purpose of increasing the pollutant removal capacity of riparian wetland adjacent Alto Creek. The purpose of the weir is to force stream flow into the riparian wetland and to increase the contact time with riparian wetland vegetation and associates wetland soils and microbial life and reduce short-circuiting of flow in the stream channel. Figure 9 through Figure 13 illustrate the percent reductions in instantaneous loadings between sample site AC-2 and AC-1. As we see in Figure 2, stream flow dramatically increases between AC-2 and AC-1 due to a large discharge in groundwater to the riparian wetlands between the two stations. While groundwater was not monitored as part of this study, loading inputs from groundwater were estimated based on instream base flow concentrations for nitrogen and phosphorus. As part of the *Fox Lake Management Strategy Evaluation and Recommendations for Future Action – 2008*, (Hey and Associates, Inc. and UW-Milwaukee, 2008), UWM maintained a continuous flow gauge at CTH F for June of 2004 through August 2005. The gauge (Figure 14) showed that Alto Creek flows were dominated by groundwater discharges and stream flow was not dramatically influenced by surface runoff except during very large storms or snow melt events. Therefore, it was assumed that instream concentrations of nutrients generally represented groundwater conditions and were used to estimate groundwater loadings.

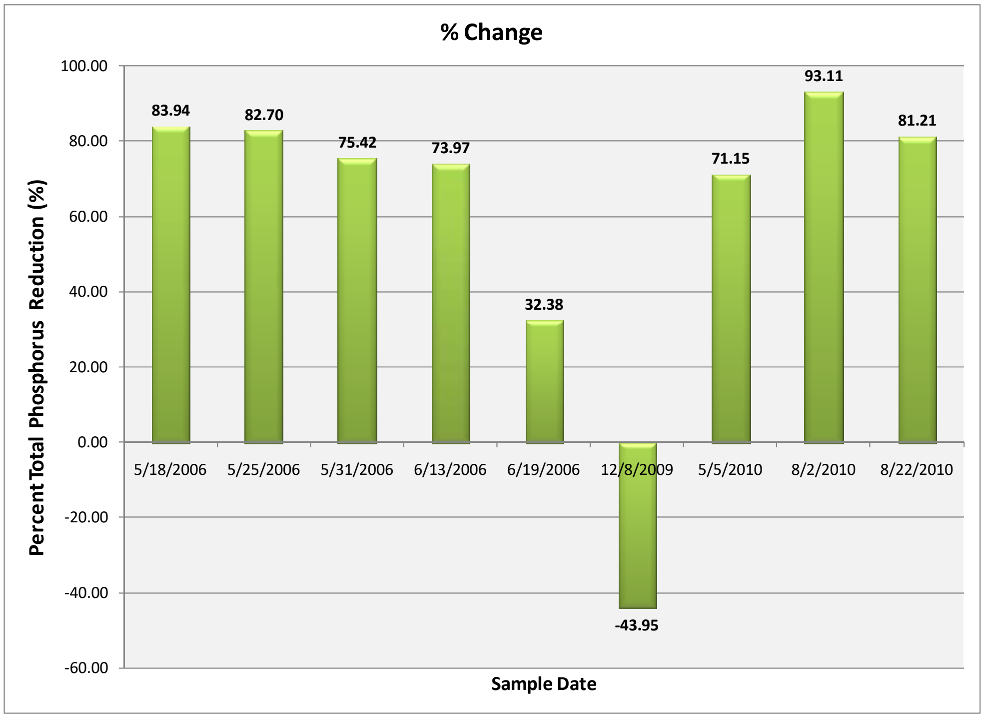

Figure 9
Percent Reduction in Total Phosphorus Loading through Wetland Upstream of CTH F

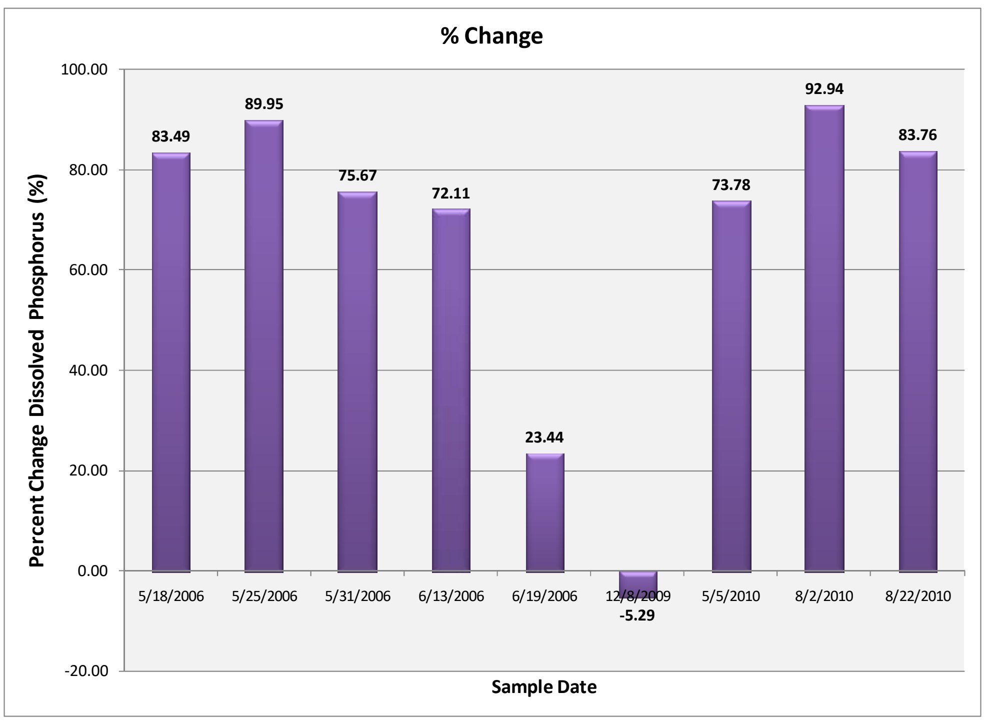

Figure 10
Percent Reduction in Dissolved Phosphorus Loading through Wetland Upstream of CTH F

Figure 11
Percent Reduction in Total Suspended Solids Loading through Wetland Upstream of CTH F

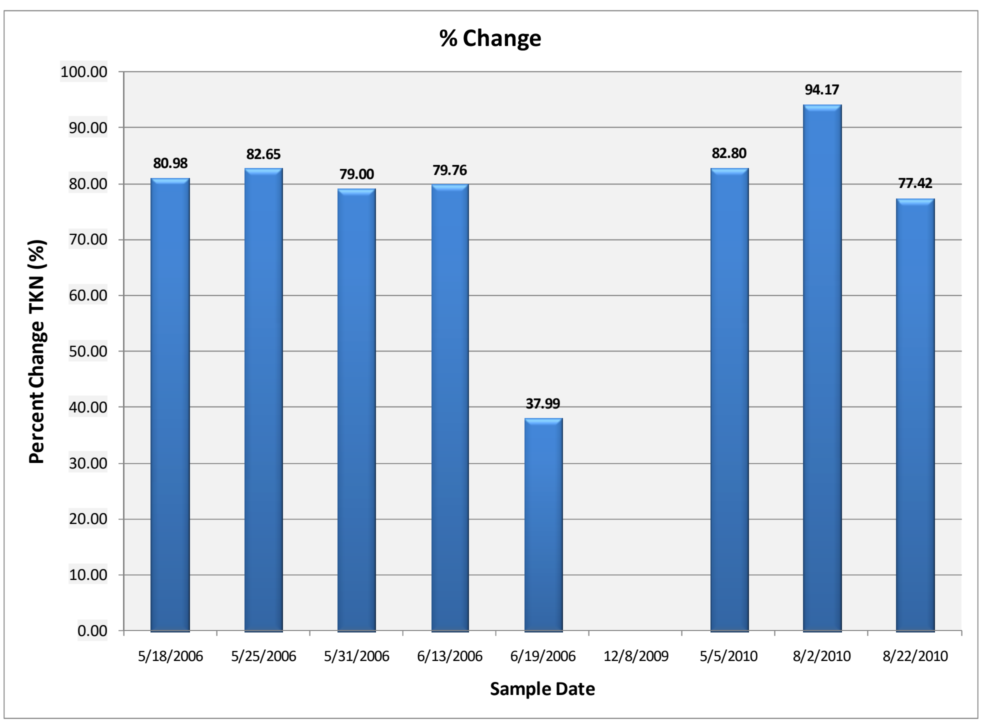

Figure 12
Percent Reduction in TKN Loading through Wetland Upstream of CTH F

Figure 13
Percent Reduction in NO2 & NO3 Loading through Wetland Upstream of CTH F

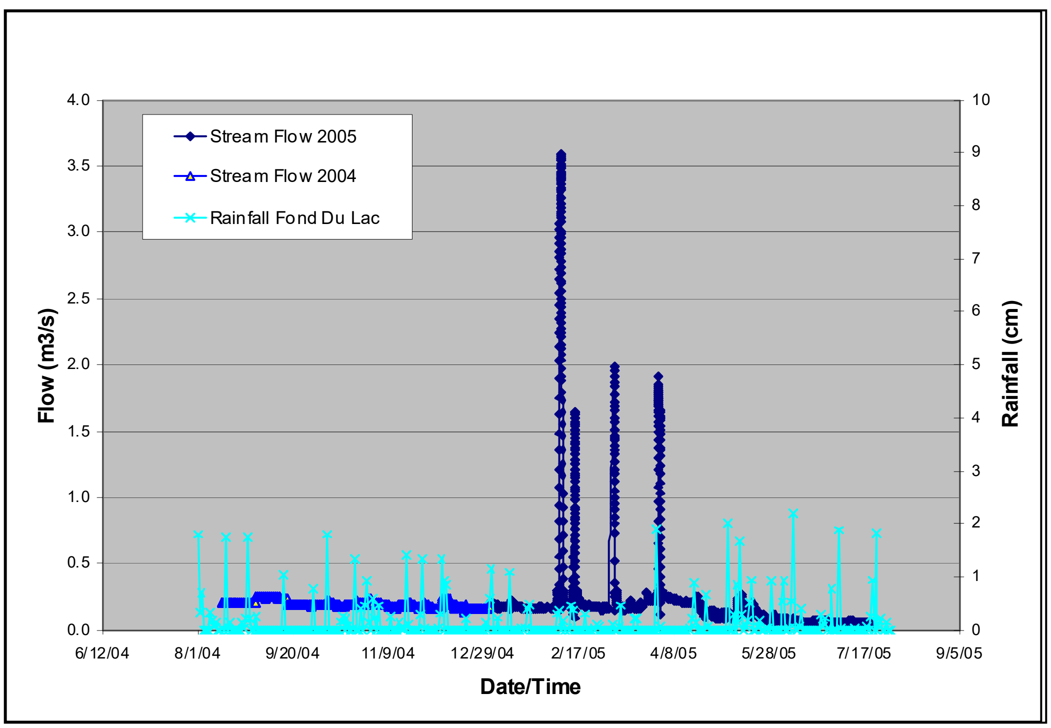

Figure 14
Flow Record at CTH F June 2004 through August 2005

For the nine sample events, total phosphorus removal ranged from -43.95% to 93.11%, with a mean of 61.1%. Dissolved phosphorus removals ranged from -5.29% to 92.94%, with a mean of 65.54%. Total suspended solids removals ranged from -200% to 83.39%, with a mean of 11.52%. TKN removals ranged from 37.99% to 94.17%, with a mean of 76.85%. NO_2 & NO_3 removals ranged from -53.96% to 83.75%, with a mean of 35.9%.

Export of material from the wetland generally took place during the one winter sample date (12/8/2009). Wetland export of nutrients during winter months is well documented in the literature. It is believed that annual basis the wetland enhancement project at CTH-F is providing good to very good nutrient removal.

CONCLUSIONS

It's been stated that "A lake is a Reflection of its Watershed". In the case of Fox Lake that reflection is one of high levels of pollution. Based on monitoring by the University of Wisconsin-Milwaukee from 2004 through 2006 it was estimated that annually approximately 176,924 pounds of sediment, 210,573 pounds of nitrogen and 1,210 pounds of phosphorus entered Fox Lake from the Alto Creek watershed. To identify the sources of the sediment and nutrients entering Fox Lake a sampling program of the Alto Creek watershed was conducted in 2009 and 2010.

The results of the sampling found the high to moderate levels of nitrate/nitrite nitrogen (NO_2+NO_3) at all of the sampling sites. Nitrite/nitrate nitrogen levels ranged from 1.42 to 12.5 mg/l, with four samples above the state's drinking water standard of 10 mg/l.

Sediment levels in the water were generally low ranging from 3 to 30 mg/l. The largest source of sediment is runoff from agricultural fields. The Alto Creek watershed contains soils with moderate levels of sand and allows rainwater to seep into the ground during moderate storms. To generate large enough runoff events to move sediment we need rain storms with high intensity or on frozen ground. None of the sampling took place during one of these large storms. This does not mean that Alto Creek is not a source of sediment to the lake.

The State of Wisconsin has established under Wisconsin Administrative Code NR 102.06 a total phosphorus standard of 100 ug/L (0.10 mg/l) for "unidirectional flowing waters" (streams) and 30 ug/L (0.03 mg/l) for lakes that are both drainage and stratified lakes. Total phosphorus concentrations in Alto Creek in 2009 and 2010 ranged from 0.049 to 0.331 mg/l, with 10 of the 17 samples above the state standard. Approximately 67% of the total phosphorus is in the form of soluble reactive or dissolved phosphorus.

E-coli bacteria (Escherichia coli) are bacteria that live in the digestive track of warm blooded animals including man and livestock. The presence of e-coli bacteria in the water is an indication of animal waste. To protect public health the U. S. Environmental Protection Agency has recommended that beaches be closed when e-coli levels exceed 235 CFU/100 ml. Generally E-coli counts were low to moderate at each sample site on each sample date, indicating that barnyard runoff and septic system leakage are not a major problem in the Alto Creek watershed.

The results of the UWM and Hey and Associates sampling indicate the groundwater contamination is the largest problem in the Alto Creek watershed. Most pollutants enter Alto Creek via groundwater discharges along the entire stream length. The best management practices to reduce pollutant discharges to the stream are those that prevent movement of pollutants into the groundwater.

RECOMMENDATIONS FOR FUTURE ACTION

The Alto Creek watershed has been identified as an area with high potential for groundwater contamination by the U. S. Geological Survey. Nitrate/nitrate and phosphorus sampling of Alto Creek has demonstrated that this contamination has already taken place. Likely sources of the contamination include barnyard runoff, spreading of manure and other industrial waste, and land application of treated wastewater from the Fox Lake Correctional Institution.

Based on the existing problems the following things should take place:

a. No new sources of animal or human waste should be imported into the watershed. Only animal waste generated within the watershed should be spread.

b. Existing land applications of animal or human waste should be minimized. The Wisconsin Legislature should explore new regulations for the land application of waste in areas with high potential for groundwater contamination.

c. All animal waste storage facilities, such as manure storage pits of tanks, should be inspected to assure that they are not leaking and are in compliance with Dodge County's Manure Storage and Nutrient Utilization Ordinance (Ordinance No. 794).

d. All applications of fertilizers in the watershed should be based on a Comprehensive Nutrient Management Plan (CNMP). The plan is based on realistic crop yield goals, soil tests to determine the nutrients available in fields, and taking credit for nutrients from legumes and manure applications. The plan may also identify areas of special concern such as flood plains and steep slopes. Nutrients are applied at the proper time using the appropriate application method. Sound nutrient management reduces fertilizer costs and protects water quality.

e. It appears that groundwater contamination in the Drew Creek watershed may be leaking into the lower end of Alto Creek between Lake Emily Road and CTH-F and may be a partial cause of the high concentrations of nitrate/nitrite nitrogen (NO_2+NO_3) at sampling site AC-1. The Fox Lake Correctional Institution (FLCI), Wisconsin Department Natural Resources (WDNR) and Fox Lake Inland Lake Protection and Rehabilitation District should put together a technical advisory committee to address corrective actions to the high nitrate/nitrite nitrogen levels in both the Drew and Alto Creek watersheds.

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