Status and Trends of Michigan's Wetlands:

Pre-European Settlement to 2005

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STATUS AND TRENDS OF MICHIGAN'S WETLANDS
PRE-EUROPEAN SETTLEMENT TO 2005

DEQ

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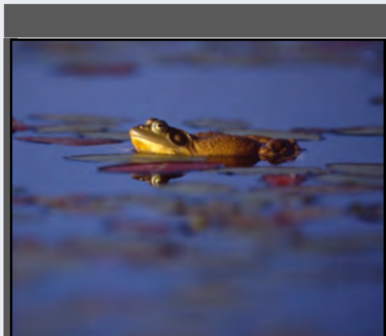
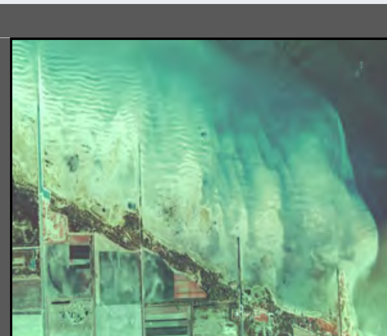
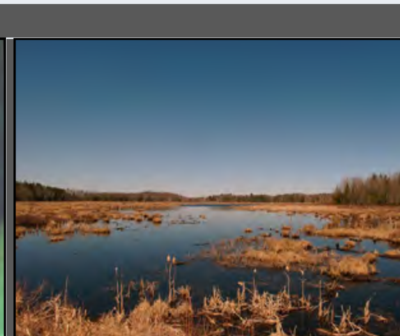






EXECUTIVE SUMMARY

There are few ecosystems on Earth as biologically diverse as wetlands, and few places where wetlands take as many forms as in Michigan. Approximately 17 percent of Michigan, representing millions of acres, is covered by one of a variety of wetland types, ranging from diversely vegetated lakeplain prairies to small vernal pools located in the isolated woodlots of Michigan's agricultural communities. These ecosystems provide crucial habitat suitable for a diverse set of organisms, from the smallest macroinvertebrates, to a varied assortment of amphibians, fish, and birds. Wetlands also serve a number of other important functions: serving as nature's kidneys by filtering out sediment and nutrients before they reach rivers and lakes, reducing flood flows by providing floodwater storage, and slowing the delivery of flood flows to surface water bodies by providing vegetated buffers. These ecological functions and services are increasingly valuable to the citizens of Michigan, as the acreage and quality of wetlands in the state has been steadily decreasing since the beginning of European settlement. The information in this report can provide more insight into the status and trends of Michigan's remaining wetlands.

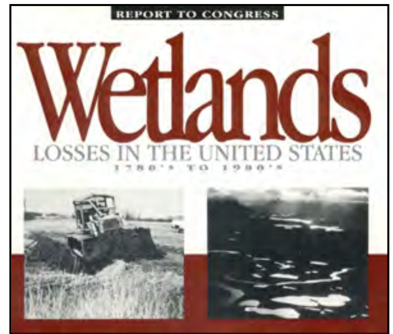
This project used wetland inventories from three time periods, 1978 to 1981 (1978), 1997 to 1999 (1998) and 2000 to 2005 (2005), to analyze wetland trends over the last 30 years in Michigan. Based on the analysis of these inventories, Michigan currently has approximately 6,465,109 acres of wetlands. Michigan originally contained approximately 10.7 million acres of wetland prior to European settlement, but by 1978, that number had dropped to approximately 6,506,044 acres. Since the passage of Michigan's wetland protection law in 1979, the rate of wetland loss has declined dramatically. The total decline of wetland since 1978 is estimated at 41,000 acres, with the rate of decline slowing between the periods 1978 to 1998 (loss of approximately 1,642 acres per year) and 1998 to 2005 (loss of approximately 1, 157 acres per year).

Michigan's geography presents certain unique challenges with wetland inventory and mapping. Encompassing approximately 9 degrees of longitude and 9 degrees of latitude, the state's wetlands are a diverse mix of ecosystems occurring across a wide range of geology, vegetation zones, and climatic conditions. Because of this and other complicating factors explained further in this report, inventorying and mapping every one of the state's millions of wetlands is a daunting task. These landscape level wetland assessment techniques will need to be expanded and refined in years to come, to ensure that future analysis continue to improve and more accurately represents the status and trends of Michigan's wetlands.

INTRODUCTION

There were several efforts in the late twentieth century to look at wetland status and trends in Michigan, focusing on two major periods of time: Pre-European settlement to late twentieth century and late twentieth century to early twenty-first century. Michigan Natural Features Inventory utilized General Land Office (GLO) survey maps of historic land cover and wetland location to analyze trends post-European settlement in "Wetland Trends in Michigan since 1800: a preliminary assessment" (Comer, P.J. 1996). The U.S. Fish and Wildlife Service (USFWS) produced a similar report in the late 1980s titled "Wetlands: Losses in the United States 1780s to 1980s."

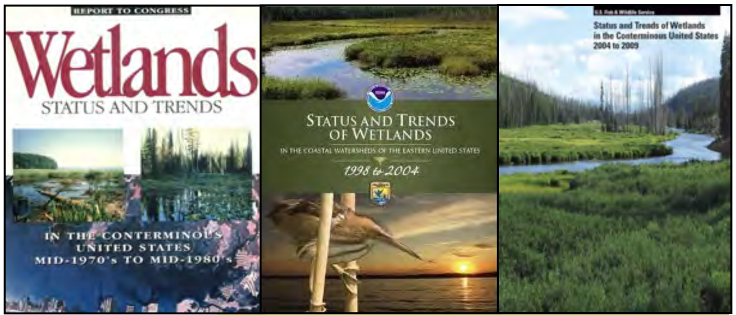
The USFWS has also been publishing national reports on more contemporary (twentieth century) wetland status and trends since the 1950s. These reports are based on sampling grids randomly selected throughout the country, and analyzed for wetland presence/absence and gains/losses. The stated goal of the reports according to USFWS's "Wetlands Status and Trends-A Step Down Strategic Plan" is to "provide the Nation with current scientifically valid information on the status and extent of wetland, riparian, and related aquatic resources, and monitor trends of these resources over time."



USFWS Wetlands Losses in the US 1780's to 1980's

Though monitoring national wetland trends is important from a federal planning and policy perspective, the USFWS acknowledges that conducting regional and more intensive analyses in areas with unique and essential resource conditions should be pursued wherever possible. The strategic plan states that "The Service will actively pursue intensified wetland trends studies in areas where there is a need for resource information that compliments Service work, resource priorities, or where opportunities exist to establish partnerships at the state or regional level. Intensification studies will be planned to compliment national status and trends updates."

Flooded forested wetland in Spring



USFWS Wetlands Status and Trends Reports

With that in mind, the USFWS along with the MDEQ, and the United States Environmental Protection Agency (USEPA) provided funding to Ducks Unlimited, Great Lakes Atlantic Regional Office to update the original National Wetlands Inventory (NWI) for Michigan from 1978. With improvements in technology, and quality statewide aerial imagery datasets available, an update to NWI had become possible at a much reduced cost in comparison to the original effort.

Two collections of aerial imagery were utilized in this effort, the pros and cons of which will be examined later in this report, one of which was collected statewide in 1998, and the other in 2005.

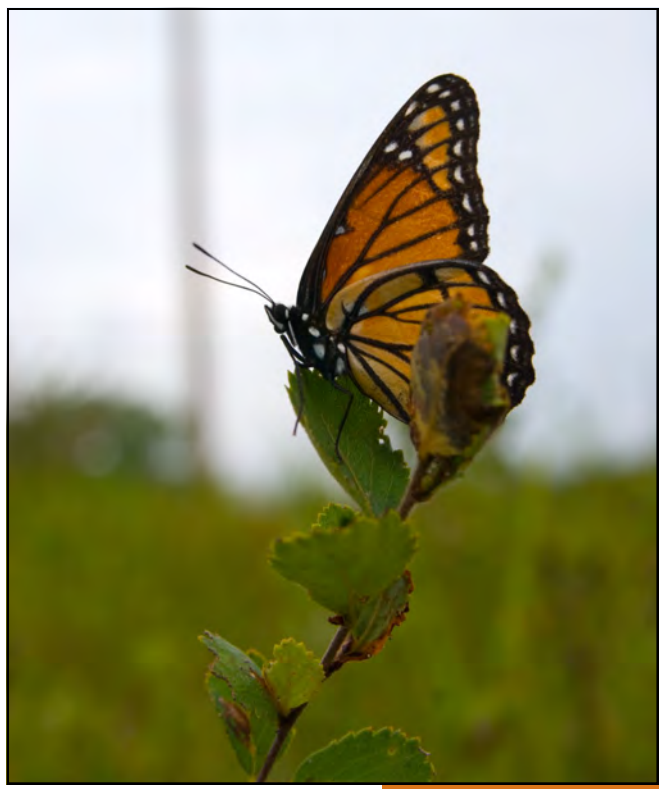
Wetland Protection in Michigan

Protection of Michigan's wetlands is shared among a variety of federal, state, tribal, and local entities. The state is unique in its regulatory jurisdiction, given its assumption of Section 404 of the Clean Water Act in the early 1980s. This assumption delegates a special authority to Michigan, making it one of only two states nationally, approved to manage its own Section 404 Program. These protections prevent filling, dredging, draining, and maintaining a use in any regulated wetland without a permit from the MDEQ. Wetlands protection is shared between the state (MDEQ) and the federal government (U.S. Army Corps of Engineers) in Section 10 waters and along the Great Lakes shore.

Wetlands are defined in state law as land characterized by the presence of water at a frequency and duration sufficient to support, and that under normal circumstances does support, wetland vegetation or aquatic life, and is commonly referred to as a bog, swamp, or marsh. Because of the diverse geology, vegetation, and climatic zones, there are many different types of wetland communities in Michigan. A full listing of Michigan's various wetland and other natural communities are available from Michigan Natural Features Inventory.

The U.S. Army Corps of Engineers Wetland Delineation Manual outlines three criteria that define the presence of a wetland; the presence of hydrophytic vegetation, hydric soils, and hydrology. Wetlands receive water from precipitation, surface water runoff, or groundwater discharge. Some are flooded year-round, daily or periodically by river overflow (e.g., floodplain wetlands), while others are never inundated but have water tables at or near the surface for a few months (e.g., wet flatwoods).

This report summarizes the findings of recent status and trends analysis efforts undertaken in the state by the MDEQ. It will focus on the status of common ecological wetland types. It will also examine the efficacy of the current inventory, new technology, and data analysis tools and their implications for improved wetland mapping, and future directions for status and trend efforts in Michigan.



Viceroy on a Bog Birch

METHODS, CONSIDERATIONS, AND LIMITATIONS

Wetland Omission in the Original NWI

With the advent of Geographic Information Systems (GIS) technology, the wetland inventory process has taken a new approach to tracking the status and trends of wetland resources through time. No longer are stereoscopes and acetate mylar overlays the norm for the imagery interpreters tasked with mapping wetlands. With GIS technology, an interpreter can view multiple dates of aerial imagery, along with ancillary data like topography, soils, and land cover to make a more holistic and comprehensive judgment on what types of resources they are analyzing. Other advantages include heads up digitizing, which allows interpreters to map directly on screen what they are seeing in the spatial data. This is a marked improvement over transferring hand drawn mylar overlays to a digital format using a puck and digitizing tablet where omission in the dataset was common.

Especially in the case of forested or drier-end (e.g., lakeplain prairie) wetlands, the variation in hydrology from year to year and season to season made it particularly difficult to identify these wetlands from the air. Given the correct imagery specifications, preferably Color Infra-Red, Spring or Fall Leaf-off (lack of leaves in forested canopy), in a year with normal to above normal precipitation, interpreting even these wetlands is possible. Due to soil saturation at the ground surface, visible when viewed from above, even the wetlands with a complete lack of inundation can be inventoried if given enough successive years of aerial imagery.

Imagery Choices

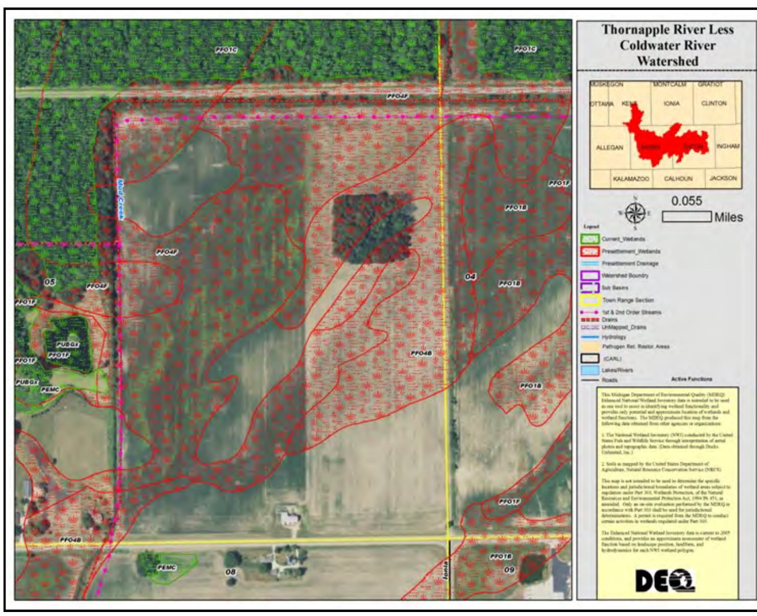
The choices of imagery used for wetland interpretation is one of the most crucial aspects to any wetland inventory effort. Time of year, weather patterns, different types of wavelengths captured (Natural Color, Infra-Red), digital vs. analog; these are all important considerations when choosing imagery datasets for wetland mapping and classification. For this particular effort, two different statewide datasets were chosen:

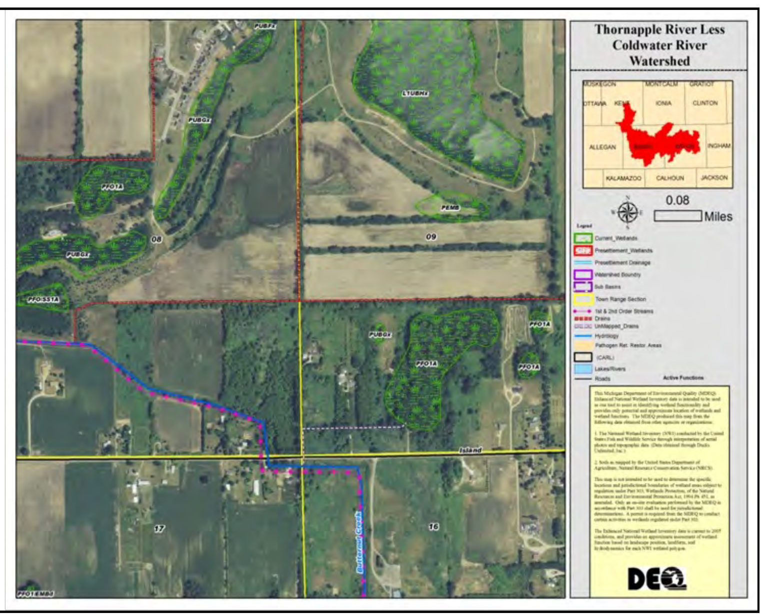
1998 USGS Digital Orthophoto Quadrangles (DOQ)

- *4 band Color Infra Red*
- *1 meter resolution*
- *Leaf-off (Spring or Fall)*

2005 National Agricultural Imagery Program (NRCS-FSA)

- *4 band True Color*
- *1 meter resolution*
- *Leaf-on (Summertime)*



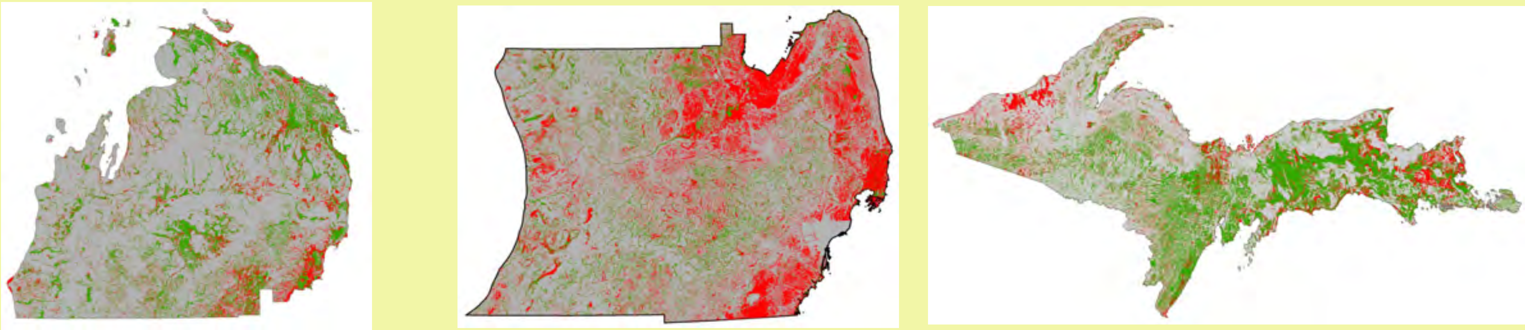


NWIPlus: In addition to the NWI update, which mainly serves as a quantitative summary of wetland gains and losses, the MDEQ has been completing more advanced wetland classification and analysis for select watersheds in the State since 2007. This advance in wetland mapping and classification adds abiotic information to NWI's normal Cowardin classification of major ecological type (emergent, scrub-shrub, forested, aquatic bed, etc) with the addition of information pertaining to landscape position, landform, and hydrologic connectivity. The NWIPlus methodology, as its become known, was developed by Ralph Tiner of USFWS in the Northeast, and adapted by the MDEQ for use in Michigan. This methodology facilitates a basic hydro geomorphic analysis of wetlands in NWI and estimation of specific wetland functions in the NWI. These efforts allow a functional analysis of wetlands gains and losses, and help to translate wetland acreage losses into loss of specific ecosystem services and functions.

Wetland Loss by Region Since Pre-European Settlement

Presettlement Wetland Inventory

2005 Wetland Inventory



Northern Lower Peninsula | Southern Lower Peninsula | Upper Peninsula

Given that Michigan encompasses a geography that includes one of the largest industrial hubs of the twentieth century in Detroit, the largest expanse of freshwater shoreline in the lower 48 states, and some of the largest tracts of forest in the Midwest in the Upper Peninsula, wetland loss in this diverse region has not been uniform.

UPPER PENINSULA	**17% LOSS (638,000 acres)**
NORTHERN LOWER PENINSULA	**20% LOSS (387,000 acres)**
SOUTHERN LOWER PENINSULA	**66% LOSS (3,320,000 acres)**

The choice of the 1998 Color Infra-red imagery was an obvious one. This imagery has the ideal mix of characteristics to ensure an effective and comprehensive wetland inventory. The dataset was completed statewide, during a leaf-off condition, and captured the critical Infra-red band which is well suited for wetland mapping as it aids interpreters by highlighting areas of vegetation, inundation, and saturation. 1998 also happened to be a high water year in Michigan, so many wetland types contained more surface or sub-surface water than they would have in normal years.

The 2005 imagery was more a choice of necessity. At the time the inventory effort was getting started, there was an influx of funding to pursue wetland mapping, but few imagery choices available that were consistent enough statewide to serve as a base for landscape scale resource mapping across the entirety of the state's geography. The USDA-Farm Service Agency had recently transformed its yearly aerial imagery flight from analog to digital, and increased the extent of the state it flew from exclusively the agricultural areas to the entirety of the state. Though this imagery was collected with a leaf-on condition, without inclusion of the Infra-Red band preferred for wetland mapping, it did represent an additional year with which to ascertain wetland gains and losses in the state, and as a result was included in the inventory update effort. These limitations must be considered when evaluating the wetland numbers generated from the 2005 dataset, and inform the decisions made in the future relating to wetland inventory updating.

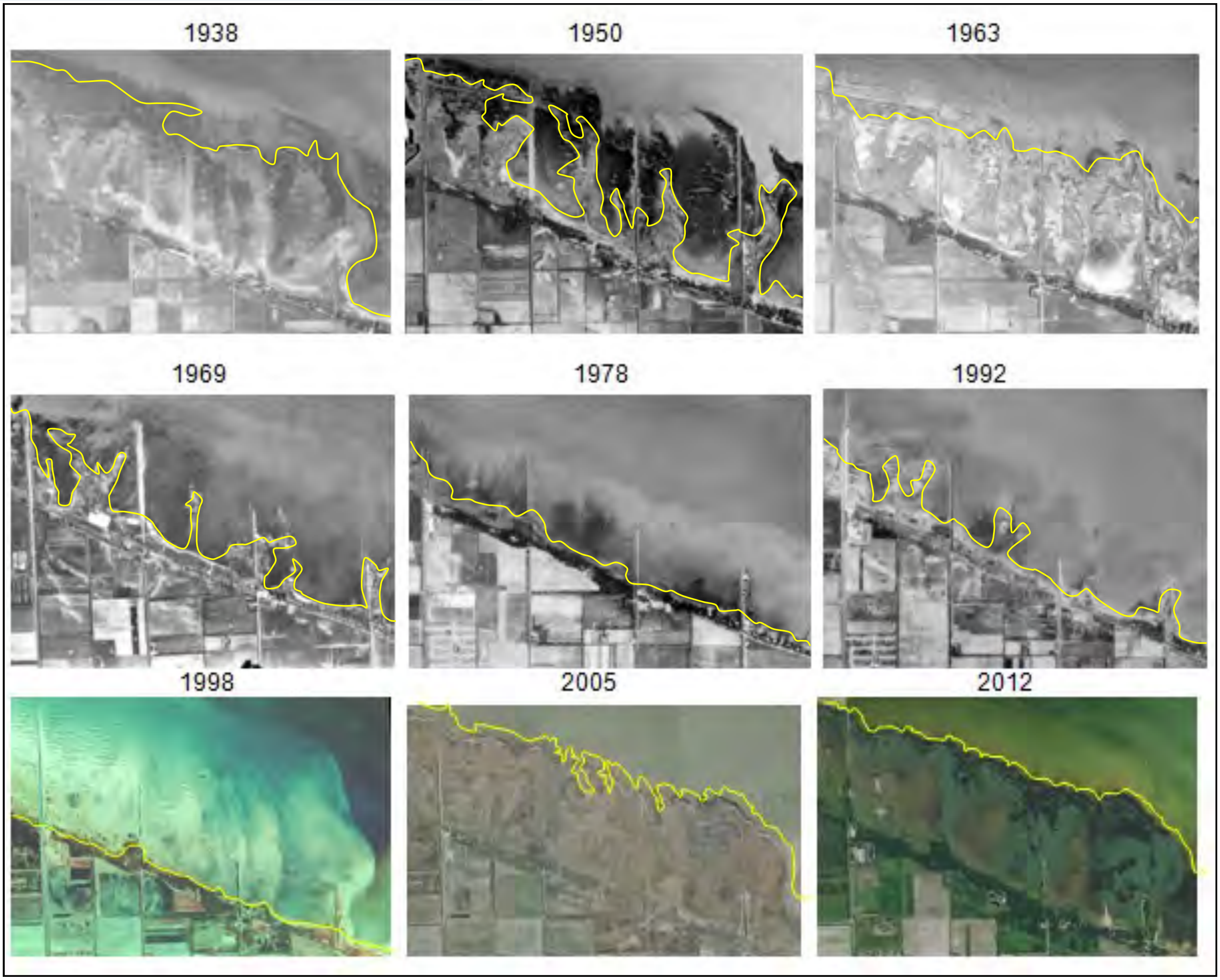
Erroneous Codes

Another issue that arose when updating the original NWI maps to more recent imagery, was the presence of erroneous Cowardin codes in the original that made it difficult to ascertain any information about a given wetland, other than the mere existence of the wetland itself.

When interpreters encountered a wetland in the late 1970s for which they could not identify the vegetation type, a unique code called a '999' was assigned. This signaled to the end user that enough information was not available to classify this wetland down to dominant vegetation type.

Examples of the imagery used to update the NWI. Area in the Pere-Marquette-White River watershed illustrating obvious differences in the tone and texture of forested wetlands when compared in different seasons (leaf-on vs. leaf-off). Areas of inundation and saturation appear darker on the CIR imagery at left vs. the Natural Color 2005 image at right.

Coastal Wetland Change on Saginaw Bay in Bay County



Coastal Wetland Change:

Given that the water levels in the Great Lakes are highly variable from year to year, and the shallow, low gradient of the lake bed in the inland bays, low water levels typically result in large coastal marshes forming. This occurrence is most prevalent in areas along Saginaw Bay, the southern Upper Peninsula , and the bays of Grand Traverse County.

The most recent GIS data available for acreage of coastal wetlands in Michigan is the 2005 National Wetlands Inventory (NWI) update, previous to that, the 1998 NWI update is the next most recent available GIS data. 1998 was marked by high Great Lakes water levels, while 2005 was marked by low water levels. Comparing the two inventories, it becomes apparent that coastal wetland acreage increased in the Lower Peninsula between 1998 and 2005. The increase in wetland acreage appears to have occurred mainly in very shallow coastal areas with extensive areas of bottomlands exposed by the low water levels. Emergent wetland vegetation rapidly colonized the exposed bottomlands.

Historic trends in Great Lakes water levels have resulted in varying exposure of coastal wetland vegetation through the years. Overall, trends show a substantial loss in coastal wetlands from historic estimates, but also indicate significant variability due to water level fluctuations.

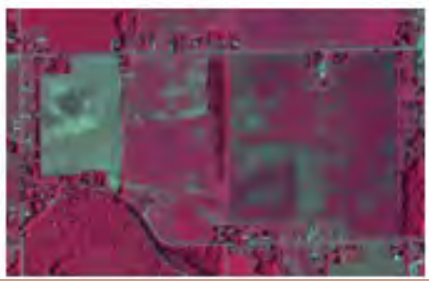
Farmed Wetlands

Another issue was wetlands labeled 'Farmed Wetlands', wetlands that were classified based on visible saturation or inundation that were in active agriculture at the time of the original inventory. These areas were coded originally as 'Palustrine Farmed.' In most cases, these areas represent former swamps or marshes that in many cases were partially drained, though ineffectively, resulting in flooded fields and/or stressed or dying crops. The classification scheme was slightly altered for these areas in the NWI update, but they were still included in the final updated inventory. Though the code existed to classify these areas accordingly, it was underused, so it is expected that large areas of wetland with partial or no drainage that are in a state of active agriculture were missed or at a minimum under-represented.

Omission of Small Wetlands

One class of wetland likely to fall through the net of wetland inventory efforts, regulatory gains and losses, and any other wetland tracking efforts are small (potentially unregulated) wetlands. Many of these smaller wetlands, if they happen to be located under the extensive forested canopy in the State, or fall on the drier end of the hydroperiod or water regime spectrum, may be missed on aerial imagery and as a result not be counted in wetland gains and losses reported here. Unfortunately, one of the wetland types that may fall into this particular class of omission is vernal pools, a particularly diverse habitat that support an array of salamanders, frogs, and turtles and provides foraging areas for many neotropical birds.

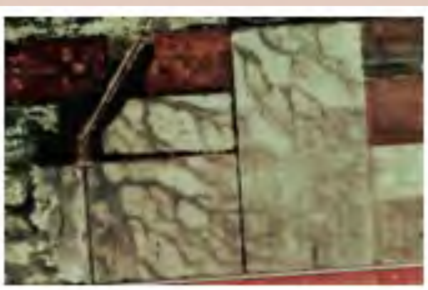
Stressed crops, inundation and saturation are all easily identified from aerial imagery.


Imagery showing the signature of inundation and saturation of the soil column. Inundated areas have a much darker tone with a clear, unmottled texture as water absorbs all wavelengths of light rendering it black to near black on imagery. Saturated areas appear darker than dry areas, though not as dark as inundated areas, though the texture is more mottled and variable given the presence of soil above the saturated zone.



Imagery showing the obvious signature of sub surface drainage lines (tiles) which appear light or white in the soil column above the tile given the artificial and expedited drainage of the soil at that location. The image at right shows a dune/swale complex in Central Eastern MI next to the same habitat being drained and farmed.



WETLAND GAINS/LOSSES

1978—1998—2005

The NWI effort in Michigan resulted in three wetland inventories for the State from which to draw conclusions and analyze trends; 1978, 1998, and 2005. The direct measure of vegetated wetland acreage for Michigan taken from the original NWI was **6,506,044** acres. The 1998 inventory shows a total loss of vegetated wetlands of **32,839** acres, resulting in a total wetland acreage statewide of **6,473,205**. The 2005 inventory shows a total loss of vegetated wetlands of **8,096** acres. Subtracting these losses from the original NWI total wetland acreage yields a total of **6,465,109** acres of vegetated wetland remaining in Michigan in 2005. This information and more detailed information for the three unique inventories is available in the Appendix A of this report.

Because of Michigan's geography, encompassing approximately 9 degrees of longitude and 9 degrees of latitude, the state's wetlands are a diverse mix of ecosystems occurring across a wide range of geology, vegetation zones, and climatic conditions. When the original NWI is lumped into major vegetated ecological types, the wetland acreage can be sub-divided into these four major vegetated categories :

70% Palustrine Forested

10% Palustrine Emergent

20% Palustrine Shrub Scrub

<1% Palustrine Aquatic Bed

Looking at the detailed statewide statistics can shed further light on wetland type and composition in the State. Based on the Wetland Classes contained within the NWI, all the vegetated types except Aquatic Bed show a marked decrease. The increase in Aquatic Bed (Open water covered by floating macrophytes) is likely due to variable water levels in these types of systems, and the time periods covered by the updates. (1998 was a high water year in the Great Lakes basin, while 2005 was a low water year.) Many of these areas will tend to bounce back and forth between open water and aquatic bed, depending on water levels, precipitation, and time of year of the imagery being utilized.

NWI YEAR		ACREAGE (All)	Vegetated Acreage	Open Water Acreage
1978		7,488,357	6,506,044	977,105
1998		7,472,576	6,473,205	994,689
2005		7,470,273	6,465,109	1,000,114
- Is Loss				
+ Is Gain				
CHANGE 78-98		-15,780	-32,839	+17,585
CHANGE 98-05		-2,303	-8,096	+5,425
CHANGE 78-05		-18,083	-40,935	+23,010

Presettlement to 2005

In addition to the NWI Update efforts, the MDEQ has developed data on Pre-European Settlement wetland locations, based on NRCS Hydric Soils data. The Hydric Soils data was developed as one of three pieces comprising the larger Part 303 State Wetland Inventory effort completed in 2007.

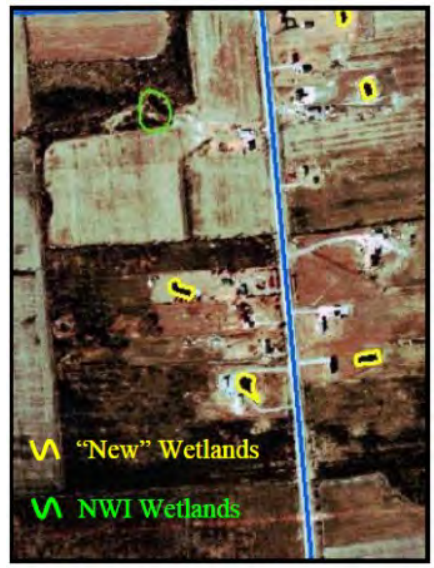
Previous to this MDEQ project, Michigan Natural Features Inventory had developed estimates on original wetland distribution for the state, and arrived at a wetland total area of 11 million acres. These figures were based off of General Land Office surveys completed in Michigan in the early 1800s, and given the spatial resolution of the source data and its variable quality, these numbers compare very well with the direct measure of hydric soils in the state.

The analysis of hydric soils yielded an original wetland area of 10,742,849 acres Pre-European Settlement, and given the methods employed by the NRCS to collect the soils data on which this figure is based, it should be reasonably accurate. When this Pre-European Settlement wetland area information is compared with the current information on wetland area, it yields a total wetland loss for the State of 4,277,740 acres. This information is further broken down by county in Appendix B.

Wetland Losses, 'New' Wetlands, and Open Water

Wetland loss was determined by comparing the three temporal inventories. This evaluation concluded that approximately **40,935** acres of vegetated wetland were converted to another use, while approximately **23,010** acres of open water areas (includes some rivers/streams, lakes, ponds, and deepwater wetland habitat) have been added in the course of the 1998 and 2005 updates. These open water gains are not good indicators of wetlands being created or restored on the landscape, but rather wetlands that were missed by interpreters in the initial inventory due to older technology or areas that were created in former upland.

The vast majority of the new open water areas are small ornamental ponds on residential lots. Though these areas may serve some benefit on the landscape in terms of floodwater storage or fish habitat, they offer significantly less functions than a vegetated wetland. Because of this, this project draws a distinction between the vegetated wetlands and open water areas included in the datasets. Furthermore, given the inconsistent mapping of open water in NWI and the availability of superior datasets like the National Hydrography Dataset (NHD) for open water areas, this project focused primarily on the vegetated wetland types in NWI.



Vegetated Wetland Loss by Type and Rates of Loss

Most of the total net loss was Emergent wetland (43%), followed by Forested wetland (33%), Shrub wetland (24%), and Aquatic Bed wetland (<1%). (See table above.)

On a positive note, the state's vegetated wetland loss rate actually decreased from the 20 year period between 1978 to 1998 and the period from 1998 to 2005:

1978 to 1998 = Loss of 1,642 acres/year

1998 to 2005 = Loss of 1,157 acres/year

However, while state wetland regulations have helped to slow the destruction of wetlands in Michigan from a quantitative perspective, watershed related wetland studies completed around the State have consistently shown a decrease in wetland function and overall quality for the wetlands that remain.

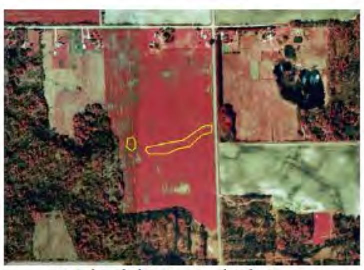
NWI YEAR	Aquatic Bed Wetlands	Emergent Wetlands	Scrub Shrub Wetlands	Forested Wetlands	VEGETATED WETLAND TOTALS	Open Water	TOTALS
1978	34,133	598,677	1,334,947	4,538,871	6,506,044	977,105	7,488,357
1998	34,762	597,108	1,325,985	4,515,557	6,473,205	994,689	7,472,576
2005	34,836	596,625	1,325,053	4,509,178	6,465,109	1,000,114	7,470,273

Agents of Wetland Loss

When losses that occurred from 1978 to2005 are combined; Palustrine vegetated wetlands were loss due to conversion from Agriculture (47%), Development (49%), and other activities such as Logging (2%), and Recreation (2%).

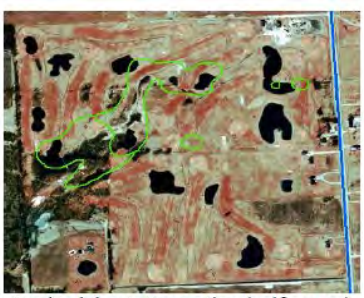
Agents of Change:

Agriculture	Development	Recreation	Other
orchards	urban housing	golf courses	logging
crops	rural housing	race tracks	airports
pasture	industry	sports fields	highways
farm houses/ structures	commercial		unknown/unidentified

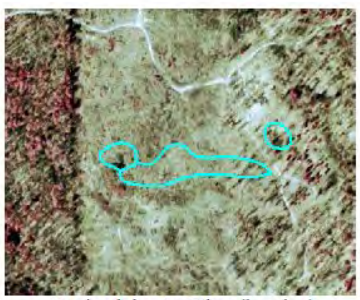


Drained due to Agriculture

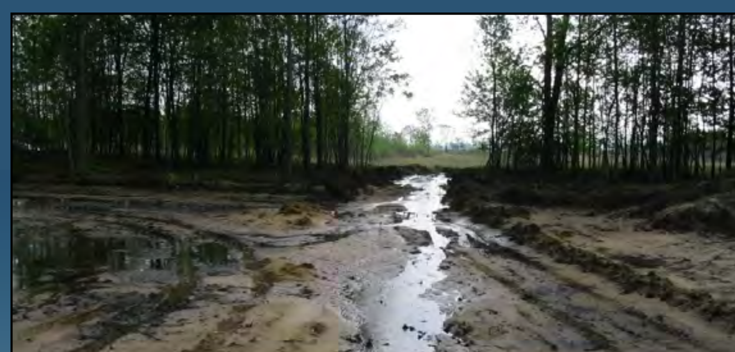
Drained due to Development

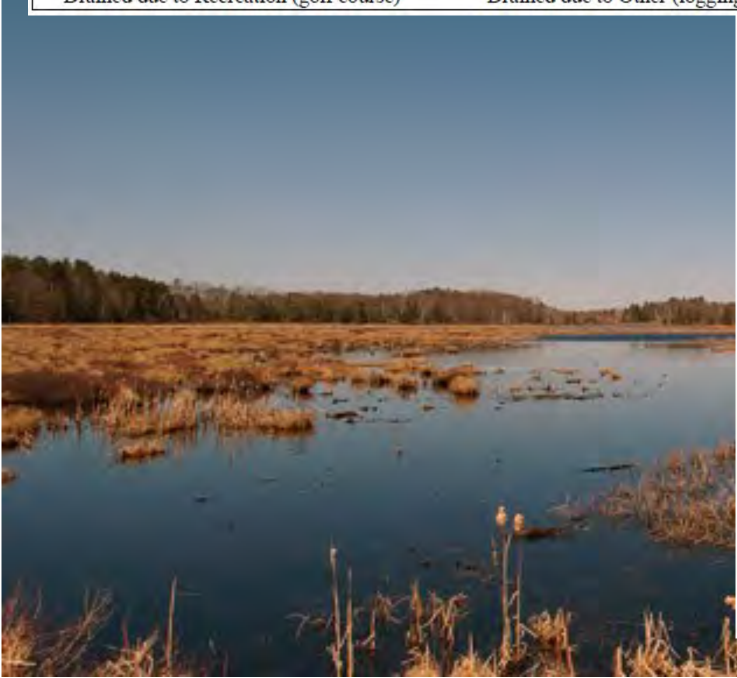


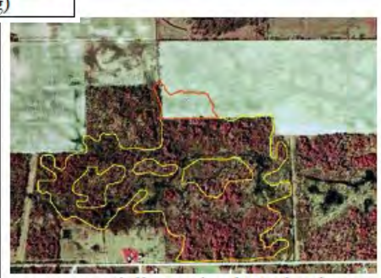
Drained due to Recreation (golf course)



Drained due to Other (logging)



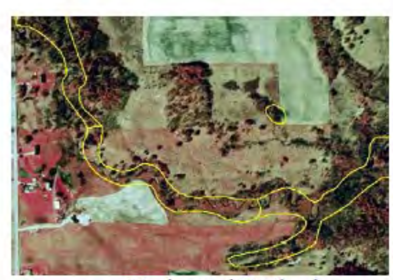




Partially Drained Wetland

Drained Wetland

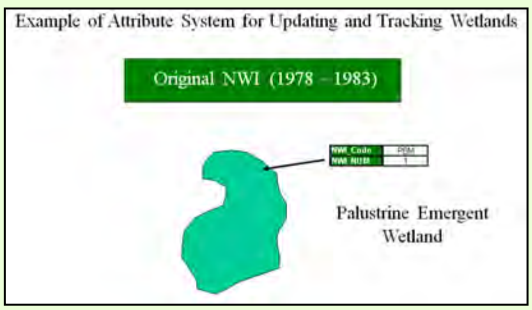
Modified Wetland

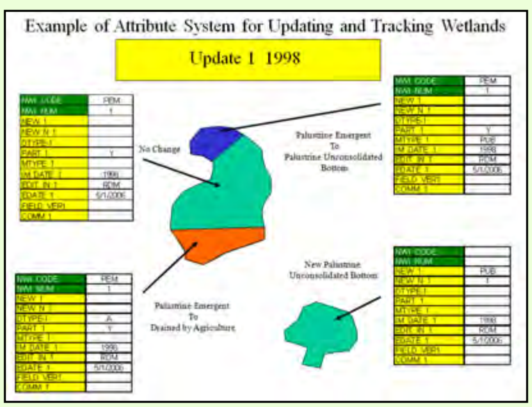


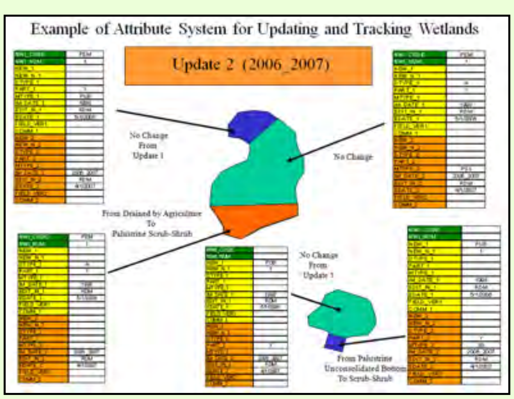
Unchanged Wetland

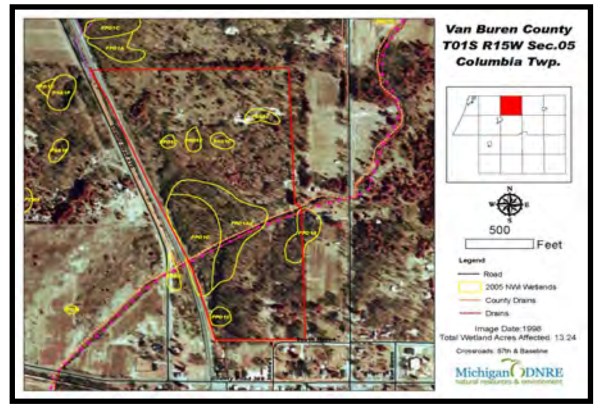
Tracking One Wetland in Time

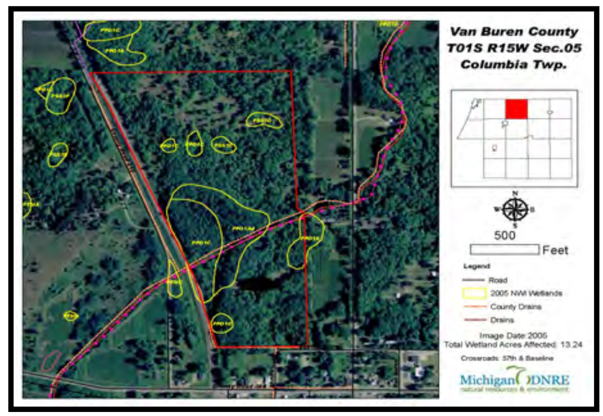
Given the complexity of tracking hundreds of thousands of wetlands in the state, and the myriad natural changes and anthropogenic impacts that they undergo, Ducks Unlimited devised a novel approach to tracking wetlands changes through time. Each wetland in the NWI dataset was given a 'Parent Key' that was assigned to it as a unique identifier, meaning that no other wetland in the dataset was assigned that number. As wetland changes were mapped and noted during the update, interpreters 'deactivated' the Parent Key of a wetland suffering some impact (e.g., filling for development), and created a new polygon representing the wetlands new extent. This wetland was assigned a new parent key, but retained the relationship to the original polygon that it originated from in the 1978 inventory. Because the original polygon was deactivated, its acreage was not double counted in inventory analysis efforts, but its relationship to all future polygons sharing its geographic location could be tracked through time.

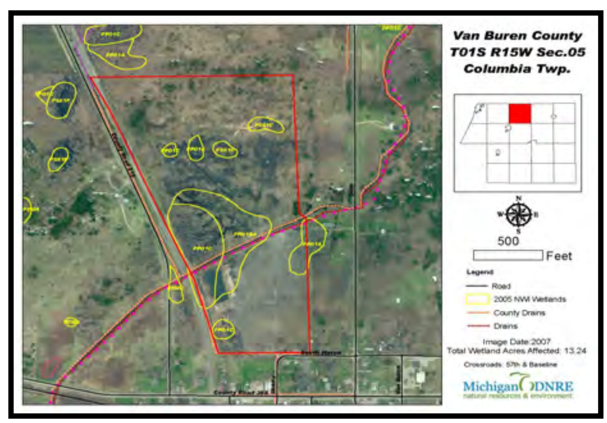








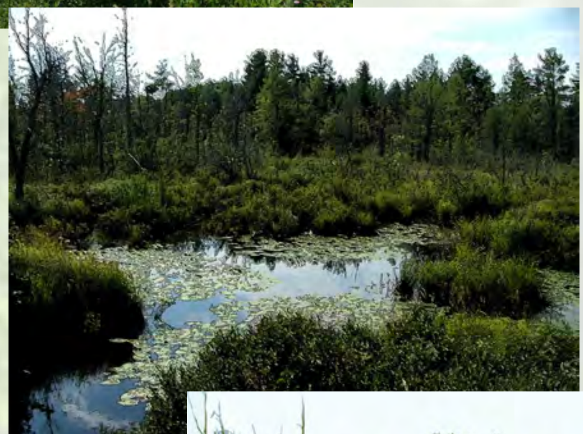


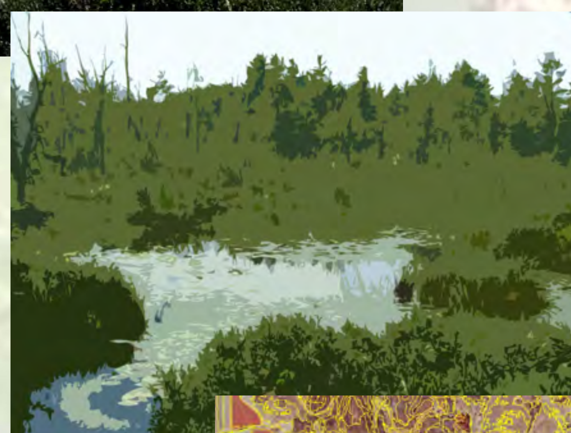


One wetland shown in a series of aerial imagery thru time

FUTURE INVENTORY EFFORTS

Advances in Remote Sensing Technology and Existing Hi-Res Imagery





The time period between 2005 and 2013 has seen a drastic increase in the collection of high resolution aerial imagery in the state. The imagery that was used for the NWI update analyzed in this report had a spectral resolution that was approximately 2 meters (each pixel represents 2m X 2m on the ground), roughly enough detail to be able to discern the shape of a car parked in a driveway on digital imagery. With advances in the technology used to capture digital aerial photography, and decreasing costs due to the switch to digital from film, current imagery is now routinely flown with a spectral resolution of six inches to one foot (allowing an interpreter to accurately predict the make and model of the car in the driveway from the previous example).

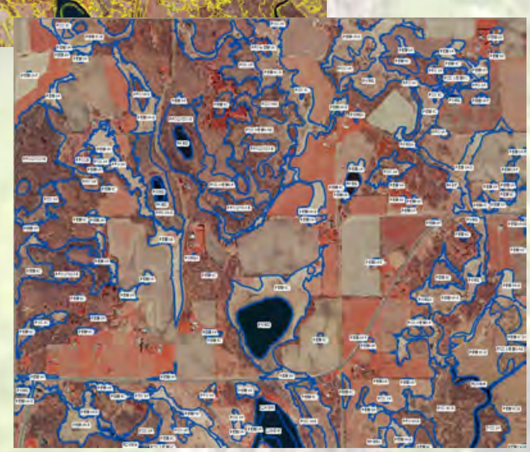
This increase in imagery quality has far reaching implications for natural resource mapping, in particular for wetlands and other hydrologic features. There is currently another statewide effort underway to fly the entirety of the State in high resolution between the years 2013-2016, with the possibility that other remote sensing products could be acquired simultaneously, particularly high resolution topography known as LiDAR.

LiDAR data is collected with an active sensor that utilizes millions of laser pulses in combination with Global Positioning Systems to produce highly accurate Digital Elevation Models. This dataset, perhaps more than all others available, could redefine wetland and hydrologic mapping in the State. Potential applications of LiDAR will be examined further later in this section, as well as some techniques already in use that could easily be adapted to Michigan.

Reference Layers for Wetland Interpretation and Automated Classification

There are many additional datasets already available that could easily be utilized to inform and improve future wetland inventories. Hydric Soils information provides a data source with a multitude of uses to not only locate and inventory wetlands that have been missed in previous efforts, but also to better characterize and analyze the hydrologic systems being studied. Information already built into the SSURGO dataset could be useful in predicting flooding frequency and ponding duration, which are the basic building blocks of NWI's water regime classification. This soils information, having been collected and verified in the field, has the potential to be a better predictor of these wetland characteristics than the 'one snapshot in time' approach that is inherent to aerialimagery interpretation.

USGS Topography Quadrangles also serve as a useful reference layer in wetland mapping and classification (e.g., wetlands and streams mapped as part of the original USGS effort, as well as topography).



Radar data also holds some promise in identifying and mapping forested wetlands that have proven difficult to inventory from aerial imagery interpretation. This information is already available and in use in the state, and at a minimum serves to provide approximate and potential locations of water under tree canopy that would not be seen on imagery alone.

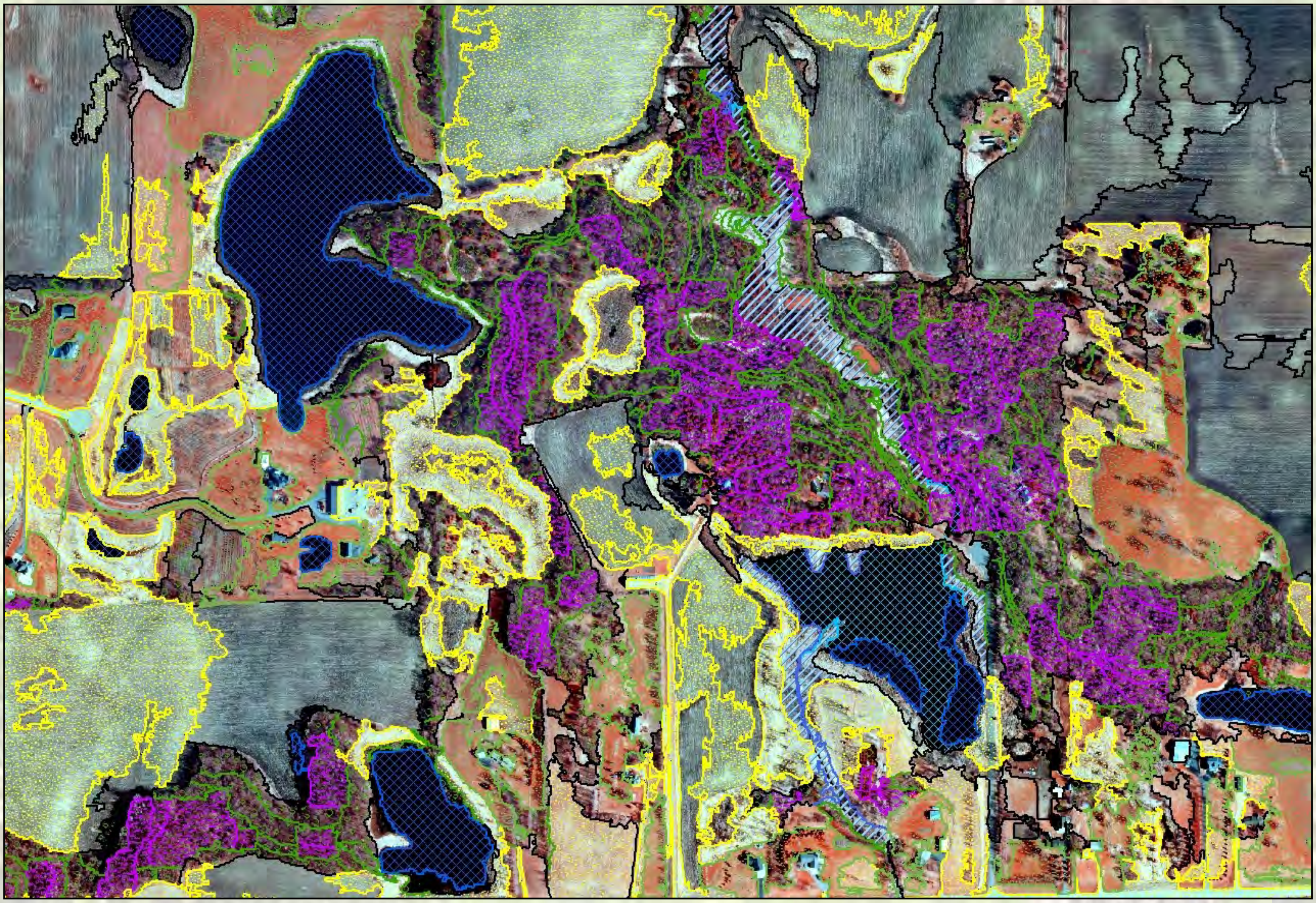
Finally, there are a variety of groundwater inventories available in Michigan that could also provide spatial data to inform future inventory efforts.

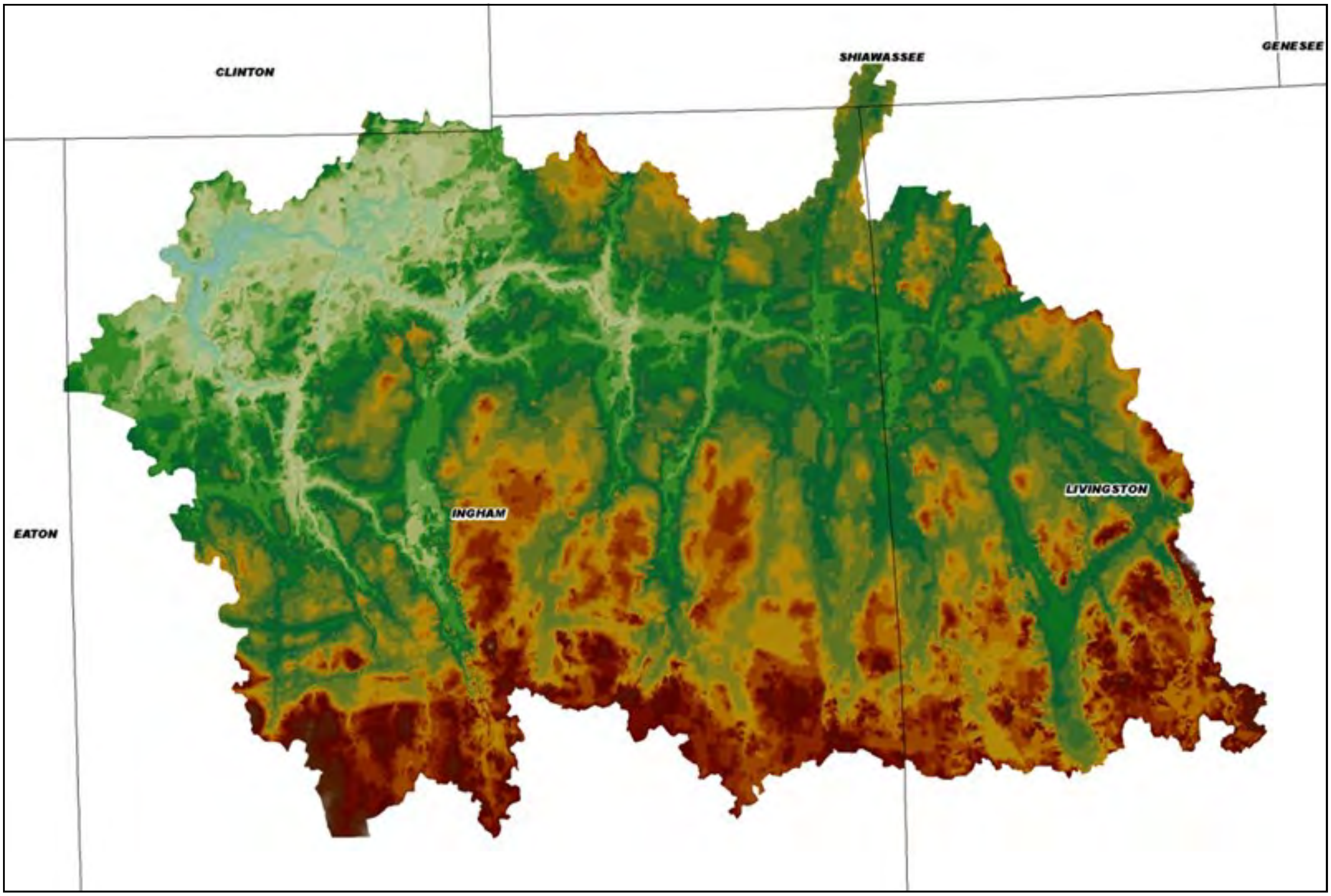
Image Segmentation

With new techniques already in use in other Great Lakes states like Minnesota, there is evidence that inventory accuracies can reach up to 95 percent confidence when high resolution imagery is paired with high resolution topography (LiDAR) and automated imagery classification. Previous accuracy assessments on existing NWI data were in the range of 75 percent to 85 percent confidence, with that number far lower in large expanses of forest typical of places like the Upper Peninsula.

Image segmentation utilizes spectral reflectance in combination with high resolution topography to automatically classify wetlands from aerial imagery, resulting in much more refined wetland boundaries for each wetland polygon. This technique would require essentially 'wiping the slate clean' in terms of existing wetland boundaries in existing inventories. In addition to providing wetland boundaries that are superior, image segmentation can produce a wetland boundary in seconds compared to the minutes it may take to digitize the boundary one vertex at a time. Below is an example of the precise boundaries that can be produced utilizing these techniques.

Technology is rapidly improving, as are the data products being delivered to perform geo spatial mapping and ecological classification. Datasets like PALSAR (Satellite Radar data available thru the Alaska Satellite Facility) show some promise in identifying forested wetlands, while LIDAR is suited for hydrologic mapping and in particular aiding in the identification of Stream Bed wetlands. These two datasets, along with advances in imagery processing and automated image segmentation techniques, can produce wetland inventories of much higher quality.





Digital Elevation Model (DEM)

LiDAR topography holds a great deal of promise in terms of changing the way that wetlands are mapped and tracked. Researchers until recently have had access to, at best, 10 foot contours for utilization in spatial analysis and mapping . Because LiDAR has the ability to penetrate tree canopy when properly processed, small depressional wetlands that exist under the tree canopy can be seen and captured. The interconnection of wetlands, surface water, and infrastructure (culverts, dams, etc) can also be analyzed.

Final Thoughts

It is clear that our wetland resources continue to be depleted at a rate that, while slowing, is still faster than efforts to restore or create wetlands. Furthermore, areas with historic loss of wetlands are still struggling with the consequences of that loss (e.g., water quality issues, flooding and flashy streams, and loss of wildlife). In addition, Michigan's wetlands continue to face increasing threats, including historic threats such as agriculture and development, as well as new threats like invasive species and climate change. Efforts, like the one examined here, are vital to our understanding of the status and trends of wetlands in Michigan.

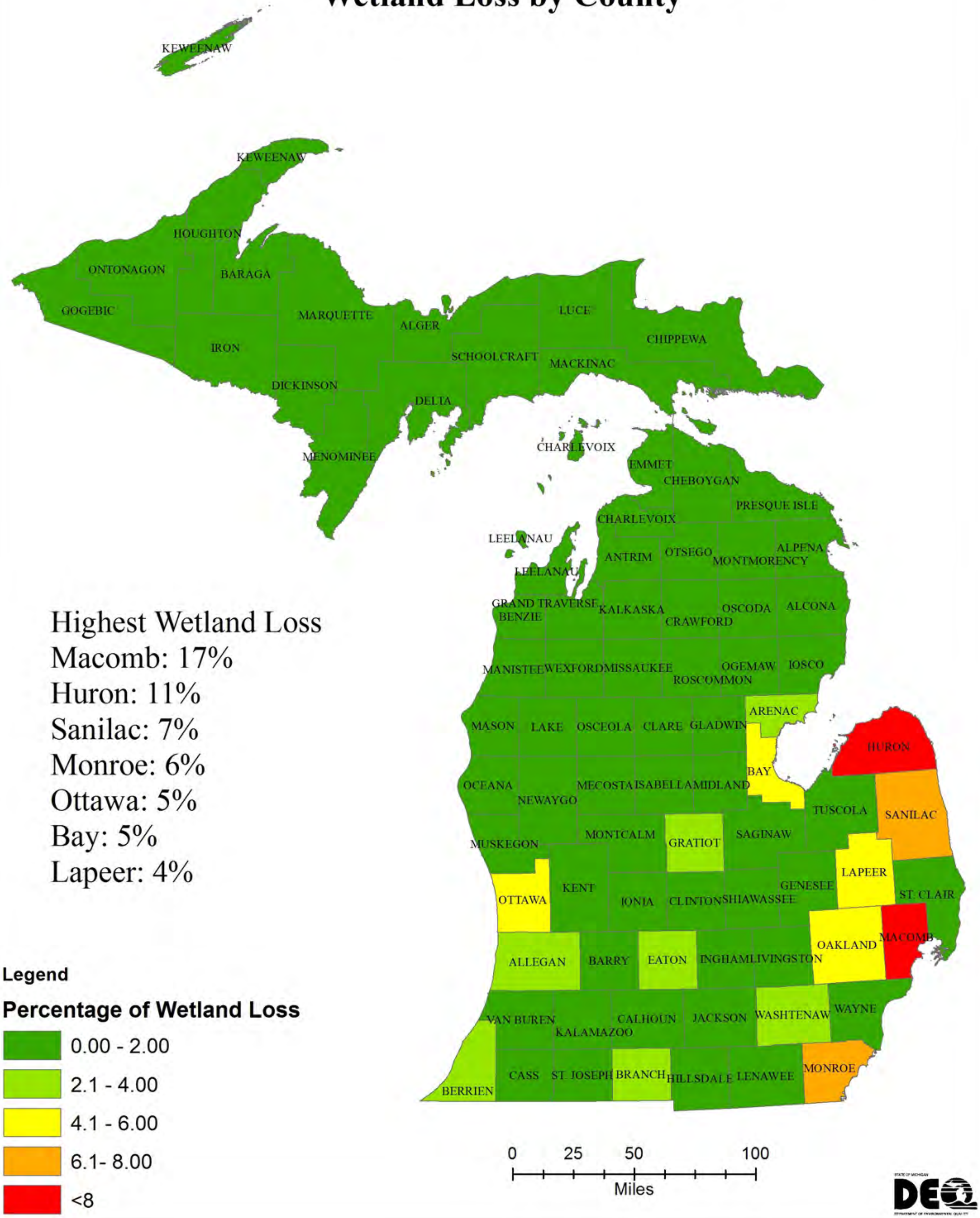
APPENDIX A: 1978—1998—2005

County	1978 Wetland Acres & % of Wetland In County		1998 Wetland Acres & % of Wetland In County		2005 Wetland Acres & % of Wetland In County		Total Percentage of Wetland Loss 78-05
ALCONA	76,537	(17.2%)	76,951	(17.3%)	76,894	(17.3%)	0%
ALGER	137,997	(23.0%)	138,103	(23.1%)	138,102	(23.1%)	0%
ALLEGAN	62,021	(11.5%)	61,189	(11.4%)	60,707	(11.3%)	-2%
ALPENA	142,767	(37.5%)	142,147	(37.4%)	142,052	(37.3%)	-1%
ANTRIM	25,294	(7.5%)	25,241	(7.5%)	25,162	(7.5%)	-1%
ARENAC	55,890	(23.7%)	53,713	(22.8%)	53,678	(22.8%)	-4%
BARAGA	111,686	(19.0%)	111,691	(19.0%)	111,655	(19.0%)	0%
BARRY	46,199	(12.5%)	46,158	(12.5%)	46,153	(12.5%)	0%
BAY	26,385	(9.2%)	25,318	(8.8%)	25,038	(8.7%)	-5%
BENZIE	24,144	(10.9%)	24,126	(10.9%)	24,125	(10.9%)	0%
BERRIEN	31,215	(8.4%)	30,454	(8.2%)	30,289	(8.2%)	-3%
BRANCH	43,883	(13.2%)	42,409	(12.8%)	42,372	(12.7%)	-3%
CALHOUN	77,612	(16.9%)	77,288	(16.8%)	77,231	(16.8%)	0%
CASS	40,486	(12.4%)	40,153	(12.3%)	40,123	(12.3%)	-1%
CHARLEVOIX	51,350	(17.7%)	50,986	(17.6%)	50,942	(17.5%)	-1%
CHEBOYGAN	111,829	(22.0%)	111,454	(21.9%)	111,225	(21.8%)	-1%
CHIPPEWA	343,735	(29.7%)	343,720	(29.7%)	343,735	(29.7%)	0%
CLARE	67,289	(18.3%)	67,388	(18.3%)	67,299	(18.3%)	0%
CLINTON	32,004	(8.7%)	31,638	(8.6%)	31,702	(8.6%)	-1%
CRAWFORD	31,628	(8.8%)	31,628	(8.8%)	31,616	(8.8%)	0%
DELTA	326,908	(43.3%)	326,330	(43.2%)	326,144	(43.2%)	0%
DICKINSON	137,246	(27.6%)	137,159	(27.6%)	137,160	(27.6%)	0%
EATON	41,827	(11.3%)	40,690	(11.0%)	40,478	(10.9%)	-3%
EMMET	52,638	(17.0%)	52,290	(16.9%)	52,230	(16.9%)	-1%
GENESEE	26,466	(6.4%)	26,304	(6.3%)	26,241	(6.3%)	-1%
GLADWIN	83,802	(25.4%)	83,597	(25.3%)	83,479	(25.3%)	0%
GOGEBIC	164,960	(22.5%)	164,876	(22.5%)	164,905	(22.5%)	0%
GRAND TRAVERS	26,067	(8.3%)	26,043	(8.3%)	25,980	(8.3%)	0%
GRATIOT	34,277	(9.4%)	33,386	(9.1%)	33,282	(9.1%)	-3%
HILLSDALE	36,566	(9.4%)	36,333	(9.4%)	36,144	(9.3%)	-1%
HOUGHTON	87,117	(13.1%)	87,169	(13.1%)	87,178	(13.1%)	0%
HURON	40,410	(7.5%)	36,479	(6.8%)	36,007	(6.7%)	-11%
INGHAM	46,398	(12.9%)	45,866	(12.8%)	45,669	(12.7%)	-2%
IONIA	34,893	(9.4%)	34,705	(9.4%)	34,720	(9.4%)	0%
IOSCO	67,029	(18.5%)	66,375	(18.3%)	66,330	(18.3%)	-1%
IRON	168,422	(21.7%)	168,317	(21.7%)	168,309	(21.7%)	0%
ISABELLA	49,094	(13.3%)	48,852	(13.2%)	48,791	(13.2%)	-1%
JACKSON	92,032	(19.9%)	91,460	(19.8%)	91,253	(19.7%)	-1%
KALAMAZOO	41,853	(11.3%)	41,410	(11.2%)	41,361	(11.1%)	-1%
KALKASKA	44,120	(12.1%)	44,093	(12.1%)	44,072	(12.1%)	0%
KENT	54,940	(9.9%)	54,473	(9.8%)	54,359	(9.7%)	-1%
KEWEENAW	64,522	(17.9%)	64,558	(17.9%)	64,562	(17.9%)	0%
LAKE	36,417	(9.9%)	36,586	(10.0%)	36,584	(10.0%)	0%
LAPEER	49,502	(11.7%)	47,311	(11.2%)	47,295	(11.2%)	-4%
LEELANAU	17,238	(7.2%)	17,133	(7.1%)	17,129	(7.1%)	-1%
LENAWEE	31,305	(6.4%)	31,260	(6.4%)	31,278	(6.4%)	0%
LIVINGSTON	65,000	(17.4%)	64,920	(17.3%)	64,713	(17.3%)	0%

LUCE	247,719	(41.8%)	247,668	(41.8%)	247,543	(41.8%)	0%
MACKINAC	269,706	(39.6%)	269,469	(39.6%)	269,461	(39.6%)	0%
MACOMB	21,524	(7.0%)	18,161	(5.9%)	17,851	(5.8%)	-17%
MANISTEE	43,754	(12.3%)	43,602	(12.2%)	43,591	(12.2%)	0%
MARQUETTE	292,686	(24.5%)	292,747	(24.5%)	292,111	(24.4%)	0%
MASON	45,488	(13.9%)	45,209	(13.9%)	45,194	(13.9%)	-1%
MECOSTA	47,245	(12.9%)	47,224	(12.9%)	47,201	(12.9%)	0%
MENOMINEE	310,261	(46.1%)	309,141	(46.0%)	309,056	(45.9%)	0%
MIDLAND	76,553	(22.7%)	75,828	(22.5%)	75,497	(22.4%)	-1%
MISSAUKEE	74,015	(20.2%)	73,893	(20.1%)	73,677	(20.1%)	0%
MONROE	13,466	(3.8%)	12,705	(3.6%)	12,632	(3.5%)	-6%
MONTCALM	70,688	(15.3%)	70,519	(15.3%)	70,479	(15.3%)	0%
MONTMORENCY	57,725	(16.0%)	57,702	(16.0%)	57,700	(16.0%)	0%
MUSKEGON	33,431	(9.9%)	33,160	(9.8%)	33,045	(9.8%)	-1%
NEWAYGO	68,139	(12.4%)	67,975	(12.3%)	67,967	(12.3%)	0%
OAKLAND	53,899	(9.3%)	51,960	(9.0%)	51,601	(8.9%)	-4%
OCEANA	40,298	(11.5%)	40,177	(11.5%)	40,072	(11.5%)	-1%
OGEMAW	58,260	(15.8%)	58,122	(15.8%)	58,104	(15.8%)	0%
ONTONAGON	60,265	(7.1%)	64,311	(7.6%)	64,256	(7.6%)	7%
OSCEOLA	53,548	(14.6%)	53,519	(14.6%)	53,511	(14.6%)	0%
OSCODA	27,495	(7.5%)	27,589	(7.5%)	27,593	(7.5%)	0%
OTSEGO	32,777	(9.7%)	32,804	(9.7%)	32,802	(9.7%)	0%
OTTAWA	28,518	(7.7%)	27,074	(7.3%)	26,877	(7.3%)	-6%
PRESQUE ISLE	143,912	(32.8%)	143,031	(32.6%)	142,466	(32.5%)	-1%
ROSCOMMON	97,499	(26.3%)	97,401	(26.3%)	97,326	(26.2%)	0%
SAGINAW	37,718	(7.2%)	37,882	(7.3%)	38,160	(7.3%)	1%
SANILAC	42,420	(6.9%)	39,258	(6.4%)	39,284	(6.4%)	-7%
SCHOOLCRAFT	399,843	(51.2%)	399,746	(51.2%)	399,323	(51.1%)	0%
SHIAWASSEE	34,330	(9.9%)	34,039	(9.8%)	33,847	(9.8%)	-1%
ST. CLAIR	41,610	(8.8%)	41,821	(8.9%)	41,380	(8.8%)	-1%
ST. JOSEPH	34,818	(10.4%)	34,747	(10.4%)	34,758	(10.4%)	0%
TUSCOLA	39,606	(7.6%)	40,732	(7.8%)	40,934	(7.9%)	3%
VAN BUREN	55,274	(13.9%)	54,885	(13.8%)	54,736	(13.7%)	-1%
WASHTENAW	51,991	(11.3%)	50,668	(11.0%)	50,441	(10.9%)	-3%
WAYNE	7,582	(1.8%)	7,687	(1.9%)	7,886	(1.9%)	4%
WEXFORD	30,978	(8.4%)	31,016	(8.4%)	30,994	(8.4%)	0%
Total	6,506,044	17.4%	6,473,205	(17.3%)	6,465,109	(17.3%)	-1%

Wild Rice Beds

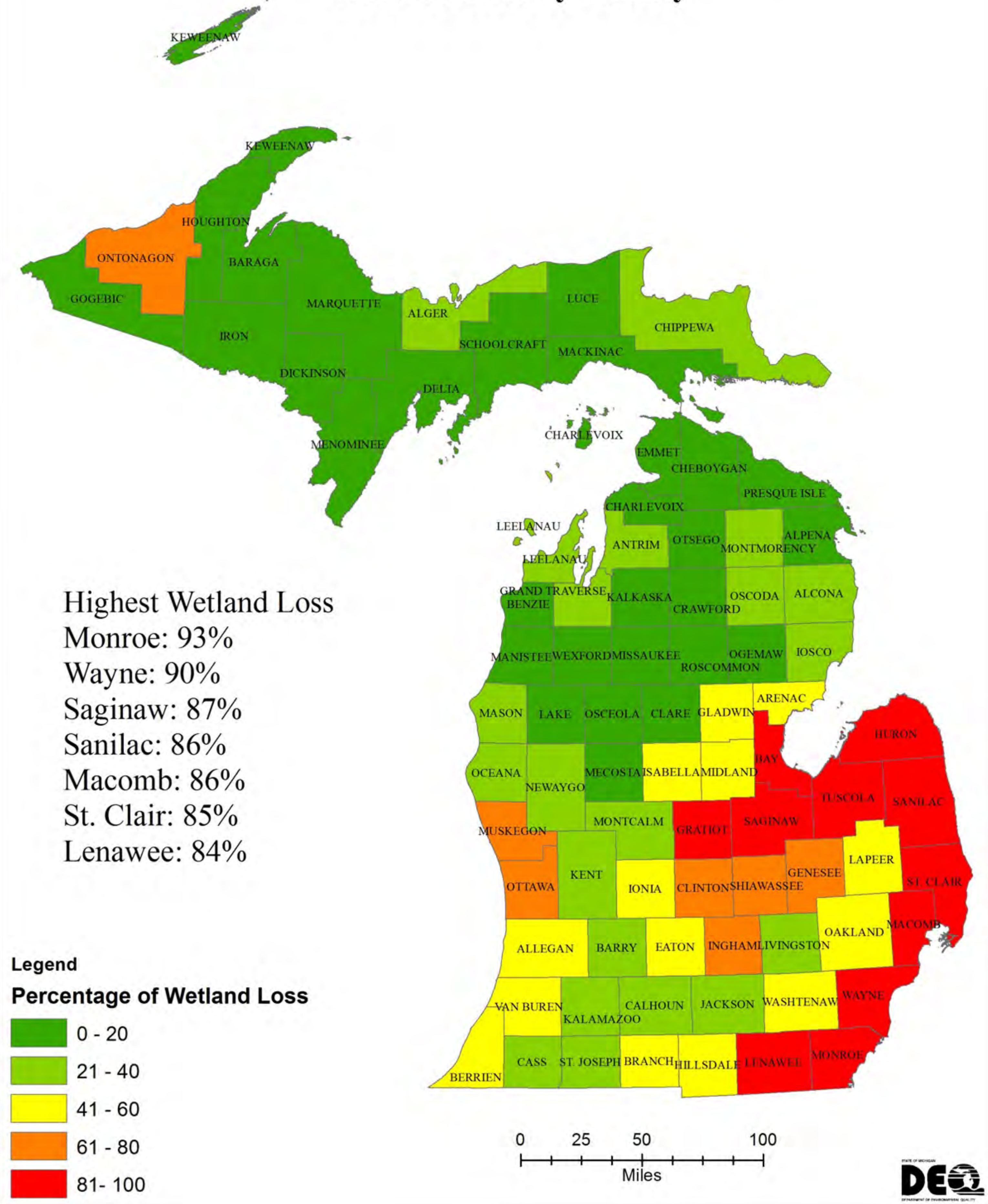
Wetland Trends In Michigan from 1978 to 2005
Wetland Loss by County

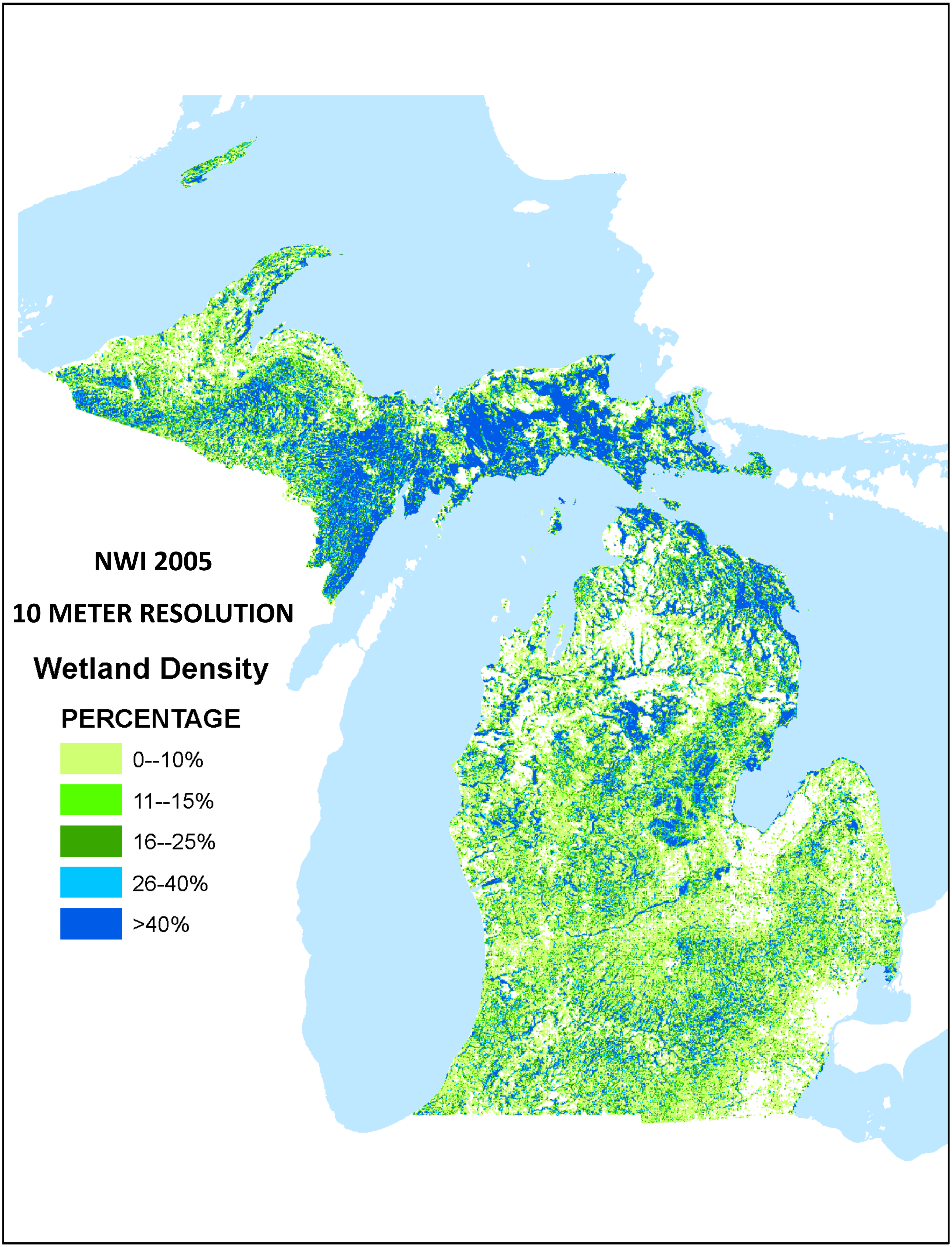


APPENDIX B: Presettlement to 2005

County	Pre-European Vegetated Wetland Acreages	2005 Vegetated Wetland Acreages	Percentage Vegetated Wetland Loss
ALCONA	104,213	76,894	-26%
ALGER	202,804	138,102	-32%
ALLEGAN	116,499	60,707	-48%
ALPENA	155,165	142,052	-8%
ANTRIM	39,891	25,162	-37%
ARENAC	101,878	53,678	-47%
BARAGA	123,884	111,655	-10%
BARRY	58,621	46,153	-21%
BAY	159,602	25,038	-84%
BENZIE	28,649	24,125	-16%
BERRIEN	65,889	30,289	-54%
BRANCH	87,374	42,372	-52%
CALHOUN	103,566	77,231	-25%
CASS	53,838	40,123	-25%
CHARLEVOIX	55,594	50,942	-8%
CHEBOYGAN	119,991	111,225	-7%
CHIPPEWA	489,307	343,735	-30%
CLARE	71,542	67,299	-6%
CLINTON	111,627	31,702	-72%
CRAWFORD	38,533	31,616	-18%
DELTA	329,743	326,144	-1%
DICKINSON	151,097	137,160	-9%
EATON	91,351	40,478	-56%
EMMET	51,781	52,230	1%
GENESEE	86,517	26,241	-70%
GLADWIN	143,612	83,479	-42%
GOGEBIC	205,493	164,905	-20%
GRAND TRAVERSE	34,242	25,980	-24%
GRATIOT	181,126	33,282	-82%
HILLSDALE	64,912	36,144	-44%
HOUGHTON	84,618	87,178	3%
HURON	214,262	36,007	-83%
INGHAM	118,661	45,669	-62%
IONIA	78,732	34,720	-56%
IOSCO	103,876	66,330	-36%
IRON	166,205	168,309	1%
ISABELLA	84,533	48,791	-42%
JACKSON	124,157	91,253	-27%
KALAMAZOO	55,447	41,361	-25%
KALKASKA	54,871	44,072	-20%
KENT	85,224	54,359	-36%
KEWEENAW	67,455	64,562	-4%
LAKE	39,171	36,584	-7%
LAPEER	98,377	47,295	-52%
LEELANAU	23,292	17,129	-26%
LENAWEE	199,432	31,278	-84%
LIVINGSTON	88,178	64,713	-27%
LUCE	289,749	247,543	-15%
MACKINAC	321,026	269,461	-16%
MACOMB	132,778	17,851	-87%
MANISTEE	48,929	43,591	-11%
MARQUETTE	344,221	292,111	-15%
MASON	61,954	45,194	-27%
MECOSTA	51,677	47,201	-9%
MENOMINEE	333,090	309,056	-7%
MIDLAND	155,270	75,497	-51%
MISSAUKEE	74,719	73,677	-1%
MONROE	198,117	12,632	-94%
MONTCALM	98,110	70,479	-28%
MONTMORENCY	78,233	57,700	-26%
MUSKEGON	85,041	33,045	-61%
NEWAYGO	99,161	67,967	-31%
OAKLAND	114,171	51,601	-55%
OCEANA	59,525	40,072	-33%
OGEMAW	64,055	58,104	-9%
ONTONAGON	203,421	64,256	-68%
OSCEOLA	62,751	53,511	-15%
OSCODA	43,422	27,593	-36%
OTSEGO	36,116	32,802	-9%
OTTAWA	93,285	26,877	-71%
PRESQUE ISLE	149,910	142,466	-5%
ROSCOMMON	118,047	97,326	-18%
SAGINAW	311,942	38,160	-88%
SANILAC	296,966	39,284	-87%
SCHOOLCRAFT	452,134	399,323	-12%
SHIAWASSEE	126,400	33,847	-73%
ST. CLAIR	285,236	41,380	-85%
ST. JOSEPH	51,280	34,758	-32%
TUSCOLA	248,595	40,934	-84%
VAN BUREN	115,023	54,736	-52%
WASHTENAW	107,447	50,441	-53%
WAYNE	80,576	7,886	-90%
WEXFORD	36,642	30,994	-15%
TOTAL	10,743,849	6,465,109	

Wetland Trends In Michigan from 1800 to 2005
Wetland Loss by County




NWI 2005
10 METER RESOLUTION
Wetland Density
PERCENTAGE
0--10%
11--15%
16--25%
26-40%
>40%