Mapping Agricultural Field Phosphorus and P index Values to Target Resources to Reduce Phosphorus Loading to Lower Fox River Basin and Lower Green Bay.

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Abstract: The highest contributor of Phosphorus to the Lower Fox River and Lower Green Bay Basin is Agriculture. The Total Maximum Daily Load (TMDL) and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay Basin (June 2010) identifies 45.7% or 251,382 lbs./yr. of phosphorus loading attributed to agriculture. Brown County staff from the Land and Water Conservation Department, Land Information Office and Information Services received a grant from the Wisconsin Department of Natural Resources (DNR) to identify, develop, and map detailed information from nutrient management plans from 2010. The aforementioned group effort resulted in the creation of a GIS map that displays Phosphorus levels and P index values by individual agricultural fields in the Brown County portion of the Lower Fox River Basin and Lower Green Bay TMDL.

New computer systems were installed, staff was trained, and nutrient management plan data was collected from private agronomists who had developed nutrient management plans for agriculture producers. The 2010 nutrient management plan data from 48,409 acres was entered onto GIS maps from the Lower Fox River Basin and Lower Green Bay TMDL. Results showed high ppm phosphorus levels near livestock facilities and streams. P index levels in the targeted resources area does not correlate with soil ppm soil levels or stream monitoring of water ppm levels of phosphorus. 10,339 acres mapped were greater than 50 ppm phosphorus while only 49 acres were greater than a P index of 6. Approximately 50% of the nutrient management plans had P Index data. The mapping GIS systems can be duplicated and be used to monitor progress of reducing soil phosphorus ppm levels by water quality staff.

Background information: Lower Fox River and Green Bay phosphorus levels

Phosphorus has long been recognized as a problem in the Lower Fox River and the Green Bay Basin. The Lower Green Bay Remedial Action Plan (1988) identified Phosphorus Inputs to the Fox River and the Green Bay Basin from nonpoint and point sources as a high priority. A U.S. Geological Survey Water-Resources Investigations Report (96-4092) identified that of all the tributary streams in the Lake Michigan Basin, the Fox River was the top contributor of phosphorous.

The Total Maximum Daily Load and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay (June 2010) identified sources of baseline Total Phosphorus in the Lower Fox River Basin.

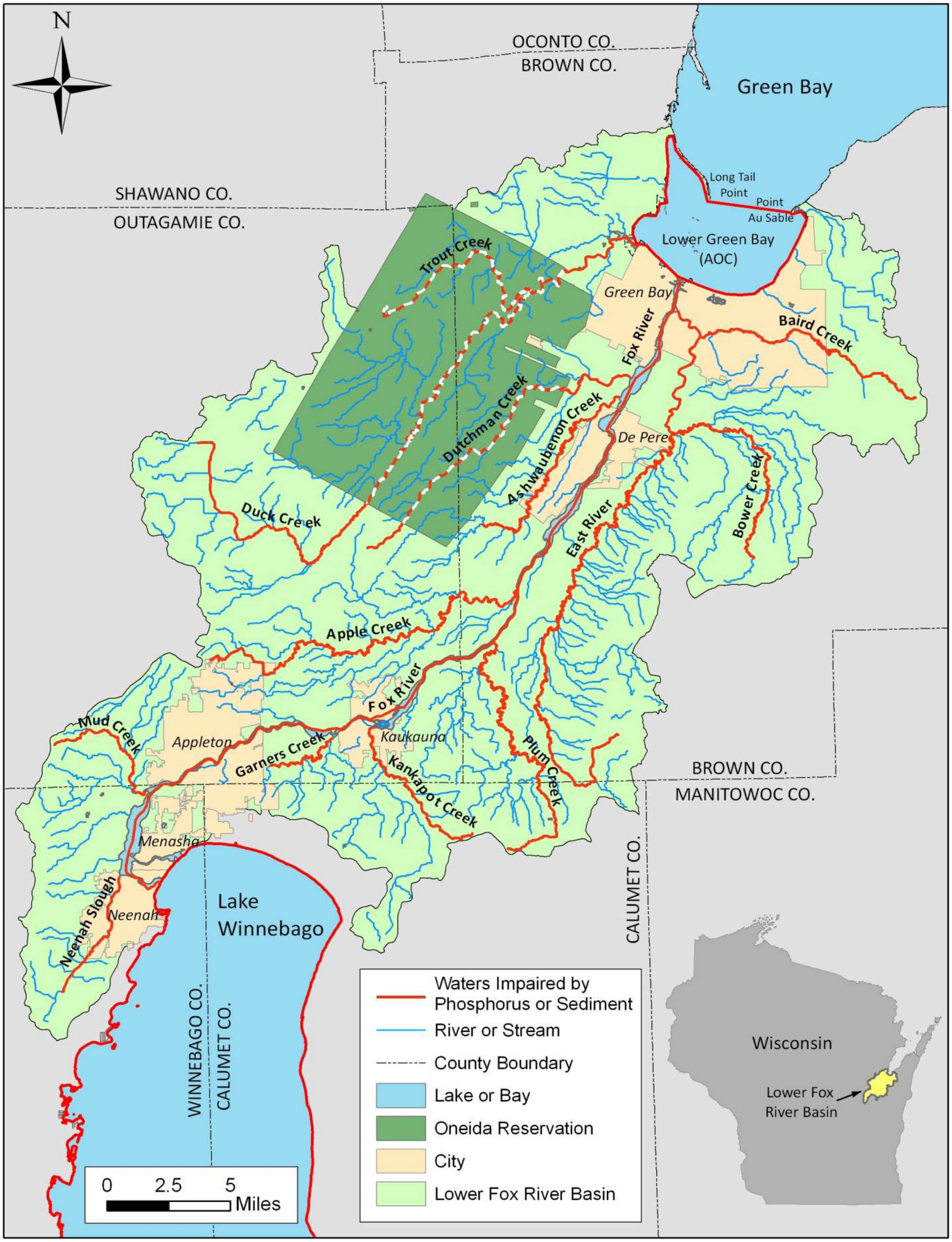
Sources of baseline Total Phosphorus loading in the Lower Fox River Basin

Source	Total Phosphorus (lbs/yr)	Percent
Natural Background	5,609	1.0%
Agriculture	**251,382**	**45.7%**
Urban (non-regulated)	15,960	2.9%
Urban (regulated MS4)	65,829	12.0%
Construction	7,296	1.3%
General Permits	2,041	0.4%
Industrial WWTFs	114,426	20.8%
Municipal WWTFs	87,160	15.9%
Total (In Basin)	**549,703**	

Sources of total phosphorus loads identified by the stream from within each sub basin.

Sub Basin	Total Phosphorus (lbs/yr)
East River	48,478
Baird Creek	12,748
Bower Creek	27,777
Apple Creek	35,088
Ashwaubenon Creek	15,681
Dutchman Creek	15,280
Plum Creek	31,569
Kankapot Creek	20,050
Garners Creek	6,575
Mud Creek	6,594
Duck Creek	63,172
Trout Creek	4,518
Neenah Slough	11,912
Lower Fox River (main)	237,339
Lower Green Bay	12,652
Total (In Basin)	**549,703**

(Source of tables: Total Maximum Daily Load and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay (June 2010))


N
OCONTO CO.
BROWN CO.
Green Bay
SHAWANO CO.
OUTAGAMIE CO.
Long Tail Point
Point Au Sable
Lower Green Bay (AOC)
Trout Creek
Green Bay
Fox River
Baird Creek
Dutchman Creek
Ashwaubenon Creek
De Pere
Bower Creek
Duck Creek
East River
Apple Creek
Fox River
Mud Creek
Appleton
Garners Creek
Kaukauna
Kankapot Creek
Plum Creek
BROWN CO.
MANITOWOC CO.
Menasha
Neenah Slough
Neenah
Lake Winnebago
CALUMET CO.
WINNEBAGO CO.
CALUMET CO.
Waters Impaired by Phosphorus or Sediment
River or Stream
County Boundary
Lake or Bay
Oneida Reservation
City
Lower Fox River Basin
0 2.5 5 Miles
Wisconsin
Lower Fox River Basin

Three year Total Phosphorus concentrations for the period 2004 and 2006 available from the Lower Fox River Watershed Monitoring Program show all the stream data with higher phosphorus levels than the state standard which was set at .075 ppm.

Sub Basin	3 year record of Total Phosphorus concentrations Lower Fox River Watershed Monitoring Program 2004-2006
Apple Creek	.2 - .31 mg/L
Ashwaubenon Creek	.275 - .4 mg/L
Baird Creek	.12 - .19 mg/L
Duck Creek	.16 - .195 mg/L
East River	.18 - .355 mg/L

Source: Lower Fox River Watershed Monitoring Program 2004-2006 (page 10 Total Maximum Daily Load and Watershed Management Plan for Total Phosphorus and Total Suspended Solids in the Lower Fox River Basin and Lower Green Bay).

Background information: Agriculture trends

Livestock numbers Fox Wolf Basin – All cattle and calves

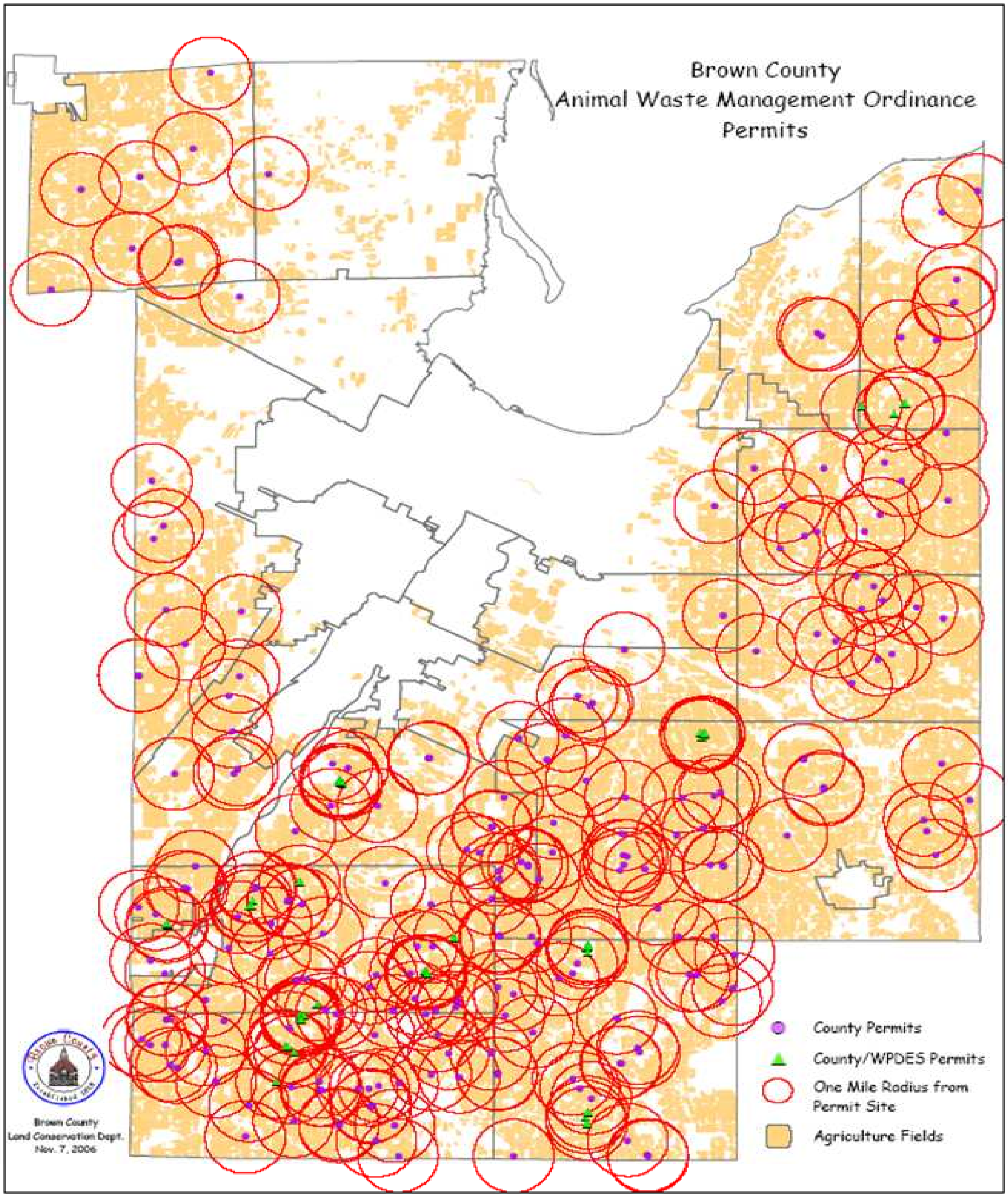
County	Cattle	Cropland	Acres per cow
Brown	105,000	162,000	**1.54**
Outagamie	85,000	194,700	2.29
Winnebago	32,000	127,600	3.99
Calumet	60,000	120,900	2.02
Fond du Lac	100,000	242,700	2.26
Waupaca	55,000	134,400	2.44
Shawano	85,000	171,900	2.02

Wisconsin counties with highest cattle numbers

County	Cattle	Cropland	Acres per cow
Grant	173,000	330,000	1.91
Dane	143,500	363,400	2.53
Marathon	139,000	288,200	2.07
Clark	136,500	235,800	1.73
Dodge	106,500	304,400	2.86
Manitowoc	97,000	183,800	1.89

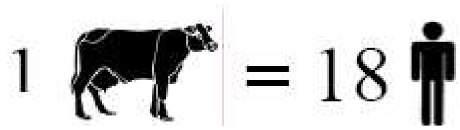
Source: 2009 Wisconsin Agricultural Statistics

Brown County has the fewest acres per cow at **1.54 acres per cow** (all cattle and calves) of any county in Wisconsin. A large portion of those livestock operations are located in the Lower Fox River Basin and Lower Green Bay TMDL. Clemson University in a 2000 study estimated 3 acres per cow needed for Phosphorus. UWEX, CALS, DATCP, USDA estimated 1.6 – 2.9 acres/ cow P.



Animal waste to human waste comparison

Livestock trends in Brown County are fewer but larger dairy farms. Currently there are 18 existing CAFO permits (>1000 AU) with 13 currently 500 AU- 1,000 AU. The 18 CAFO's is the highest number of CAFO's in any county in Wisconsin. 1000 dairy cows (that weigh 1400 lb. each) generate the waste equivalent to 18,000 humans (source DNR).



Brown Counties 105,000 cows (all cattle) is equivalent to approximately 80,000 animal units which generates the waste equivalent to 1,440,000 humans. The human population of Brown County in 2009 was estimated to be 245,426. The city of Green Bay and De Pere metropolitan area have approximately 200,000 humans on effluent treatment by Green Bay Metropolitan Sewage District (GBMSD). 100 Staff work at sewage district; the total number of employees working from DNR, Brown County Land and Water Conservation, NRCS, UWEX, private agronomist is estimated to be less than 15. GBMSD incinerates and landfills its waste.

Milk Production Trends

According to 2009 US Dairy Statistics on Milk Production from Progressive Dairyman magazine, Wisconsin ranks second nationwide in total milk production. The average Wisconsin herd size is 95. Brown County average milk herd is 171.5 (2009 Wisconsin Agriculture Statistics). The number of dairy herds is 13,170 (13,730 in 2008).

TOP DAIRY COUNTIES IN MIDWEST Region (12 states) Milk Production 2008-09

County	Lbs. of milk produced	Percent increase from 2008-2009
1. Stearns Mn	106 million lbs	+67%
2. Clark, WI	103 million lbs	+35%
3. Marathon, WI	94 million lbs	+25%
4. Dane, WI	94 million lbs	+15%
5. Fond du Lac, WI	81 million lbs	+39%
6. Brown, WI	**80 million lbs**	**+16% (14% in 2008)**
7. Outagamie	75 million lbs	+40%

Land Use

Brown County total land area approximately 350,000 acres.

Year	Farms	Land in Farms
1954	2,672	300,900 acres
1972	1,920	274,800 acres
1978	1,730	263,400 acres
1983	1,480	241,500 acres
2008	**1,053***	**162,000 acres**

(Source: 1991 Brown County Farmland Preservation Plan; NASS 2007*, 2009)

A number of factors identified in the maps and charts are impacting phosphorus loads in streams being over the state standard of .075 ppm:

1. Reduced acres of cropland per cow available for land application of animal waste.
2. An estimated 33% of cropland has spreading restrictions or limitations such as setbacks from streams, setbacks from wells or karst features which further reduces the amount of cropland available for land application of waste to estimated 105,000 acres of cropland without land application limitations.
3. Livestock density resulting in greater distances and costs to haul and land apply animal waste.
4. Increased milk production per cow resulting in more waste production.
5. A high percentage of high ppm phosphorus fields and livestock facilities are close to streams or have streams intersecting the field providing a delivery point.
6. High soluble phosphorus runoff.

Identifying agriculture fields with high phosphorus levels (ppm) and high P index

In December of 2009 the Wisconsin DNR entered into an agreement with Brown County to:

- Gather data from farmers including detailed information from Nutrient Management Plans, in particular, in the Plum and East River Watersheds in Brown County.
- Use part of the grant to collect supplemental data for fields that do not have soil tests.
- Input appropriate data into SNAP-Plus.
- Create a GIS map displaying PI values for targeting resources to reduce phosphorus loading in the Plum and East River Watersheds as part of planning for the Lower Fox River TMDL implementation.

Goals of the project were to focus efforts on planning for water quality improvements and provide crucial information to create targeted performance standards (phosphorus index) needed for nonpoint source controls to meet the phosphorus load allocations expressed in the Lower Fox River TMDL for the Plum and East River Watersheds.

Creating GIS mapping system

The goal of the Geographic Information Systems (GIS) mapping was to assemble the phosphorus values contained on the individual nutrient management plans into a compiled map that could show the spatial distribution of phosphorus levels.

Source data:

The County owned copies of the nutrient management plans in PDF and paper format, but not in a database format.   Looking at the PDF plans, it was clear to us that many of the nutrient management plan data were collected using Global Positioning Systems (GPS) and GIS and compiled in computer database format (SnapPlus, for example). To avoid data re-entry, an attempt was made to gather the source information in database format that could be imported directly into our GIS and linked to the mapping.   After some exploration, we discovered could not obtain the nutrient management plan data in a computer format that could be imported into the GIS, so the phosphorus data had to be keyed in manually by county staff onto the GIS base map.

GIS base map:

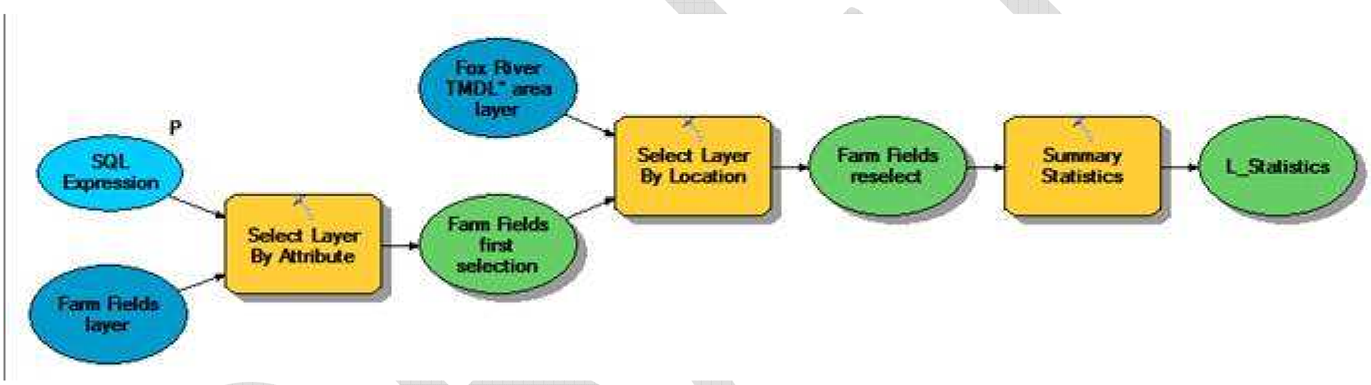
The base map consisted primarily of a GIS layer of agricultural fields digitized from aerial orthphotographs. Coding the phosphorus values into the agriculture fields (instead of parcels or other base map) allowed for a very straightforward association between the nutrient management plans and the base map.   The agricultural field GIS layer provided a more direct way to enter data, compute acreages, and display the final maps. Additional GIS layers such as aerial photographs, parcels, hydrography, and watershed boundaries were used as overlays to reference land use, ownership, TMDL areas, and other information.

Data entry:

ESRI's ArcGIS software was used for the GIS data entry.   The workflow involved viewing the nutrient management plan on paper or PDF, and then finding the corresponding agricultural fields on the ArcMap GIS display. The shape and acreage of the fields were verified as being accurate on both the plan and the GIS as one measure of data quality assurance. County staff edited and re-shaped fields on the GIS if needed. Once the shape and acreage of the fields were corresponding with the nutrient management plan, the agricultural field would be coded with GIS data attributes including phosphorus values. As the phosphorus data attributes were keyed into the GIS, the agricultural field immediately changed to the green-yellow-red coloring scheme shown on the final maps. This was another measure used for quality assurance as County staff entering data would immediately see the results of the data entry.

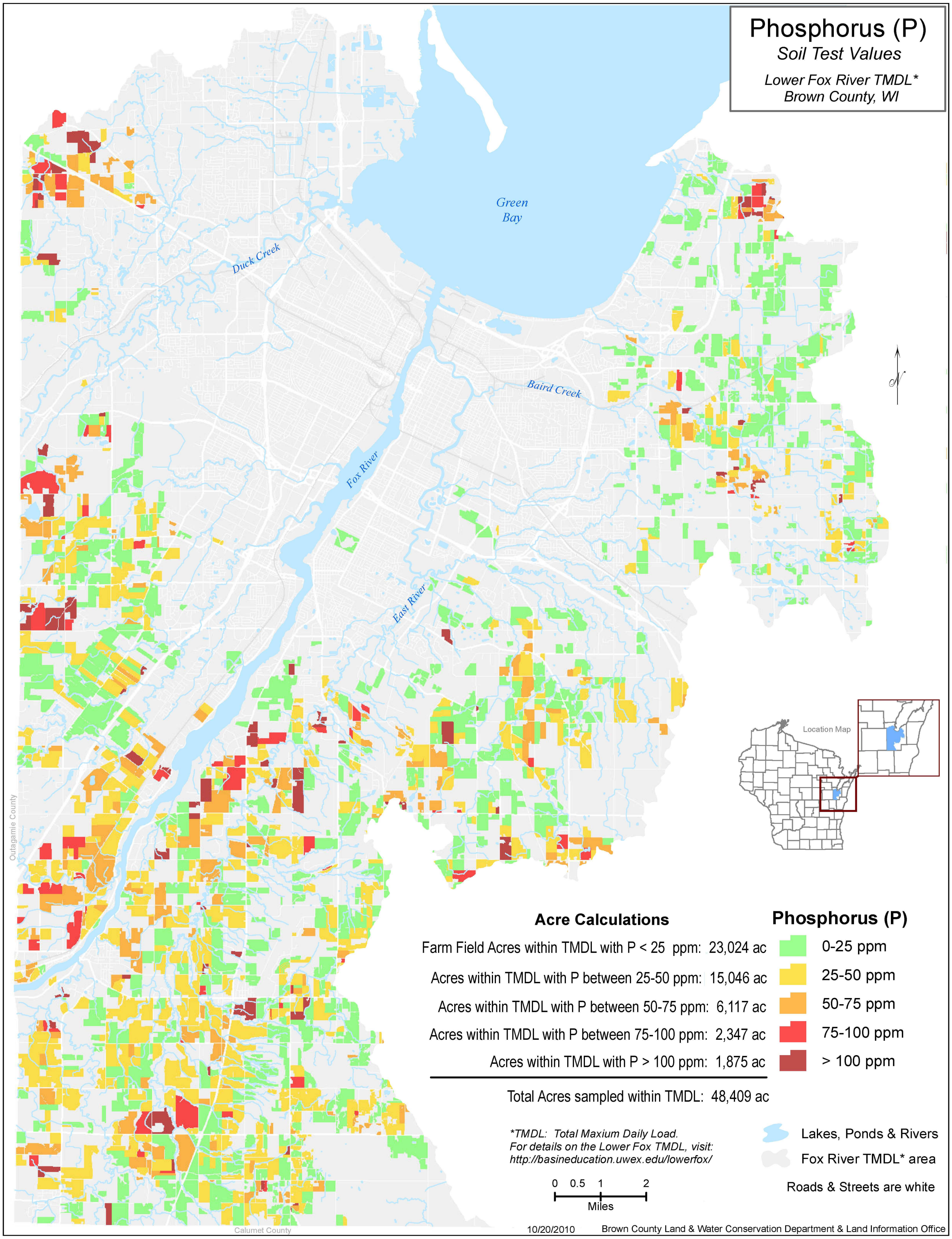
Analysis & final mapping:

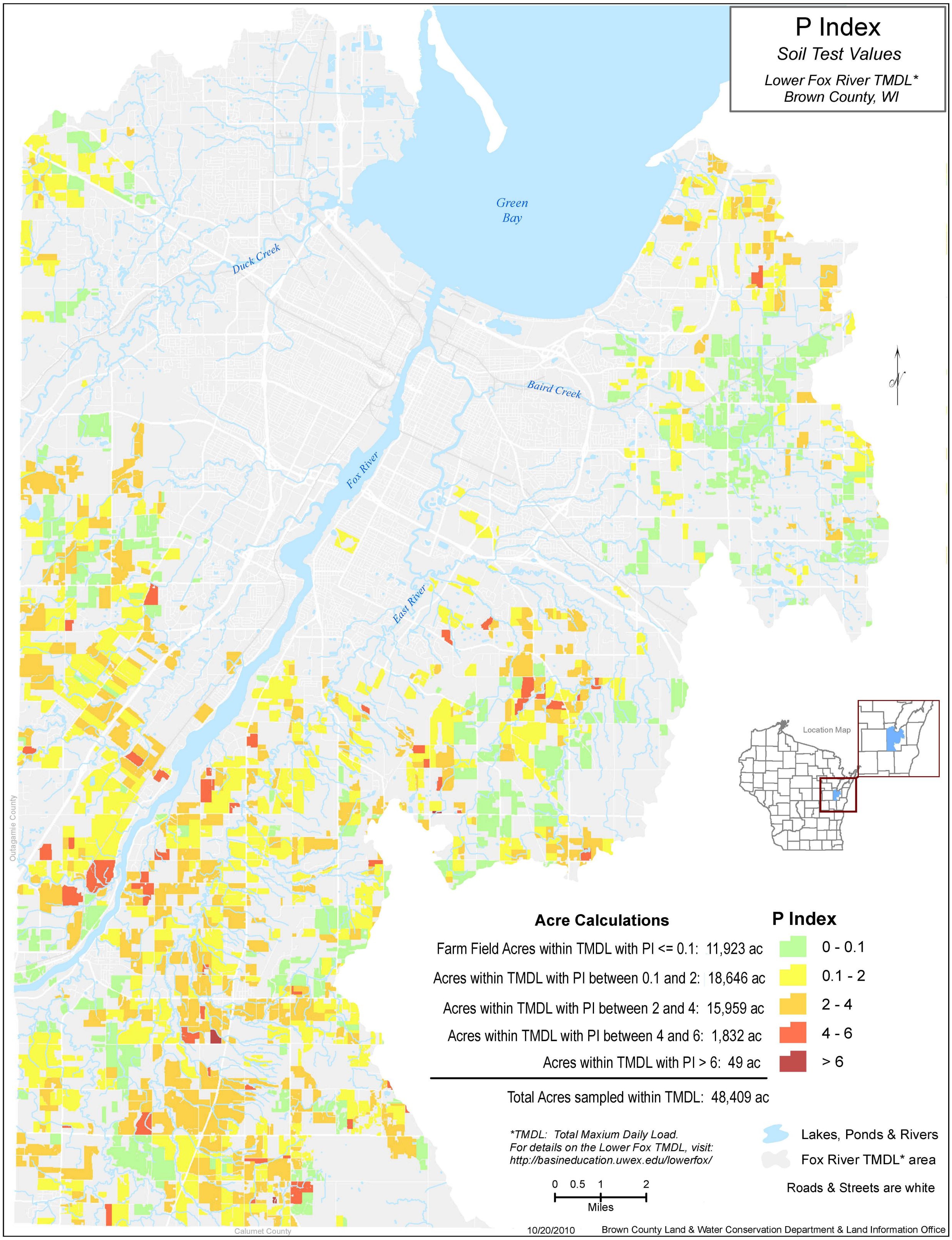
After the data entry was complete, ArcGIS (ArcMap) was used for spatial analysis and to create the final maps. Using GIS “overlay analysis” and other techniques, we selected agricultural fields within the TMDL area and computed the total acreages of each of the phosphorus value classifications within. To speed up the analysis process and ensure consistency, we created a custom “geoprocessing tool” using the “Model Builder” package that comes with ArcGIS. This model strung together the series of steps necessary to compute the acre calculations including the SQL queries, the selection of fields within the TMDL area, and the summary statistics. Saving this workflow as an analytical model will also ensure consistency as we perform this task in the future to look for progress.



Lessons learned:

In the future, we hope to obtain the nutrient management plan source databases from the agronomists and farmers in a format that can be imported directly into our GIS. This would reduce the time spent on the data entry portion of this project.


Phosphorus (P)
Soil Test Values
Lower Fox River TMDL*
Brown County, WI
Green Bay
Duck Creek
Baird Creek
Fox River
East River
Outagamie County
Calumet County
Location Map
Acre Calculations
Farm Field Acres within TMDL with P < 25 ppm: 23,024 ac
Acres within TMDL with P between 25-50 ppm: 15,046 ac
Acres within TMDL with P between 50-75 ppm: 6,117 ac
Acres within TMDL with P between 75-100 ppm: 2,347 ac
Acres within TMDL with P > 100 ppm: 1,875 ac
Total Acres sampled within TMDL: 48,409 ac
Phosphorus (P)
0-25 ppm
25-50 ppm
50-75 ppm
75-100 ppm
> 100 ppm
*TMDL: Total Maxium Daily Load.
For details on the Lower Fox TMDL, visit:
http://basineducation.uwex.edu/lowerfox/
Lakes, Ponds & Rivers
Fox River TMDL* area
Roads & Streets are white
0 0.5 1 2
Miles
10/20/2010
Brown County Land & Water Conservation Department & Land Information Office



Approximately 50% of 2010 590 plans have P Index data. (This map may need to be adjusted to reflect)

Phosphorus and Phosphorus index maps created

The nutrient management plans in TMDL from 2010 which were submitted by landowners and consultants were entered into the GIS data base. A total of 48,409 acres of nutrient management plans were entered. According to our current farm field map layer, we have 88,317 total acres of cropland within the TMDL area in Brown County. This means 55% of the cropland acres have nutrient management plans in the TMDL area in Brown County and were entered onto maps.

Phosphorus ppm	Farm Field Acres	Percent of Total
0-25 ppm	23,024	47.56%
25-50ppm	15,046	31.08%
50-75 ppm	6,117	12.63%
75-100 ppm	2,347	4.85%
> 100 ppm	1,875	3.87%
Total	**48,409**	**100%**

P Index	Farm Field Acres	Percent of Total
0-0.1	11,923	24.63%
0.1-2	18,646	38.52%
2-4	15,959	32.97%
4-6	1,832	3.78%
> 6	49	0.10%
Total	**48,409**	**100%**

Future Applications of GIS mapping of ppm phosphorus

Monitoring non point has always been difficult due to the complex nature of non-point pollution. There are many variables and a large area of the landscape making monitoring of agriculture non point progress difficult. The GIS mapping of phosphorus from nutrient management plans by field provides a valuable non point monitoring tool that can accomplish the following:

- Identify cropland that does not have a nutrient management plan which is required by state administrative code NR151 and target land parcels, landowners and operators that need to obtain a nutrient management plan to obtain compliance with NR151.
- Identify cropland with high ppm phosphorus for reduction in future land application of phosphorus. Monitor future soil phosphorus ppm levels and trends as a result of nutrient management as a result of periodic soil sampling for phosphorus through nutrient management plan process.
- Assist agriculture producers and agronomists in land application of waste to assist with profitability and planning future cropping rotations.

- The GIS mapping system process identified could help other TMDL's or units of government set up a GIS mapping system to track and monitor nutrient management plan progress and soil phosphorus response.

Conclusions and observations derived from the Phosphorus mapping project

- 10,339 or 21% of the cropland acres from 2010 nutrient management plans entered into the GIS mapping system are greater than 50 ppm phosphorus (Bray 1) and only 49 acres or 0.10% is greater than PI 6 (new Wisconsin state standard).
- P Index phosphorus levels on nutrient management plan information does not appear to be consistent with phosphorus levels found in water through monitoring and new state standard of .075 ppm phosphorus.
- Soil phosphorus ppm appears to be a more accurate indicator of agriculture locations causing phosphorus delivery from agriculture fields than P Index. 99.9% of current 590 plans analyzed meet P Index yet the TMDL identifies Agriculture sources of phosphorus at 46 % and water quality monitoring identifies stream phosphorus levels at greater than .075 ppm.
- 92 of 132 (70%) of the agriculture fields mapped with over 75 ppm of phosphorus had a stream which intersected the agriculture field as a delivery point for phosphorus.
- Many of the high soil phosphorus ppm fields are located in close proximity to livestock facilities where historical farm building sites were located.
- The GIS mapping of phosphorus ppm on a field basis could be used to monitor phosphorus levels by field and be used to focus conservation resources to highest Phosphorus ppm fields.
- The GIS mapping procedure can be replicated in other locations.

References Cited

Wisconsin Department of Natural Resources; February 1988 Lower Green Bay Remedial Action Plan for the Lower Fox River and Lower Green Bay Area of Concern.

U.S Geological Survey Water – Resources Investigation Report 96-4092; Use of Frequency –Volume Analyses to Estimate Regionalized Yields and Loads of Sediment, Phosphorus, and Polychlorinated Biphenyls to Lake Michigan and Superior.

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John P. Chastain, Ph.D. Department of Agricultural and Biological Engineering Clemson University; 2000; Planning Free stall Facilities for the Expanding Dairy.

UWEX, CALS, USDA-ARS Dairy Forage Research Center, USDACSREES Initiative for future agriculture and food systems, WDATCP UWEX, CALS, DATCP, USDA – 1.6 – 2.9 acres/ cow P.