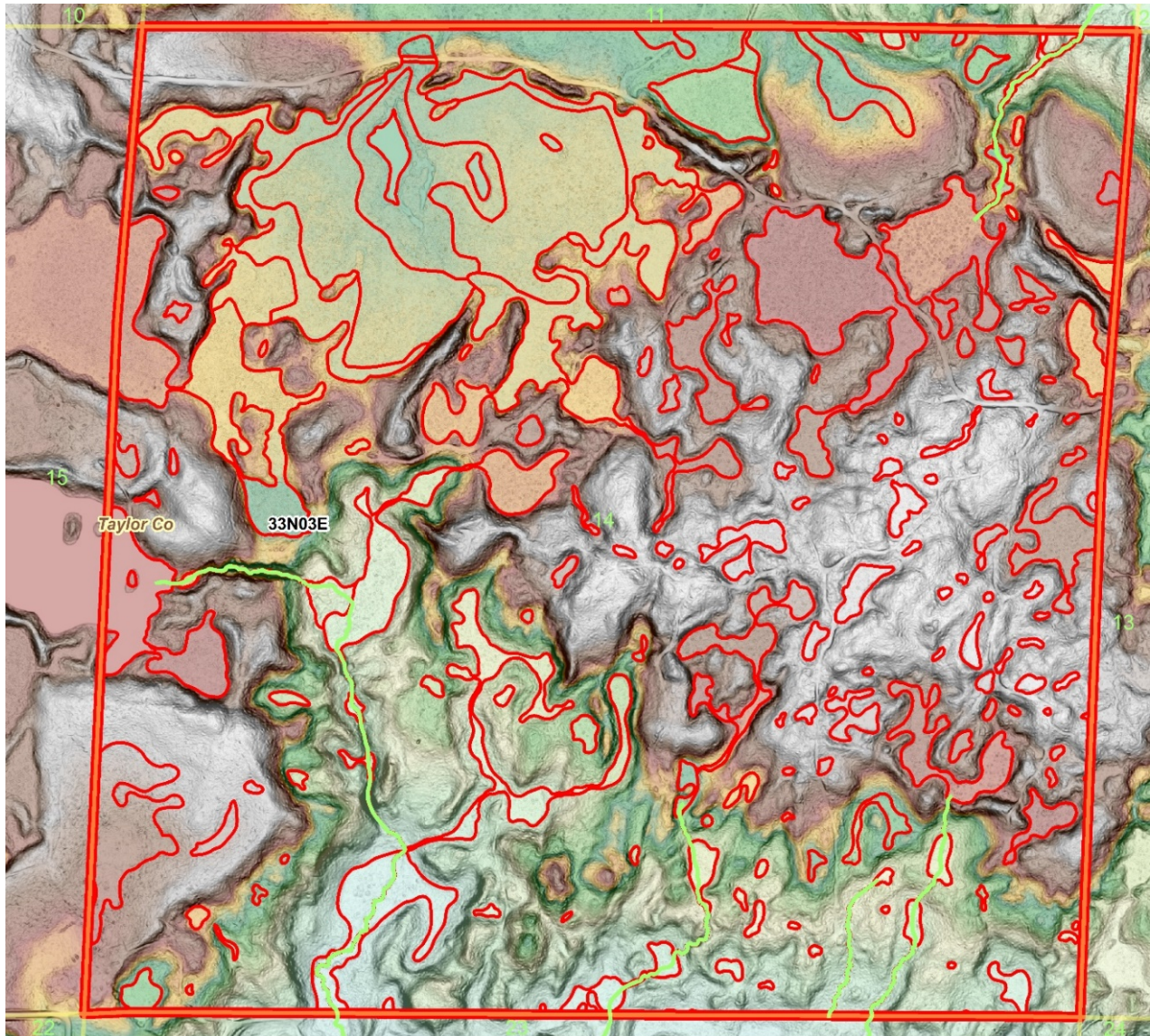


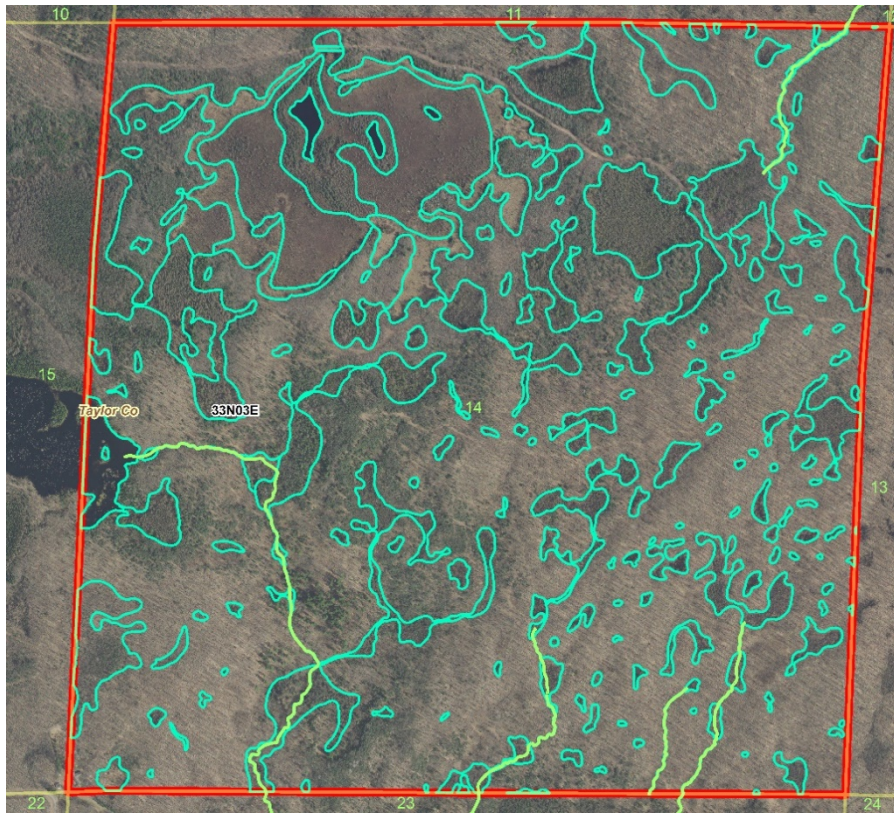
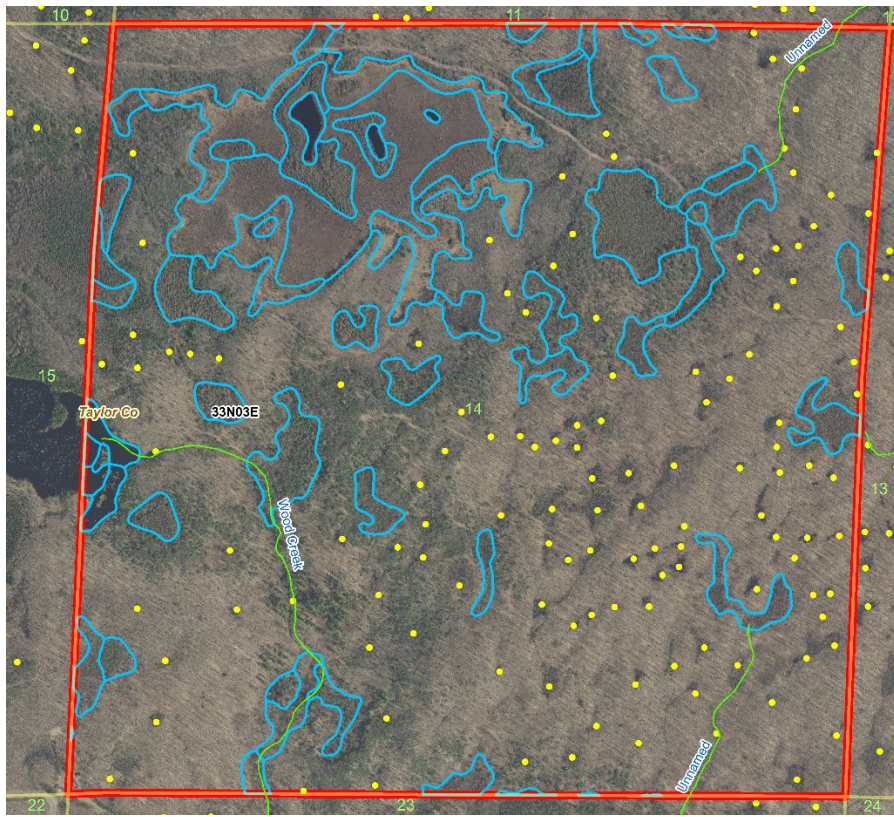
WDNR Wisconsin Wetland Inventory (WWI) Map Production SOP

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This page - Comparison of analog hard-copy data drafting (top) end-product with new lidar and high-res image-based product (bottom) within a 1 square mile section of Taylor Co (T33N 3E Sec 14). Expert staff required 2 hours and 50 minutes to remap this square mile, much longer than average. As a result, point symbols have been upgraded to accurate boundaries which, along with improved boundaries elsewhere, captured fifty-three additional acres (8.2% of the total section area) of wetland in addition to two added intermittent streams.

Front Cover – LiDAR visualization using semi-transparent color-stretched elevation overlaid with slope. This combination allows for viewing and interpretation of the landscape in unprecedented detail.

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Introduction

The goal of the Wisconsin Wetland Inventory (WWI) Wetland Mapping SOP is to standardize and outline as much as practical the standards and steps used to draft new wetland and surface water map data from start to finish. As staff at WDNR, partner agencies, and the general public read this SOP, they can contact Calvin Lawrence (calvin.lawrence@wisconsin.gov), Digital Wisconsin Wetland Inventory Coordinator, with any comments and questions. A spreadsheet has been located along with this SOP for internal use to track needed updates.

Origins & History of Wisconsin Wetland Inventory

The Wisconsin State Legislature passed a law in [1978 \(Ch. 374, Act of 1977\)](#) requiring the Department to map all wetlands in the state. The law also established a statutory definition of wetlands (Wis. Stats., s. 23.32(1)) with which to accomplish the mapping; “an area where water is at, near, or above the land surface long enough to be capable of supporting aquatic or hydrophytic vegetation and which has soils indicative of wet conditions.”

Following an intensive, years-long multimillion dollar effort, initial mapping of the state's wetlands was completed in 1984. The 1984-85 Legislature session produced legislation requiring an update to the original Wisconsin Wetland Inventory (WWI) maps on a 10 year cycle. This updating was to be accomplished with newer aerial photography to improve the data layer and capture aeral change from the previous version. Updating wetland maps is necessary to keep pace with landscape change, improve accuracy, and contribute to the various research, resource management, and regulatory programs needs within the Department and beyond. Since 1986 DNR has requested adequate staff and funding to update the WWI on a 10-year cycle. Doing this work in-house was determined to be more economical and efficient but, the DNR has been unsuccessful in obtaining permanent staff and funds to update the WWI on a 10-year cycle.

Various improvements in data standards have been implemented over the years. The first WWI maps were drafted on paper aerial photo prints with wetlands delineated using ink pens. These “hard copy” photos had to be “digitized” using cumbersome early GIS software, hardware, and techniques, had large minimum mapping units, and were not corrected for the horizontal error that results from local elevation changes. Subsequent mapping standards still used hard-copy drafting techniques, but evolved to use finer-point pens, different color inks to facilitate data separation, and added orthorectification steps during digitization to improve horizontal accuracy and map smaller wetlands. The final two counties using this hard-copy orthorectified data standard were completed in 2016. This ended 24 years of updates that resulted in each county being remapped one to two times. Due to further budget cuts and the general obsolescence of film-based printing, this also marked the end of the methods used to map wetlands using infrared-sensitive black and white stereo-pair photos as well as the last counties where the WWI classification system was used to categorize and classify the wetland vegetation and hydrology.

In 2016, the WDNR was awarded an EPA Region 5 Wetland Program Development Grant to help develop improved, modernized methods that utilized existing photography and elevation data for the purpose of mapping wetlands and surface waters in a single digital workflow. Additional objectives include the use of the Cowardin Classification System for polygon attribution, the production of updated flow-network polylines for hydro mapping purposes, and all data produced according to the National Wetland Inventory

standards outlined by the Federal Geographic Data Committee (2013). The WDNR contracted with Geospatial Services at St. Mary's University in Winona, MN to help develop methodology and train WDNR staff how to map wetlands according to NWI standards. The WDNR also performed independent research and development to create internal standards that go beyond the minimum requirements of the NWI (FGDC 2013) to address high-value Wisconsin-specific needs within the WDNR and state. While some minor elements of mapping convention have carried over from the early WWI methods, the procedures outlined in this document are the result of a years-long sifting and winnowing process that adapts elements of methodology delivered by St. Mary's University and combines it with the result of WDNR's research.

Definition of a Wetland for Mapping Purposes, Limits of Remotely Produced Maps, and Disclaimer

Conceptually, wetlands are places where the presence of saturated conditions, either on the surface or underground, is a predominant force shaping the physical factors and biotic community present. While many definitions of a wetland exist, the two relevant to discuss here represent the legal and mapping interpretations of what defines a wetland.

The U.S. Army Corps of Engineers Wetland Delineation Manual (1987) establishes the criteria an area must meet to be delineated as a wetland based on soils, vegetation, and hydrologic indicators by an on-the-ground wetland delineation professional. This is the standard used by the Clean Water Act Section 404 regulatory program which further divides wetlands into federal and non-federal categories.

Due to the reasons discussed below, remotely produced wetland maps cannot be used for jurisdictional decision making. The key concept to note in the ACOE's approach to wetland determination revolves around indicators that are observed "on-the-ground". Many indicators used in the ACOE Wetland Delineation Manual consist of fine surface and subsurface details that cannot be observed on even the best aerial images. As a result, remotely mapped wetlands represent a reconnaissance level survey standard that relies on primary indicators observable through aerial interpretation of vegetation signatures, surface hydrology, and topography to build a compelling case for the presence of wetlands. While this process results in a high-quality wetland map product that is suitable for many applications, remotely produced wetland maps still require a blanket disclaimer removing them from use in jurisdictional settings. Legal questions involving wetlands can only be resolved through a field delineation performed by a wetland delineation professional.

The principal focus and objective of the wetland inventory is to produce reliable reconnaissance-level wetland maps showing graphic representations of the type, size and location of wetlands in Wisconsin that are accurate when overlaid with a 1:2,000 (1 inch = 167 feet) base map. *They may be used as a reliable guide to wetland presence at a statewide level, but there is no attempt, in either the design or products of this inventory, to define the limits of jurisdiction of any federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies.*

The Wisconsin Wetland Inventory's definition of a "mappable" wetland is the same as the one used for the National Wetland Inventory as first defined by Lewis Cowardin and Francis Golet (1979) and later enshrined in many subsequent data standards guidance documents published by the Federal Geographic Data Committee (FGDC). The most recent FGDC guidance documents include the Wetland Mapping

Standard (2009) and [“Classification of Wetlands and Deepwater Habitats of the United States”](#) (Cowardin et al. 2013) – a.k.a. The Cowardin Classification System.

It is important to understand that remote Geographic Information System (GIS)-based mapping of wetlands, surface waters, and cover type relies heavily on human decisions based on the interpretation of one or more primary data sources and potentially several ancillary data sets. Further, each cartographer brings forth their own sets of strengths and weaknesses from their domain of knowledge and experience. Because wetland mapping is an interpretive process based around image and topographic-based cues set within a geologically diverse state, it is important to acknowledge that individual skill, training, and familiarity with Wisconsin’s landscape are very important components of producing accurate wetland maps. This still results in a somewhat variable interpretive process where one photo interpreter works within a set rules to arrive at, ideally, a boundary that ought to be very similar - but often not identical - to what another cartographer would produce.

Just as training a dog or building a house from a single set of written instructions with little prior experience would prove an extremely difficult, variable task with each new situation, it is not practical to outline a single start-to-finish sequence of tasks that works across the entire state. As a result, this SOP outlines the methods, data, standards, and constraints used to arrive at the photo-interpretive and topography-based decisions necessary to produce attributed wetland and surface water maps.

Data Production Standards and Overview

Project Boundary Determination

Until 2018, the WWI was mapped based on the Public Land Survey Township/Range land classification system (PLSS) due to computer processing limitations. Flight paths were flown based on county boundaries and final wetland maps were broken apart along the Towns/Ranges that made up the county. With the inclusion of hydrography in the mapping process, the WWI is moving away from county-based mapping to project boundaries based on Hydrologic Unit Code (HUC) watersheds. The smallest order of watershed division is the “HUC-12”, which typically forms the base unit of wetland mapping. Depending on the watershed boundary, each new mapping project may include more than one county and/or HUC-12 watershed. As of 2020, with full statewide LiDAR data coverage, smaller PLSS section-based project boundaries may be considered on a case-by-case basis to address special needs across the state.

Mapping Scale

The WWI produces maps with a nominal mapping scale of 1:2,000. Practically speaking, this means that when viewed with imagery at 1:2,000 scale, mapped boundaries should appear tight and precise. During the drafting process, it is often necessary to “zoom in” to examine imagery at a sub-1:2,000 scale, but most lines and attribute determinations are made with information discernable at 1:2,000.

Minimum Mapping Unit

There are no hard-exclusionary lower area thresholds for wetlands that can remotely detected and mapped. Per FGDC (2009) standards, the National Wetland Inventory Target Mapping Unit for the lower 48 states is 0.5 acres. The WWI aims to capture all remotely detectable wetlands down to 0.1 acres and may be smaller than 0.05 acres in the case of ephemeral ponds, excavated ponds, and pothole wetlands. At a certain size point, a wetland may be difficult to even see at a 1:1,000 scale or represent non-target wetland features like puddles in dirt roads.

That said, the WWI recognizes the need to maintain certain minimum units of subdivision from larger wetland complexes for the sake of production efficiency. In the same sense that a handful of trees do not make a forest, pockets of vegetation differing from a larger, surrounding wetland type are typically not subdivided unless they are at least 0.2 acres in size or represent a surface water feature.

Target Wetland Feature, Horizontal, and Attribute Accuracy

The WWI follows standards laid out by the FGDC (2009) Wetland Subcommittee for producer's accuracy for NWI data. Wetland feature accuracy refers to the percent of mapped features correctly identified as a wetland, which is 98% for the lower 48 states. For a wetland feature to meet horizontal accuracy standards, the mapped boundary should fall within 5 meters of the ground-truthed boundary. Finally, attribution accuracy should be at least 85% correct. These accuracy targets are verified in the QA/QC and field-checking process described in later sections.

Standard Coordinate System

The official Wisconsin DNR coordinate system is Wisconsin Transverse Mercator. All data layers inside the DNR's wetland geodatabase use this coordinate system. The Wisconsin Transverse Mercator projection uses meters as the X, Y units. Vertical units for elevation data may be U.S. Survey foot or meters. If it is unclear what units a LiDAR data layer uses, it is helpful to keep in mind the highest point in Wisconsin is Timms Hill at 1,951 ft/595 meters, and the lowest points are Lake Michigan at 577 ft/176 m and the Mississippi River in Grant Co at 593 ft/180 m). When working in ArcGIS, the following WKID (**Well Known ID**) projection file is to be used. To ensure consistent coordinate systems are used, the first layer added to a new MXD should be the "WWI_Polys" layer from the WWI template geodatabase.

"NAD_1983_HARN_Wisconsin_TM" - WKID: 3071 Authority: EPSG

Projection: Transverse Mercator

False Easting: 520000.0

False Northing: -4480000.0

Central Meridian: -90.0

Scale_Factor: 0.9996

Latitude_Of_Origin: 0.0

Linear Unit: **Meter (1.0)**

Geographic Coordinate System: GCS_North_American_1983_HARN

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D_North_American_1983_HARN

Spheroid: GRS_1980

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314140356

Inverse Flattening: 298.257222101

NAD_1983_HARN_Wisconsin_TM

Vertical units for elevation data can be U.S. Survey foot or meters – however, meters are strongly encouraged. Check the metadata along with the linear units to make sure both are in meters.

Template Geodatabase for New Mapping Projects

A standardized template geodatabase exists on the DNR network ([here](#)) and an empty copy should be created in your working directory before for starting each new mapping project. All layers have edit tracking enabled to allow for transparency in the source and time of edits.

Standard Production Layers

The most important layers are contained within the “Wetlands_Waters” group layer.

HYDRO_FlowLines – This polyline layer contains three types of flow line – perennial, intermittent, and fluctuating - that are intended to become source data for 24k Hydro updates.

HYDRO_SurfaceWater – This polygon layer is a generalized subset of the WWI_POLYS layer that has been dissolved to the DNR 24k Hydro geodatabase standard. It is populated through the execution of a query.

“Wetlands_Waters_Topology” – This set of topology rules defines the allowable geographic constraints that features must fit within. The rules can be viewed by right clicking the topology layer and selecting properties.

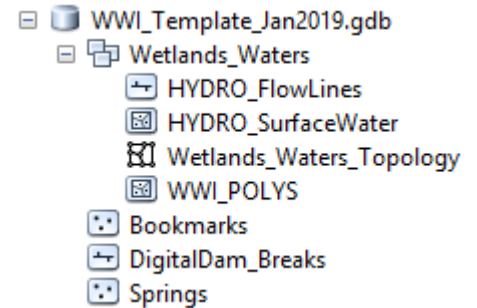
“WWI_POLYS” – This is the primary and most important layer for drafting.

“Bookmarks” – These points are intended for simple cartographic notes and reminders which can be added in the attribute table. This layer is also useful for identifying possible field verification locations when used in combination with a parcel layer.

“DigitalDam_Breaks” – This layer is optional but encouraged for the creation of bridge, culvert, and wetland divide data that is being aggregated at the State Cartographers Office.

“Springs” – This layer is for capturing spring pool locations to supplement the Wisconsin Geologic and Natural History Survey’s database.

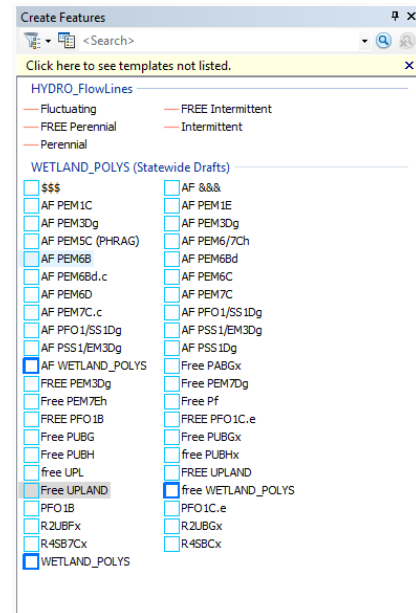
“Point_Analytics” – This layer is used to provide information to an experimental, semi-automated point-based wetland boundary analysis process that is in development.



Feature Editing Templates

Feature editing templates are highly useful tools for directly creating fully attributed polygon and polyline data. Templates can be created by simply right-clicking on an existing template and selecting “copy”. When creating new templates, there are three important considerations

- 1.) Properly assign the FULL WWI and NWI attributes.
- 2.) Select the most appropriate, commonly used drafting method (usually polygon, freehand, or auto-freehand).
- 3.) Rename the template as appropriate. If using freehand and auto-freehand drafting methods, prefacing your template name with AF (auto-free) and FREE (standard freehand) can be helpful to keep the editing window orderly.



Primary Data Overview

Primary Data and Secondary Data

For a given class of data, the most valuable and heavily used layers for basing mapping decisions are referred to as primary data layers. Examples of primary data include recent leaf-off tiff imagery and LiDAR-derived elevation products. Secondary data layers still possess valuable information but do not provide the cartographer with enough information or precision to base certain decisions or create accurate boundaries and largely plays a supporting role. Examples of secondary data include historic imagery, leaf-on imagery, DNR 24k Hydro flow network, SSURGO soil-based data products, and previous versions of the Wisconsin Wetland Inventory.

Primary TIFF Imagery

It is critical to use the best available imagery for the primary aerial image layer when delineating wetlands. In landscapes where wetlands lack clearly defined boundaries, such as those on mineral soils and/or seepage slopes, visual interpretation of wetland signatures from aerial photography is necessary to draft boundaries. The ideal primary aerial image layer is the most recent, highest resolution (6-12 inch) county-wide set of leaf-off uncompressed TIFF orthoimagery that can be sourced. Often, this image layer is supplied in the form of many small “tiles” which need to be mosaicked together through the creation of a raster catalog or using the “mosaic to new raster” tool in the ArcToolbox.

If uncompressed imagery is unavailable, then the highest-resolution compressed leaf-off imagery may be used. JPEG or MrSID are examples of compressed image file formats. Image compression algorithms use data-compression techniques to reduce file sizes and appear blurry or “blockified” at close viewing scales. As a result, they are not ideal for the cartographic decision making. Compressed images should not be used for mapping where uncompressed imagery from the same flight is available. If detailed leaf-off imagery less than 10 years old is unavailable for a given county, drafting of new wetlands maps should be discouraged except for high-priority needs.

Ideally, the primary aerial image should have been flown close to the same year as the LiDAR data during a period of normal precipitation, as this reduces inconsistencies that arise from changes on the landscape

(e.g. widening of roads, construction of buildings, etc.). Uncompressed TIFF data is typically not hosted on the DNR network due to space constraints. Check the [BTS data holdings intranet page to check for availability](#). Imagery can be requested from the DNR Bureau of Technology Services through Cherwell along with providing an external hard drive for data to be copied to. If necessary, contact the county land information officer. It should not be assumed that TIFF data is unavailable unless it is confirmed by either of these offices.

Mosaicking TIFF Images

TIFF images demand extra storage space and processing power. The files for a county are usually broken up into an unwieldy number of small chunks or “tiles”. When you obtain new TIFF imagery, chances are good that individual tiles will need to be mosaicked together into a new TIFF image. Fortunately, the spatial properties of HUC watersheds and TIFF images can be leveraged to automate the process of mosaicking images together.

In order to accomplish this, four items are needed:

- Uncompressed tiff images with a consistent file structure
- An “image tile index” (or similarly named layer) containing an attribute column containing the image file name
- HUC 12 or HUC 10 polygon features
- An example python script to automate the mosaicking process is located at \\dnr.state.wi.us\programs\WT\Temp\WT_W4WETLANDS\Wetland_Hydro_Mapping --> "Watershed_MosaicGenerator_OneidaHuc10.py"

If any of the above items are not available, a TIFF mosaic image can be manually created using the “Create Mosaic Dataset” and the “Add To Mosaic Dataset” tools within the Data Management, Raster toolbox of ArcMap. Tutorials for how to use these tools are available within ArcGIS and searchable online. In any situation, original TIFF image tiles should **never** be deleted after mosaicking.

Secondary Image Layers

In addition to the primary aerial image layer, secondary image layers need to be assembled and organized. Functions of secondary image layers include observing vegetation during summer months, checking water levels across multiple years, and confirming the presence or absence of live trees, shrubs, and herbaceous vegetation.

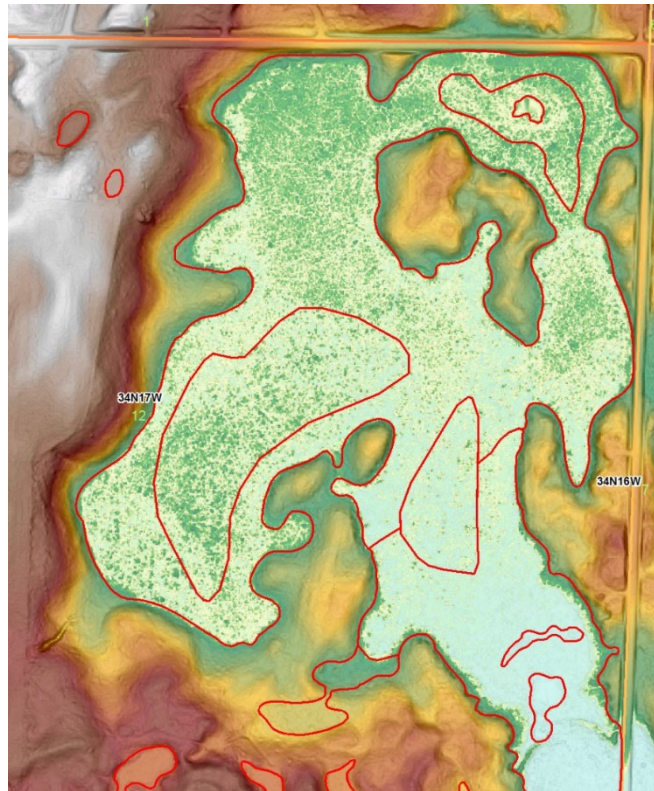
For better performance and stability in ArcMap, all relevant data from the network for the project area should be copied to a local folder before adding the layers to an ArcMap document. This is because every time ArcMap refreshes due to a display update, it must redraw all visible layers. Layers being pulled from the network will often take extra seconds to load and when multiplied by the tens or hundreds of thousands of screen refresh cycles, many extra hours of unproductive load time can be saved by taking a few minutes to copy data before starting. It is important to note any restrictions placed on an image layer by the locality that provided the data and be careful about distributing this data to unauthorized partners.

In addition to readily available imagery on the WDNR network, other sources of secondary imagery can be leveraged. These include, but are not limited to layers in the following list:

- Orthorectified Historic WWI grayscale imagery - Maintained by [Calvin Lawrence](#) and stored on external hard drives.
- Hard-copy WWI imagery – Requires Tracking Down on Roller-shelves and manual scanning.
- [B | A | G Tool](#) - Opens an internet browser window using Bing Maps, ArcGIS Online, or Google Maps. This is a python add-in toolbar that must be installed.
- [Historic Aerial Imagery 1937-1940](#) - 600 DPI TIFF scans can be downloaded from the “WHAIF” website.
- [USGS Earth Explorer](#) – Hosts uncompressed NAIP Imagery and Volumes of historic scanned single-frame aerial images.
- ESRI World Imagery - Can be streamed from the internet by “Adding data from ArcGIS Online”.

LiDAR Data

LiDAR data products are the result of a rapidly improving technology that has expanded in the last 20 years from niche applications to a foundational landscape-scale dataset. Similar in principle to weather radar, LiDAR data is generated by flying a specialized instrument that sends millions of laser light pulses toward the Earth from an aircraft per second. By measuring the number of returns for each light pulse and the time it takes for each to occur, a 3-D model of the Earth’s surface is generated. Once these signals are properly classified and converted into a Digital Elevation Model (DEM), a “bare earth” view of the ground surface is constructed which provides critical information for visual interpretation and computational detection of the topographic shifts that indicate wetland boundaries and hydrologic regimes. Often, this information cannot be reliably interpreted through imagery alone. As a result, most LiDAR DEM’s produced since 2008 are considered a primary data layer for drafting wetland and surface water data. As of 2020, all Wisconsin counties have at least one set LiDAR data products. As a rapidly advancing technology, counties with older LiDAR data containing less information per square meter than newer flights. While coarser, even older layers with 1.5 m horizontal resolution are usable for drafting improved wetland maps.



1 LiDAR raster with a histogram-equalized color ramp applied to emphasize flat wetland areas

LiDAR DEM ("Bare Earth" Digital Elevation Model)

There are two main options when it comes to importing LiDAR data for use in the wetland mapping process.

1. Use the contractor-delivered pre-processed BARE EARTH elevation raster (DEM).
2. Manually create your own bare earth raster using the raw LiDAR point cloud (.LAS extension) data files.

In most cases, the contractor-delivered DEM is good enough for basing decisions regarding wetland boundaries. It is important to note that these DEM products typically undergo a series of modifications which may create issues of which the cartographer should be aware. Notably, contractor delivered DEM's often have breaklines "burned" into the elevation data. Where this is most relevant is around surface water features, where the contractor or a county has used polygon features to enforce a hard "break" on the terrain in order to remove visually unpleasant elevation artifacts on water surfaces, cliff edges, and other places where a sharp change in elevation needs to be enforced. Frequently these breaklines have inaccuracies and/or were created from an outdated or unknown images source. In other cases, breaklines are apparently derived through an automated or semi-automated algorithm by the contractor where the same caveats apply.

In some instances, after initial review of the contractor-delivered pre-processed DEM, errors may be discovered in various aspects of the DEM. An example may be points that are improperly classified as ground. In this case, it may be necessary to re-create the DEM through a manual process using point-cloud (LAS) data.

Because LiDAR data collection flights are often contracted through the counties, data may be provided in county coordinate systems and non-metric horizontal and/or vertical units that needs to be projected to Wisconsin Transverse Mercator. This is discussed further under the "Official Coordinate System" section.

Potential future uses of LiDAR may evolve to include the use of first-return data to create more reliable estimates of vegetation cover classes like emergent, shrub, and forest as well as semi-automated boundary detection through terrain analysis.

A large collection of pre-made bare-earth Digital Elevation Models projected to WTM are available on the [internal DNR network](#). It should be attempted to use these layers first before spending time on manual DEM creation. A few counties may require the creation of a DEM through mosaicking tiles or LAS classification. Additional data is listed on the [Bureau of Technology Services data holding intranet page](#). Also, <https://www.wisconsinview.org> hosts LiDAR data with supplementary files that may not be held elsewhere. Lastly, contacting county land information offices may be necessary to obtain recently collected LiDAR data.

Slope vs. Hillshade

Slope and Hillshade layers are LiDAR-derived rasters that are used to add 3-D "pop" by providing visual context for changes in the slope of the terrain. Both tools are found in the ArcToolbox under "3D Analyst Tools à Raster Surface". While these layers share similarities, it is important to note a few key differences.

Hillshades use a simulated sun angle to create areas of light and shadow on hills. Slope rasters, on the other hand, are unidirectional and represent slopes of an equal degree with the same shade of gray.

Because hillshade use a simulated sun to create areas of light and shadow, these tonal characters may be cast beyond areas of actual topographic shift and cannot be relied upon to indicate the toe of a slope where uplands transition to wetland – a critically important area for delineating wetland extent. While cartographically pleasing, compared with the consistent unidirectional properties of a slope raster hillshades provide an inferior visualization of the actual land surface and should be avoided for use in boundary interpretation. Because of these issues, the WWI does not use hillshades for wetland data drafting. The following DEM visualization scheme provides more accurate information about the landscape when coupled with the slope raster.

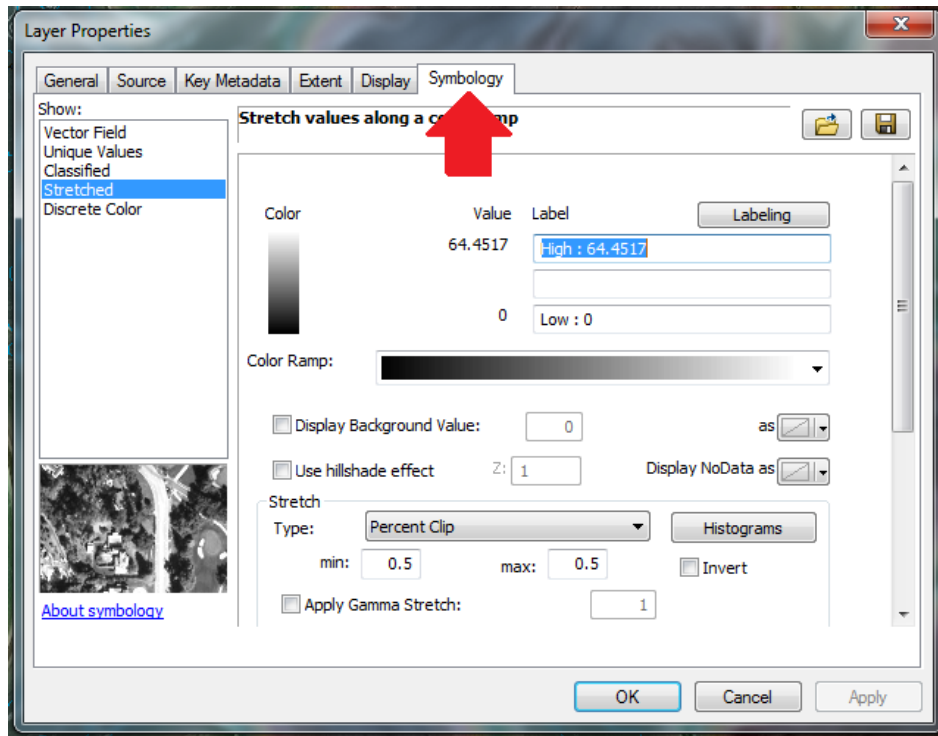
Visualization of Bare-earth LiDAR DEM and Slope Data

Preferably, your source elevation DEM should use meters as the vertical units. The slope raster should be placed *under* the bare earth Color-Stretched LiDAR DEM. Histogram Equalize is the stretch of choice for most of Wisconsin, especially where wetlands form large, flat or gently sloping lowlands, but it is not always the most useful stretch in every landscape. Low-relief landscapes in particular tend to be challenging and may require different stretches should be tried. Raster display statistics should **always** be maintained as "From Current Display Extent".

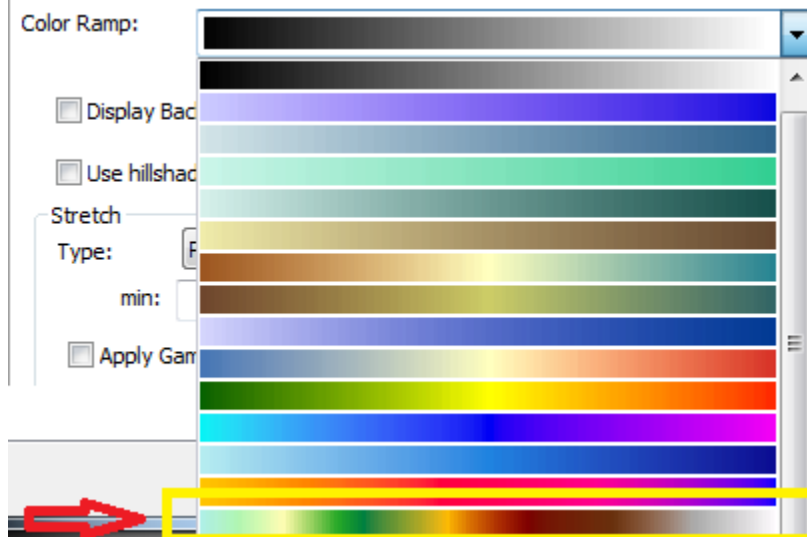
Steps for adding LiDAR images and properly applying a color ramp in ArcMap

1. **ADD THE LIDAR ELEVATION RASTER.** Click the "Add Data" button. Navigate to your raster, click "Add"
 - a. In the table of contents, Right-click the newly added Lidar Elevation Tiff layer, then click "zoom to layer".
 - b. In the table of contents, Right-click on your Lidar Elevation tiff, select "Properties" at the bottom of the menu. Within the properties box:

- c. Click the “Symbology” Tab



- d. Change the Color ramp from grayscale to multi-color. Click “Apply” (bottom right)



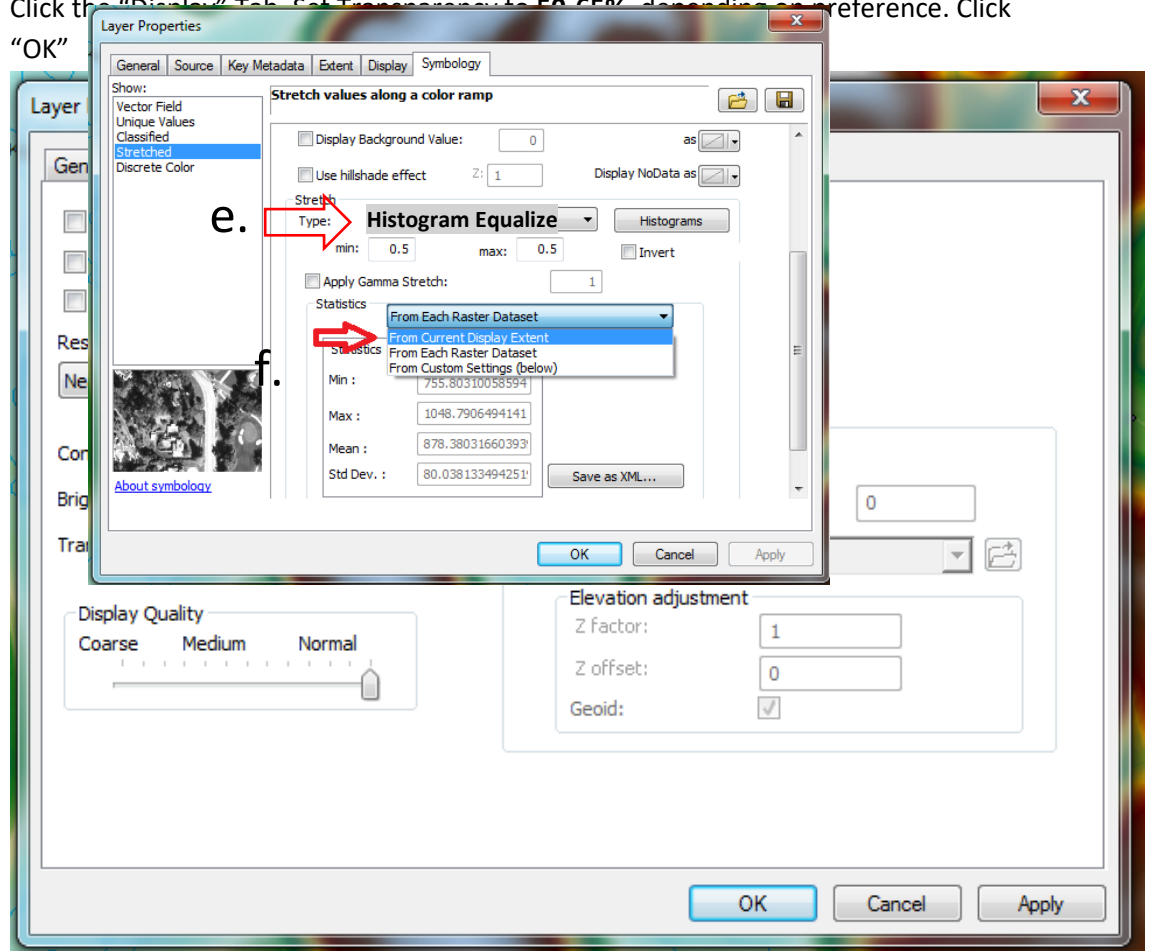
- e. Change the Stretch Type to “Histogram Equalize”

Note: In landscapes where wetlands tend to form broad, flat lowlands that stand in contrast to more irregular uplands, generally the “**Histogram Equalize**” stretch is your best option. This stretch works well for much of the state. In landscapes with **very low relief and unclear distinctions between equally sloped uplands and wetlands** (areas of low drumlins in Rusk County are just one example), the

histogram equalize stretch can create a misleading view of the landscape. In these cases, experiment with linear stretches like minimum-maximum and percent clip (vary the % clipped) to create something that makes visual sense. It is important, however, to maintain statistics using the "Current Display Extent".

- f. Scroll down until you see "Statistics". Change to "From Current Display Extent". Click Apply. This will re-stretch the image to the maximum color range within elevations displayed on screen.

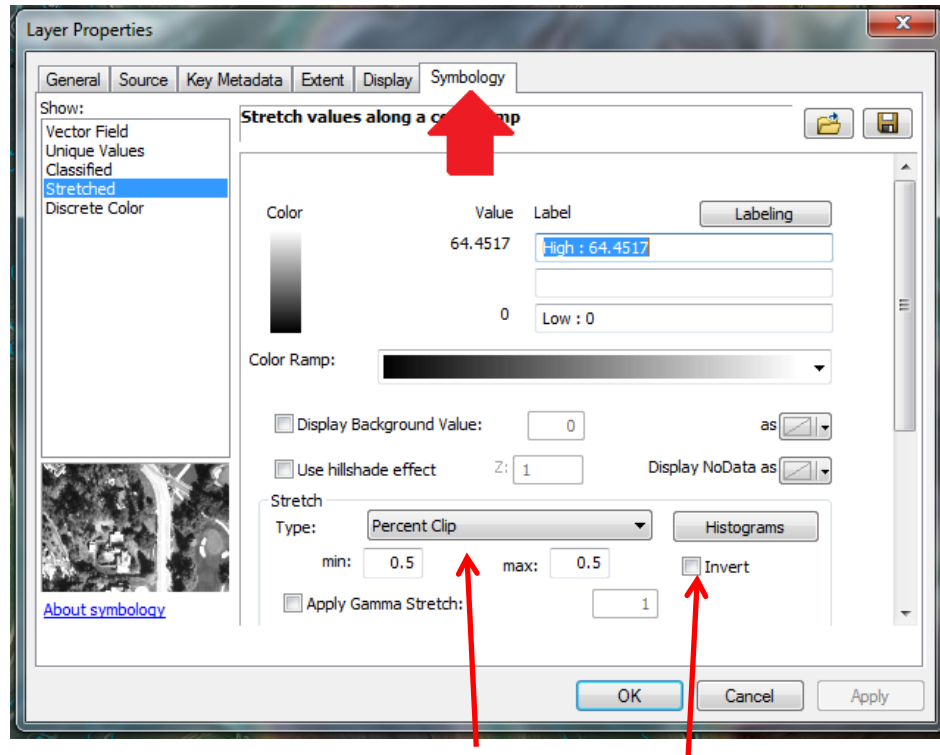
- g. Click the "Display" Tab. Set Transparency to 50-65% depending on preference. Click "OK"



2. ADD THE SLOPE RASTER.

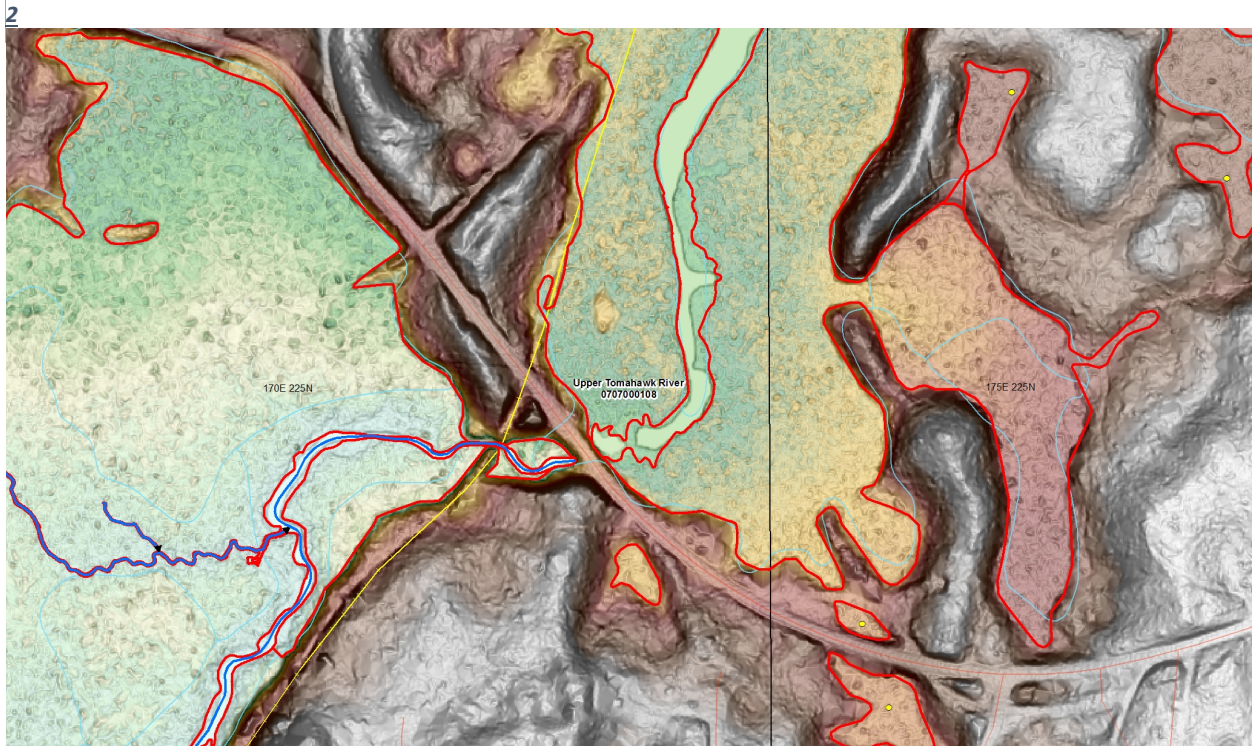
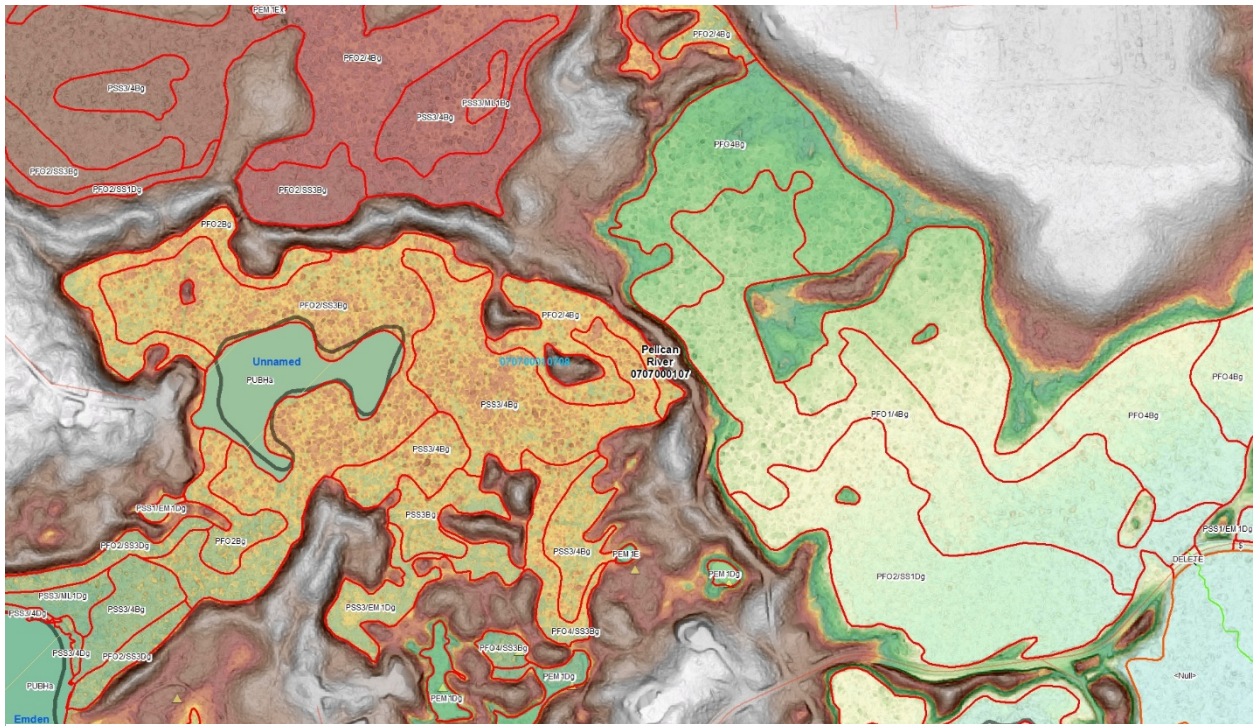
- a. If not already created, generate a slope raster using ArcToolbox "Spatial Analyst Tools" -> "Surface" -> "Slope" Tool
- b. Click the "add data" button, browse to your slope raster file location. Click "Add"
- c. In the table of contents, **click and hold** on "dane_slope1.tif" and **drag it below the LiDAR Tiff from the previous step.**

- d. Right-click your slope raster in the table of contents and select “Properties”. Click the “Symbology” Tab.



- e. Change the stretch type to “Minimum-maximum”
- f. Click the “Invert” Checkbox and hit “apply”. STATISTICS SHOULD BE MAINTAINED AS “From Each Raster Dataset”.
- g. Scroll around in your new map background! If happy with the results, **save your MXD**.

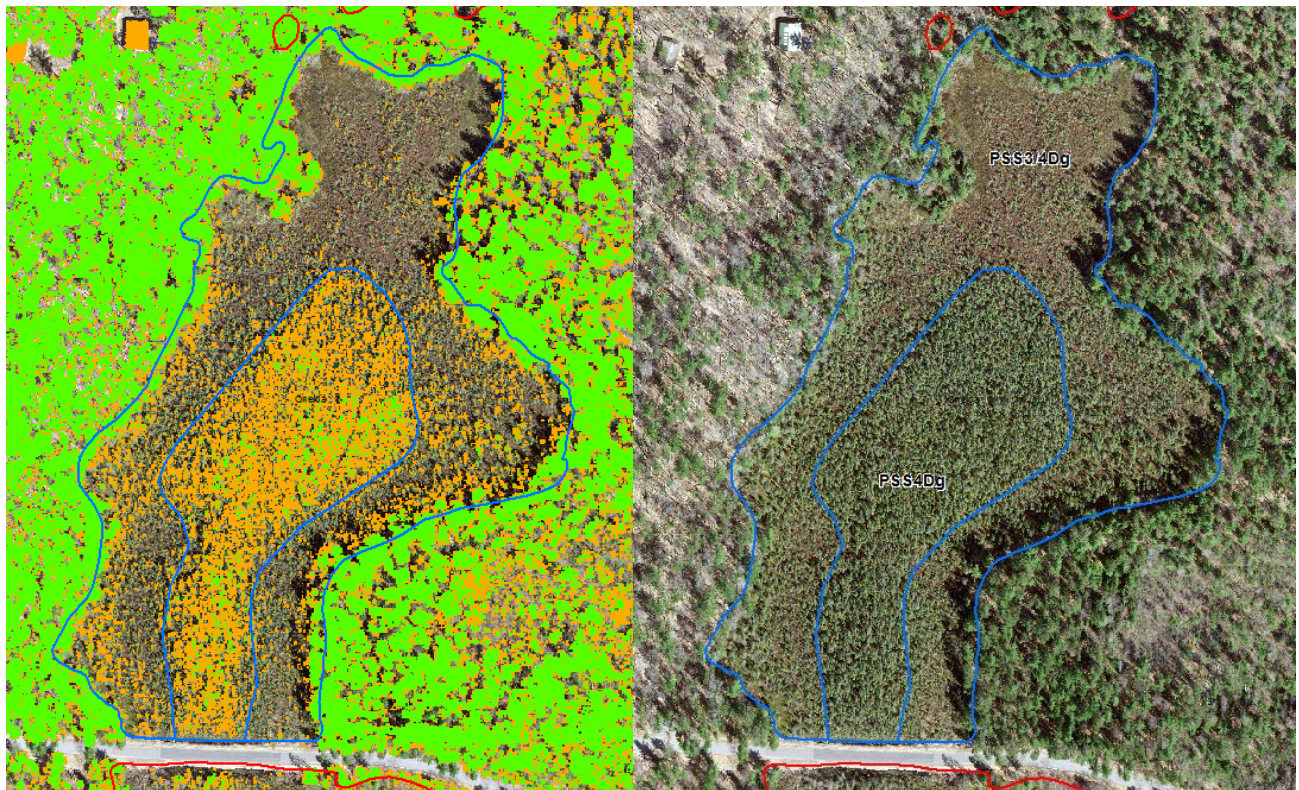
Comments: This arrangement of LiDAR data layers allows for both slope and elevation to be easily recognized. Pale greens and blues (think water) represents the low elevations, while brown and white (think snow-capped mountains) represent higher elevations. Gray-shaded areas indicate areas where the ground is sloped, with darker gray corresponding to steeper slopes. Because “Statistics are calculated from display extent”, ArcMap re-stretches the color ramp to take full advantage of the display capabilities to greatly exaggerate small changes in elevations when fully zoomed in. This allows us to see features like mounded peat domes in an otherwise almost-flat wetland complex quite clearly, **but it can also over-accentuate topographical features to create false upland/wetland signatures**, so judicious use is encouraged!



Resulting Slope + Histogram-equalized elevation overlay used for wetland outer boundary delineation in Oneida Co, WI

Digital Surface Models (DSM) and Canopy Height Models

Digital surface models use first return data to create a surface representation of the landscape that includes treetops, shrubs, buildings, and other non-ground features. Using raster math, subtracting a bare earth DEM from a DSM. The resulting raster represents canopy height raster which can be reclassified according to a deciduous shrub height of 1.5 – 6m, and forested vegetation height of 6m or greater. Not all shrubs will meet a minimum height of 1.5 m, so accurate interpretation is needed to separate short-statured shrubs from emergent vegetation. In the example below, areas with vegetation less than 1.5 m tall contains stunted black spruce evergreens (SS4), broadleaf evergreen (Ericaceae family) shrubs (SS3), and minor, non-attributed components of emergent (EM3) vegetation. classifying wetland vegetation types within the Emergent, Shrub-scrub.



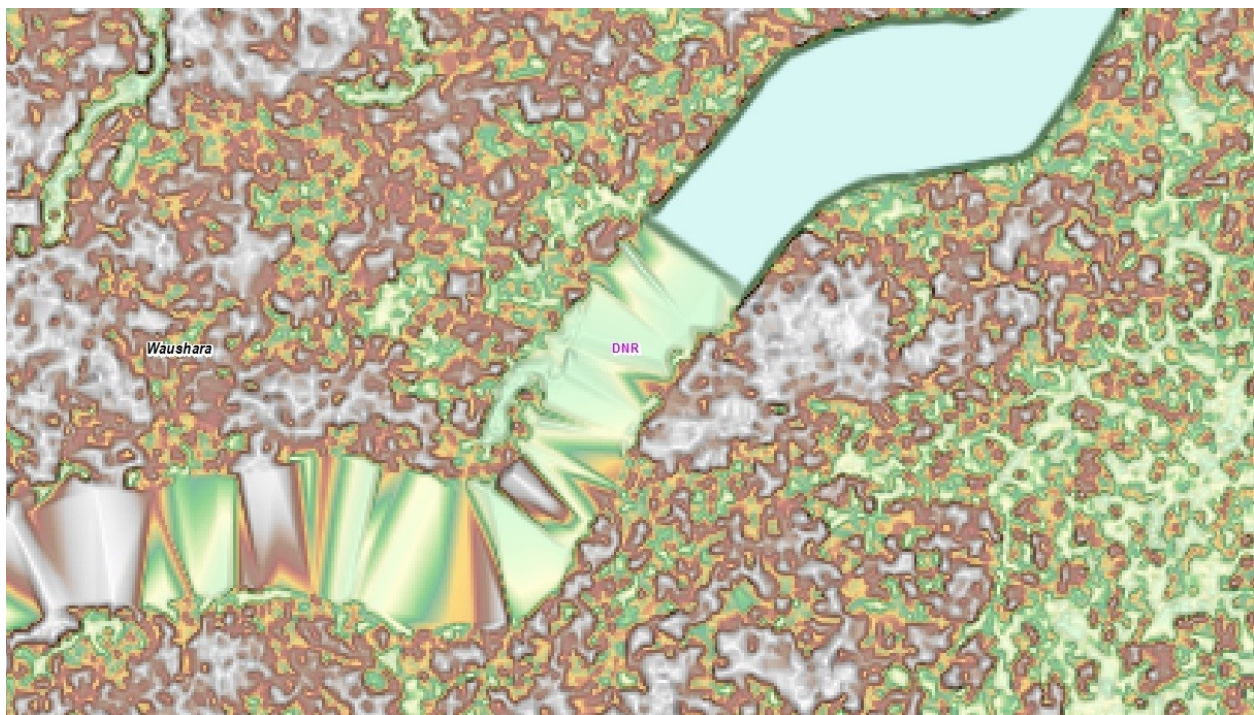
3 Visually estimating NWI tree height of 6+ meters can be a difficult task from imagery alone, especially in stunted muskegs where small spruce and tamarack appear similar to tree-size specimens. Left, a reclassified canopy height raster displays tree-height (6+ meters) areas in green, shrub-height (1.5 – 6 meters) areas in orange) vegetation, and emergent height areas (0 – 1.5 meters) as transparent over an open bog and muskeg wetland. Lidar data suggests that not enough black spruces are of NWI tree height to warrant assigning a forested subclass. Right, the resulting subdivision and classification, which was not obvious from the aerial image alone, overlays nicely with the aerial image.

Overview of Ancillary Vector Data

The layers below may be used for a small subset of cartographic decisions within a watershed or to increase data production efficiency but are not typically not required for dataset production.

LiDAR Breaklines

When LiDAR data packages are delivered, there is often “breakline” data included. These are vector features that have an elevation value embedded in the attribute table that are used for enforcing a smooth, visually pleasing surface in areas where return signals to the LiDAR sensor are weak and produce artifacts. A key area where breaklines are applied are over water features like lakes, rivers, streams and ponds where one would expect to see a smooth surface. In the image below, breakline elevation data for a river was burned into the NE corner but stops halfway through.



4 Screenshot shows the difference between breakline-enforced elevation (upper right portion of the river) and unedited lidar surface water artifacts (lower left portion of the river).

The origin of these features is often unknown, so it is often hard to say when or how these features were drafted. Regardless of the origin, **wherever these breakline features closely match the primary aerial image layer, they may be copied and pasted directly into the new wetland & surface water layer.** In the image pair below, a breakline is shown for a fluctuating pond. In this case, it may make sense to cut out an inner regularly inundated pond polygon and an outer regularly exposed emergent polygon.



5 Spring leaf-off view and summer color-infrared of the same kettle pond in different years overlaid with the corresponding breakline feature. In this case, the outer boundary may be used but the interior should be subdivided to an aquatic bed, flooded (PABF) polygon while the exterior ring should be labeled as an emergent – persistent seasonally flooded (PEM1E).

Breakline quality varies widely. The adoption of breakline features into the mapping layer requires examination of each feature during the mapping process. Those that do not meet FGDC standards for spatial accuracy or otherwise don't accurately represent the surface feature being mapped (such as breaklines created during flood conditions) should be rejected or deleted from your editing layer and re-drafted. Depending on overall quality, breaklines can be incorporated wholesale or added individually into a new mapping project. If a breakline polygon for a stream or river is copied into your

editing geodatabase, a centerline for that polygon can be calculated efficiently using the DNR's [AutoStream](#) toolbar.

Current Wisconsin Wetlands Inventory (WWI)

Existing WWI data always needs to be available for viewing during the data creation process. This data was created using hard copy stereo-pair drafting methods at roughly 1:15,000 scale and is composed of polygons (mostly larger than ¼ acre) and point symbols for smaller wetlands. This layer is useful for checking approximate boundary accuracy, checking wetland attribution, and confirming the presence of larger wetlands.

DNR 24K Hydrography

The existing 1:24k DNR Hydro Geodatabase is a fundamental dataset for the DNR for mapping waterbodies and river centerlines. It is also outdated and, in many places, contains inaccurate flow paths. Regardless, this data is useful for getting a good idea of the placement of most streams in a watershed. Linework from WWI updates are currently slated to provide the raw data needed to update this geodatabase.

Hydric Soils (Network Layer: W11101.EN_WI_SOIL_HYDRIC_AR_SV)

This layer is based on the Natural Resources Conservation Service Soil Survey Geographic database (NRCS SSURGO soils database). It indicates the extent of soil polygons that are predominately hydric. It is worthwhile to note that the data in this layer can vary wildly in age and was typically drafted at a similar scale as the Wisconsin Wetland Inventory. As such, it should not be expected to possess a level of accuracy and detail to distinguish topographic features at 1:10,000 scale and larger ("zoomed in").

Public Lands (PAD CBI) and Parcels (SDEDNR.EN_PARCEL_AR_VAR)

Highlighting public lands within a watershed is useful for deciding where to perform field checks. Wetlands on public lands can be easily marked with point symbols indicating questions related to boundary decisions. Always confirm public ownership or receive written authorization from a private landowner before setting foot on a site.

Political Lines (PLSS, Counties, Cities, Roads)

These basic cartographic layers are used for overall orientation, determining where and how to obtain data, and for tracking progress. One of the more useful layers for tracking progress is the Public Land Survey System (PLSS) sections layer. Working within sections can be very useful for dividing a watershed into manageable chunks that can be mapped to completion with a high degree of confidence that the entire area was visually checked for wetland presence. Sections can also provide a measurable indicator of progress as one works through a watershed.

Hydrologic Units (10 & 12-digit HUC) The WWI has largely transitioned to creating project areas around on 10- and 12-digit watershed boundaries. As a result, the HUC-10 and HUC-12 watersheds should be a standard part of a map MXD. The statewide watershed layer can be found on the DNR network inside the following path here: [Watershed GIS layers](#).

Though often imperfect, these watershed boundaries provide the most coherent watershed-based project area boundaries where flow networks are concerned.

Pro-tip: Do not keep this layer in an editing geodatabase. Inevitably, doing so will result in holes being clipped in the watershed during the editing process!

Springs

This layer contains known springs, sourced from the Wisconsin Geologic and Natural History Survey. The original springs point layer contains many features which no longer exist, so it is only to be used as a general guide.

Contours – (LiDAR Deliverable)

Contours can be useful for directly overlaying elevation data over imagery in a way that topographic cues can be interpreted. Due to the lumpy texture of bare-earth data, contours often consist of wobbly lines that are not cartographically pleasing and should generally not be used for boundary tracing purposes.

(Note: ARCMAP often crashes when pushed beyond the limits of what source data can reliably support, such as creating a 2 ft layer from a 1 m DEM)

Data Processing Techniques

Hydrographic Position Index or “HPI” Raster (Also described in “Appendix A”)

The HPI was developed by the Minnesota DNR (Vaughn 2013) to aid in the interpretation of surface water flow and improve mapping for the state. It is particularly useful in areas of the state that have thick forest canopy obscuring a small stream channel.

In areas of Wisconsin where the terrain is highly dissected like the Driftless Area and parts of the Lake Superior Clay Plain, it is also sometimes possible to use reclassified HPI values and data processing techniques to isolate the centerline of a stream for accurate, semi-automated stream delineation. These methods are currently being refined as of 2020 and will be outlined in more detail in future versions of the wetland mapping SOP.

Vaughn, S.R., (2017). Hydrographic Position Index = Description and Symbolization. Technical Manuscript. MNIT at Minnesota Dept of Natural Resources – Ecological and Water Resources.

AG Conservation Planning Framework (ACPF) Tools

[The Agricultural Conservation Planning Framework \(ACPF\) Toolbox](#) software includes tools to process LiDAR-based digital elevation models for hydrologic analysis. These tools use the DEM to model surface water flow and direction in a watershed. These tools were extensively tested during the R&D phase of updated WWI methods and found to be of limited practical applicability in terms of generating cartographic-quality output. The success of the tool is entirely dependent on how well the flow impediments have been removed from a given DEM. Because DEMs are rarely hydro-enforced, the amount of work required to correct & surface obstacles during the hydro-conditioning process equals or exceeds the time it takes to simply digitize the final line. Even if hydro-conditioning steps are properly followed, the modeled stream flow outputs from ACPF are typically of poor cartographic quality. As a result, the main application for

ACPF for wetland mapping is to help inform the user of potential stream presence that is hidden under dense canopy cover. If found, these features will still be re-drafted in the final map.

Data Production Steps and Methods

Hydrography

While there is often an element of uncertainty with remote mapping, WDNR staff use the best available information from imagery, LiDAR, and river gages (where available) to interpret flow regime and apply NWI water regime modifiers to describe the stream environment within the R2 and R4 subsystems.

Rivers, streams, lakes, ponds, and ditches are all part of the NWI 2.0 standard and need to be drafted if they convey water and are part of a wetland or wetland complex and meet the minimum definition of a wetland (not just ephemeral flow). Riverine features can be of Intermittent, Perennial, and Fluctuating water features are captured as part of the NWI process. Once captured, they can be copied out of the wetland layer and used for hydrography updates.

As mentioned earlier, many counties now have surface water breakline data included in their deliverables package from LiDAR contractors. This data should always be sought out and included in the drafting map so quality can be assessed. Where acceptable, breaklines can be directly copied into wetland maps and further processed into finished polygon data.

Hydro features, along with wetlands, are mapped at a scale of 1:2,000 or closer.

Mining Breaklines for Feature Data

Breakline products are the result of a semi or fully automated LiDAR processing. These features generally don't cover the smallest perennial stream, but they do capture larger streams, rivers, ponds and lakes. These features can be mined for outlines and centerlines to update the features in the current DNR 24k Hydro Layer.

1. Export all "lakes, ponds, and river" data from within the HUC12 you are working on into a new layer within your editing template geodatabase.
2. Start Editing.
3. Examine all captured streams, rivers, and drainage lake features. Breakline features can be copied without further modification if the **horizontal error meets the federal standard by being less than 5 meters compared to the image / boundary on the ground.**
4. Especially with riverine features, look for culverts, bridges, and other anomalies that are causing hydrologically connected water features to be represented as disconnected polygons.
 - a. If two river polygons are disconnected because of a culvert, for instance, manually connect and merge the two polygons with a new feature that follows the path of the culvert as closely as possible.

5. When all riverine breakline polygons are properly connected, the “AutoStream” toolbar can be used to generate a centerline. The “Value” Attribute should be populated as “1”. Click the “Poly to Raster” button, then click on the polygon you want to reclassify into a 1-bit raster
6. Use ArcScan to create a centerline within the output raster from step 5.
 - a. Compression tolerance = 0.01
 - b. Smoothing Weight = 3
7. If islands or multiple paths exist, pick the wider side to have the centerline follow. Try to avoid flow paths that cross islands. Very small islands (100 sq m or less) do not need to be digitized and are irrelevant for the purposes of centerline creation.
8. Abnormalities may occur where two line features meet and where ArcScan tries to create very short segments due to noise. These should be manually edited out by right clicking the line with the editor tool and selecting “edit vertices.” Often, just selecting a few vertices at a time and deleting them will be enough to smooth out the line.
 - a. **TIP** – It helps to assign a shortcut to the “Editor: Merge” function (“Ctrl + ALT + S”). Do this in the “Customize” menu in ArcMap

If breaklines do not exist or do not fit the quality criteria for inclusion in the WWI, a variety of manual and semi-automated processes can be used create a complete stream course.

Riverine Features

Criteria to consider for stream features vectorization:

- Drainage ditches are digitized if they meet the basic definition of a palustrine or riverine wetland system. They may or may not exist inside of a wetland feature.
- The current DNR 24K Hydrology geodatabase was sourced from data of varying ages and may be several decades old. Landscapes may have changed significantly in this time and no attempt should be made to re-create lines originally present in the geodatabase that no longer exist on the ground (i.e. - no banks or clear flow path observed). Caution and sound professional judgement must be used to avoid the propagation of error from old datasets to new datasets.
- If there is no evidence of intermittent or perennial surface water flow as evidenced by identifiable banks, or flow only occurs during heavy precipitation events, then it should be assumed to be ephemeral flow and not digitized as a wetland or intermittent stream. In most cases there will be no associated feature mapped in the 24K Hydro layer, however some ephemeral flow paths subject to erosion, like gullies in the Driftless Area, may be over-represented in 24K Hydro and should not be remapped unless they sustain intermittent flow for at least 1 week/yr after spring melt.
- Narrow stream polygons should be buffered a **minimum of 0.75 m** on each side of the polyline. Use the measuring tool to determine the appropriate buffer width.
- There is no NWI requirement to burn-in every intermittent stream on the landscape. Intermittent “R4” streams often are identifiable as ditches on the landscape until they empty into a larger wetland complex and the flow path disappears. Poorly defined flow paths should not be digitized as “R4” polygons cutting through wetland complexes. Instead, a “fluctuating” polyline may be used to connect the intermittent flow with the nearest connecting flow line. “R4” polygons should only be created where there is a defined flow path and/or they are not surrounded by an existing wetland.

- The National Wetland Inventory “v2.0” incorporated the National Hydrographic Dataset as a means to map the Riverine and Lacustrine environments as polygons. Occasionally, an **R5** or “**Unknown Perennial**” subsystem is created in the conversion process of merging NWI wetland data with NHD flowlines. As a result, the **R5** subsystem is redundant and not used in new WWI mapping projects, however it does appear in older NWI data.
- A WWI Specific special modifier of “l” was created for channelized or “canalized” rivers that historically occupied a meandering channel. This stands in contrast to ditches that did not exist on the landscape prior to European colonization, which are identified as excavated “x” in their attribute. “l” generalizes to “x” in NWI classification.

Riverine Vectorization Methods

1. Heads-up Center **polyline** Vectorization + Polygon Buffer
 1. Manually digitize the center of the water feature from upstream to downstream using suitable recent image using the appropriate polyline editing template (Perennial, intermittent, or Fluctuating).



6 Above: Pink lines = 24k hydro, Red = new linework

2. Snap polylines to adjacent/intersecting polylines
3. Buffer the polyline with a minimum 0.75-meter buffer width to create the Riverine polygon feature. If a riverine polygon template exists, you can buffer straight into an attributed polygon.

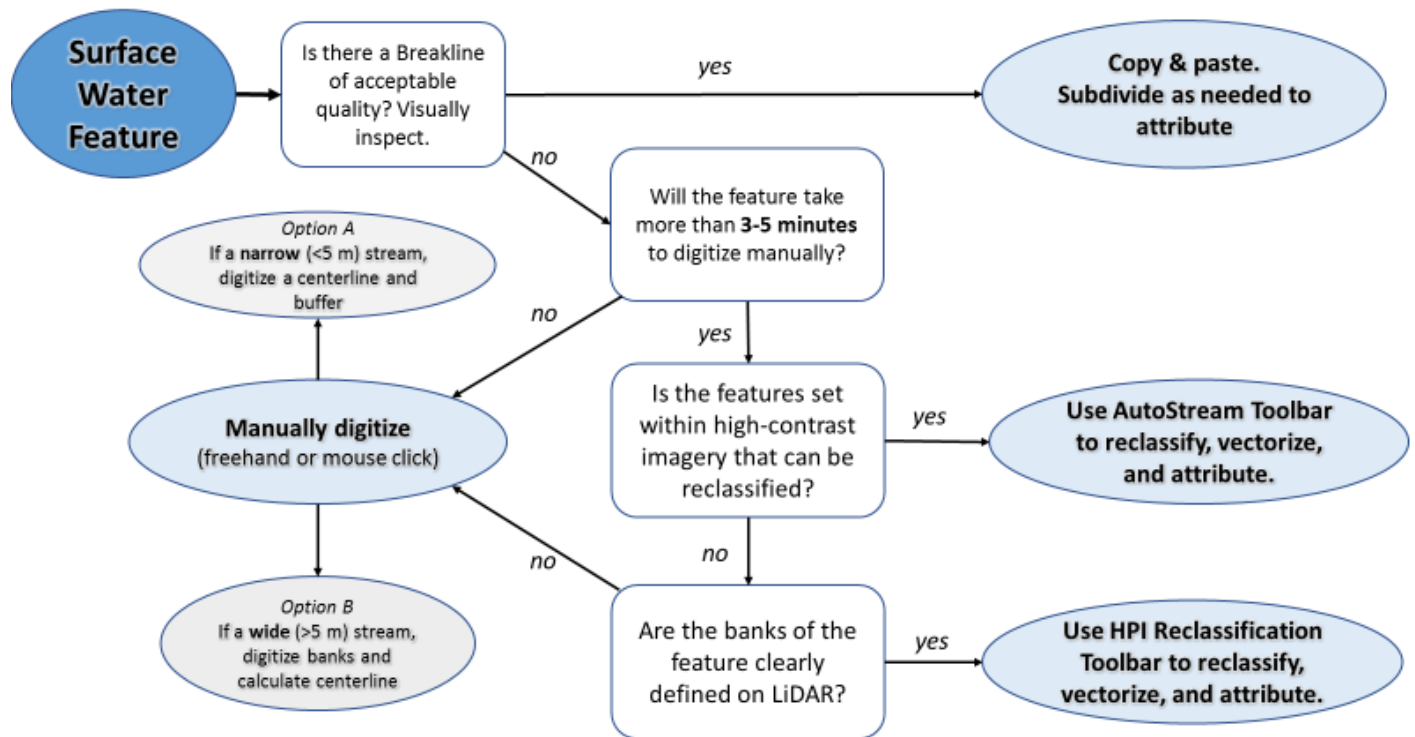


7 Finished centerline with polygon buffer

2. Heads-up **polygon** vectorization of Banks on **larger rivers**
 1. On larger, more complex rivers, the banks should be digitized in polygon form first
 2. Once the banks are digitized, a centerline can be created in two ways

- Convert the polygon to a 1-bit raster using the "AutoStream" toolbar and create a centerline with ArcScan
 - Manually plot a general centerline through the finished polygon, snapping to any upstream/downstream polylines
3. Semi-Automated Image Processing - "AutoStream Toolbar" See "Appendix A".
 1. Use when you have TIFF images and unobstructed views of the banks.
 2. This tool creates a reclassified 1-bit raster that can be vectorized into a polygon and centerline using ArcScan.
 4. Semi-Automated HPI Processing Using ArcScan.
 1. See [HPI HydroRasterProcess.docx](#) or Appendix A of this document and follow the steps to map streams and conveyance features. This process works best in dissected landscapes like the Driftless Area where streams create incised banks. This approach is also useful in areas where dense forest cover obscures stream banks on aerial images.

8 Flowchart for deciding vectorization approach



Lacustrine

According to the NWI FGDC standard, lacustrine features must be at least 20 acres (80,000 square meters) in size, or more than 9 ft deep. A set of steps similar to drafting riverine feature drafting is used in the creation of lacustrine features.

In some cases, lakes and ponds can be captured directly from the image.

Special Criteria to consider for lake and pond feature vectorization:

- Drainage ditches are digitized if they meet the basic definition of a palustrine or riverine wetland system. They may or may not exist inside of a wetland feature.
- In northern counties, add the “a” acid special modifier if the pond/lake is mostly or entirely surrounded by bog and in an area known to have soft water.
- Flow lines must be manually digitized to connect any lake inlets and outlets.

Drafting Wetland Polygon Boundaries

Wetland polygon boundaries require one or more pieces of visual evidence that can be used to identify primary indicators of surface hydrology. This can be visual evidence from one or more aerial photos, LiDAR topographic signatures, or both.

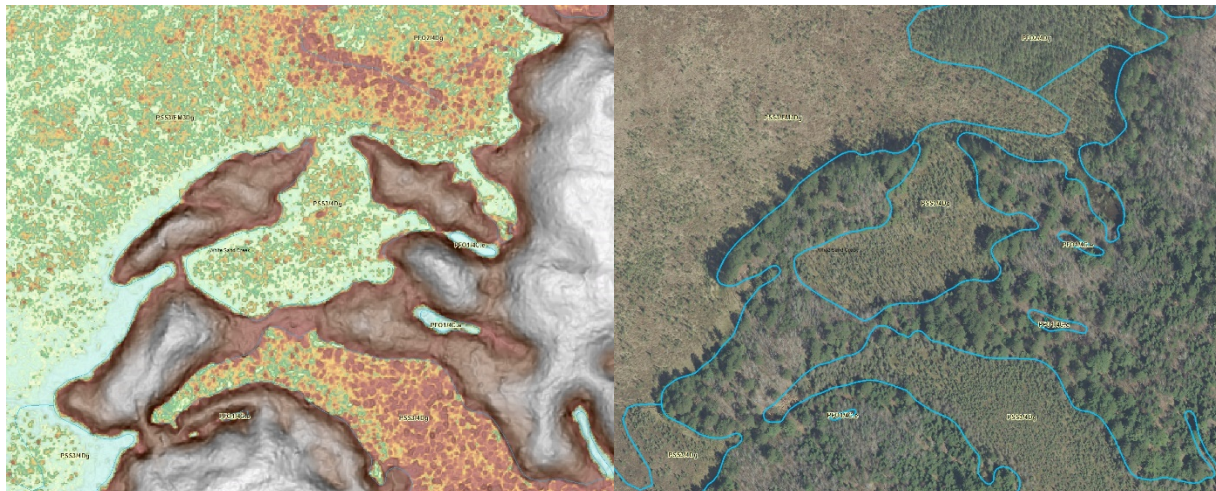
The fundamentals of imagery interpretation rely on the interpretation of visual characters related to tone, size, shape, texture, patterning, association, and other cues. A more thorough treatment of these visual characters and on-screen methods is handled more thoroughly by the NWI National Standards and Support Team’s (2017) “Technical Procedures for Conducting Status and Trends of the Nations Wetlands” publication.



9 Seasonally saturated swamp bisected by a right of way shows characteristic signs of surface water mottling. In this case, the cut-over right of way can also help provide visual clues to the outer boundary of the wetland due to the higher contrast between grassy vegetation and wet pockets. Care must be taken to ensure tree shadows from small conifers are properly distinguished from surface water mottles.

With the statewide availability of LiDAR data, it is now possible to look at high-accuracy surface elevation data to find the toe-slope or “slope inflection point” on the landscape which marks the transition from upland mineral soils transition into organic or organic-rich hydric soils. The basic concepts establishing the use of this topographic transition zone to identify a wetland boundary line are outlined in Brinson’s “Hydrogeomorphic Classification for Wetlands” (1993). In simple terms, the slope inflection point is a narrow zone that can be identified by a flattening of the heterogeneous upland surface to a more uniform wetland seepage slope, typically between 0.3% - 2.5% grade, often comprised of organic hydric soils.

Where possible, WWI cartographers attempt to draw the outer boundary of a wetland first using a slope and elevation LiDAR data overlay viewed at 1:2,000 scale.



10 Left, the broad, flat areas of peatland stand in stark contrast to the uplands in the White Sand Creek Watershed when using Histogram-equalize + slope overlay visualization. This boundary is best drawn straight from the LiDAR image to avoid misinterpretation from tree shadow and overhang. Right, wetland boundaries are overlaid with a leaf-off aerial photo for attribute photointerpretation.

If the outer boundary of a wetland cannot be determined from lidar data, imagery is then used to look for primary indicators of wetland hydrology, namely evidence of surface water and shifts in the composition of dominant vegetation. Figure 9 shows an example of a seasonally saturated, mineral soil swamp that lacked a slope inflection point and had to be delineated on imagery.

Wetland Polygon Subdivision and Attribution

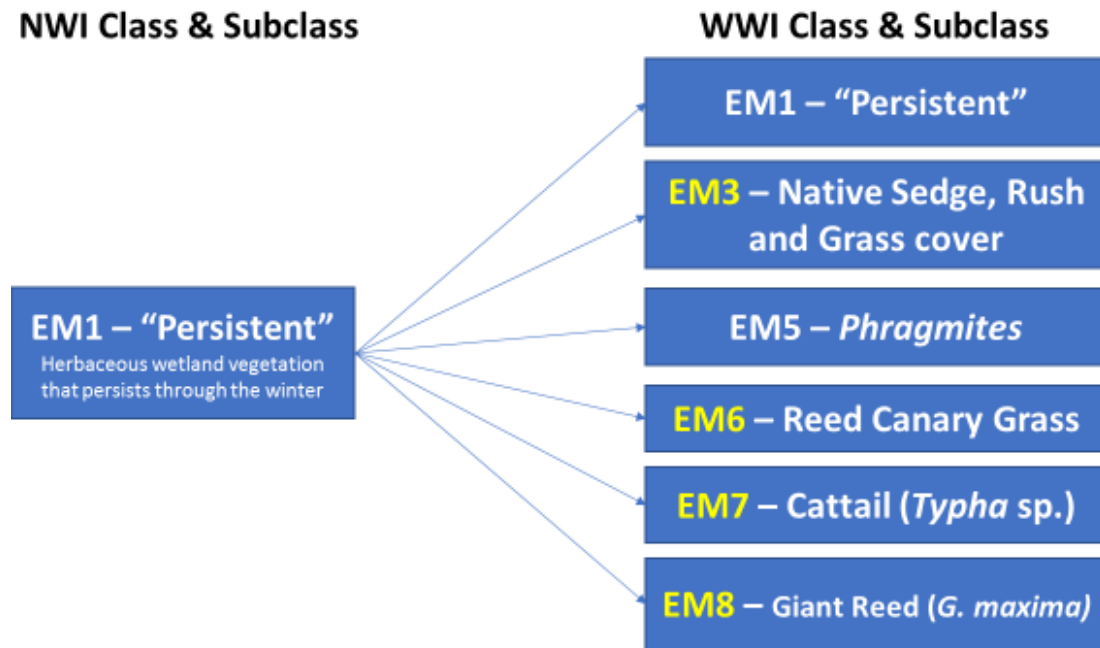
All polygons, wetland or surface water, must be attributed. On larger wetlands with a diversity of vegetation cover types and/or hydrologic regimes, the wetland boundary polygon must be subdivided so that each area can be accurately represented. As noted previously in the data production standards, subdivision of larger wetland polygons into sub-units smaller than 0.2 acres is avoided to maintain data production efficiency in addition to the diminishing relevance of increasingly small subdivisions. Exceptions to this 0.2-acre threshold may be made for excavated ponds, adjacent areas of wetland fill, and upland islands surrounded by wetland.

Polygons are subdivided using the “Cut Polygon” Editor tool in ArcMap or drawn incrementally from the inside-out using autocomplete tools.

The WWI’s standard attribution schema for all new wetland mapping is largely defined in the NWI’s “Classification of Wetlands and Deepwater Habitats of the United States” (FGDC 2013), an updated version of the document originally published by Cowardin et. al 1979.

In addition to terms and conventions outlined by the FGDC (2013), the WWI is working to incorporate state-specific subclasses and special modifiers to add specificity to dominant vegetation cover types and land uses to add extra value to newly produced WWI data. These added classifications are defined in “Appendix B” and are designed to fit within the Cowardin framework. To ensure compatibility with base NWI Cowardin Classification, two attribute columns are maintained. “WWI_Attribute” is designated for WWI-specific attributes and a second, “ATTRIBUTE”, for the generalized NWI polygon attributes. Often, WWI and NWI attributes are identical, but sometimes appear differently where certain subclasses and

special modifiers are concerned. WWI-specific attributes are stripped from data submitted to the NWI in order to maintain compatibility with the national standard.



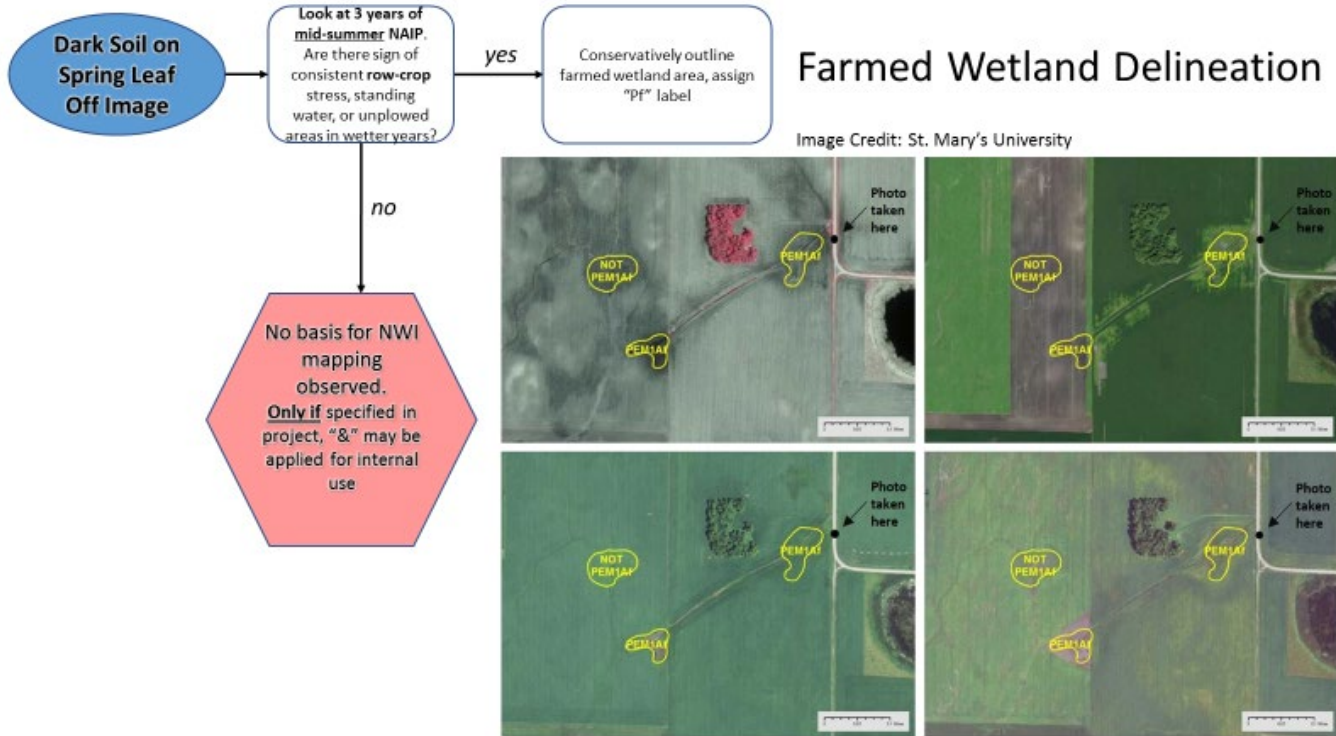
11 Wisconsin-specific breakout of the persistent emergent vegetation class and subclass (PEM1) to reflect the wide array of recognizable, dominant native and invasive vegetation cover types in Wisconsin. Note, Phragmites sp. are included in NWI attribution



12 Example of WWI breakout of emergent mapping units. Using standard NWI attribution, invasive cattail-dominated areas on the right side would receive the same attribute code as diverse sedge meadow on the left, despite being easily distinguished on aerial imagery and having drastically differing habitat value for plants and wildlife.

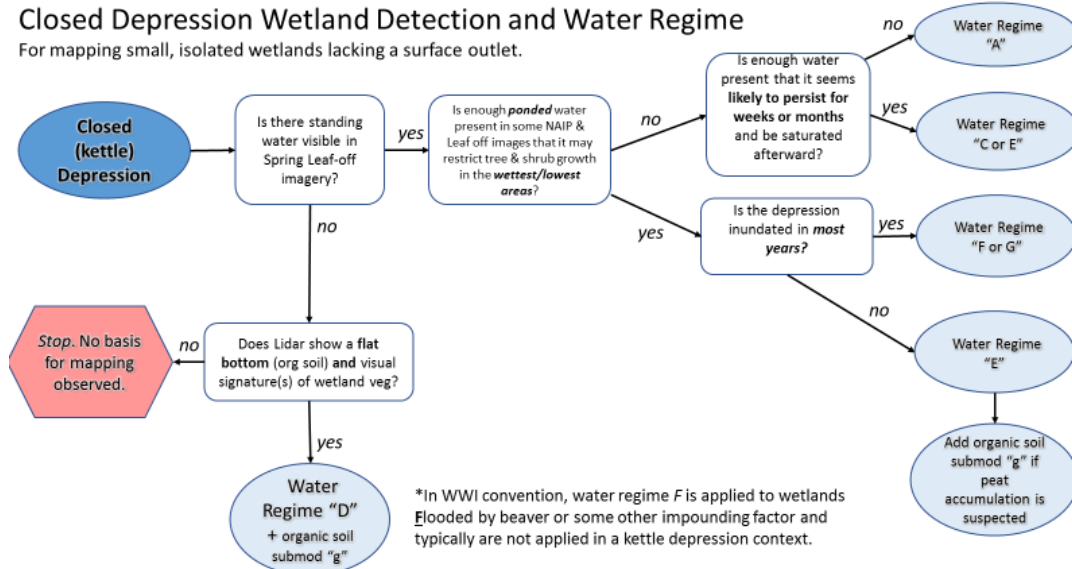
Finally, it is the intent of the WWI to develop methods and models to automatically assign Tiner LLWW codes to newly mapped wetlands. Amongst many aspects of wetland function that can be modeled with

LLWW codes, they are important for identifying wetlands that may be considered Waters of the United States. As of 2020, this capability had been developed and applied to the original WWI classification system, but processes have not yet been updated make them function with new attribute codes and geodatabase schema.



Closed Depression Wetland Detection and Water Regime

For mapping small, isolated wetlands lacking a surface outlet.



QA/QC

Procedures used to ensure data quality and accuracy follow standards laid out by the National Wetland Inventory. NWI has produced data validation tools that are used by WWI staff

Tools and instructions can be viewed and downloaded from the following location:

<https://www.fws.gov/wetlands/Data/Verification-Tools.html>

Additional procedures for ensuring the quality and validity of wetland data with WWI-specific attributes are in development and expected by the end of 2020.

Field Verification

It is important for a cartographer to have a detailed understand the landscape they are mapping. To this end, field verification of mapped wetlands should be done across each project area. A project area may include one or more HUC-12 watersheds. Field verification should include a documented set of check points where wetlands can be accessed and assessed on public lands.

In order to assist in finding public land to conduct field verification, a public lands layer and/or parcel dataset should be included in each working map document. As the cartographer makes decisions across a watershed, questionable areas can be identified and bookmarked with the “bookmarks” point layer included in the WWI Geodatabase Template.

Metadata

Each project area will include metadata that, at minimum, conforms with NWI and FGDC metadata standards. Work on WWI-specific metadata standards is ongoing and will continue to evolve and improve with time.

Appendix A: HPI Terrain Processing, Reclassification, and Vectorization

The steps outlined pertain to ArcMap 10.x, utilizing the ArcScan extension – not available in ArcGIS Pro

Manual Processing Method

1. Create HPI using the bare earth DEM as the source input DEM found in the WWI Toolbox (See Fig 14)
2. Color the HPI raster as found in the HPI documentation or use a preset Symbology layer (.lyr) file loaded from the Symbology menu.
3. You will need the highest resolution (TIFF image), Leaf-off image you can find as one of your base layers.
4. Duplicate (Copy and paste) your HPI raster from within your ArcMap session to get a second version. This will be the test raster you will use to find the indexed elevation values stored in the HPI raster that best represent the stream and hydro features you are trying to extract.
5. Rename this copied layer to **FocusedHPI**
6. Double click on **<VALUE>** from your **FocusedHPI** raster, Select **CLASSIFIED**, and change the classification to **2** classes.

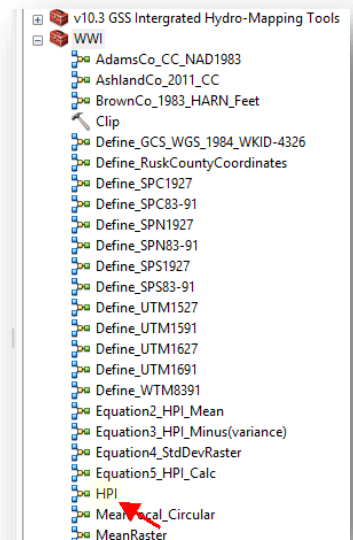


Figure 13

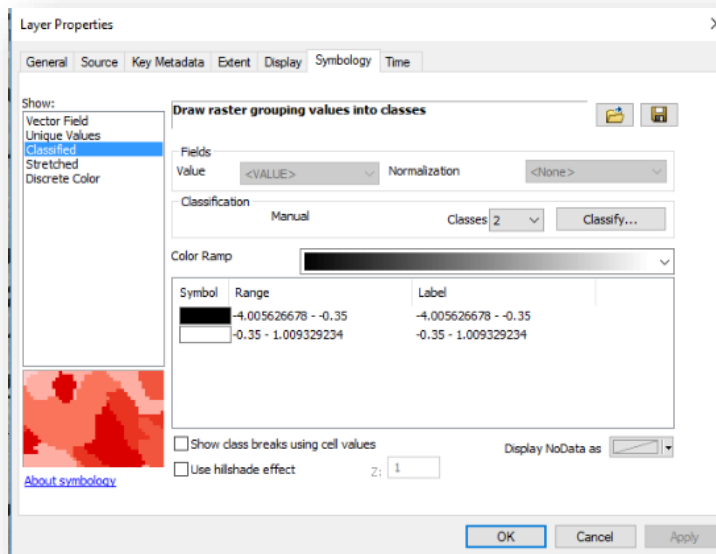


Figure 15 Focused HPI range

Slide your first class somewhere between -.6 and -.2 as a starting range. Turn the background to No Color and turn the pixels that cover the stream sections to a color that allows you to see the stream bounds amongst the colored pixels.

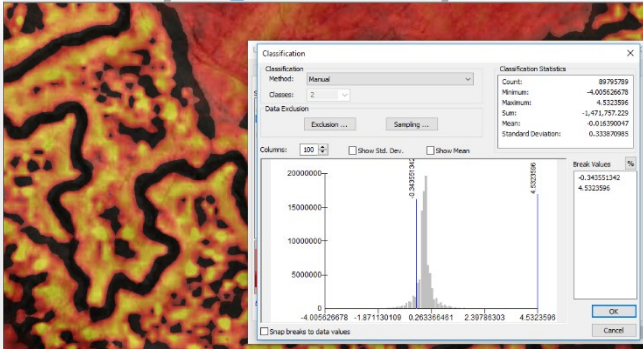


Figure 15

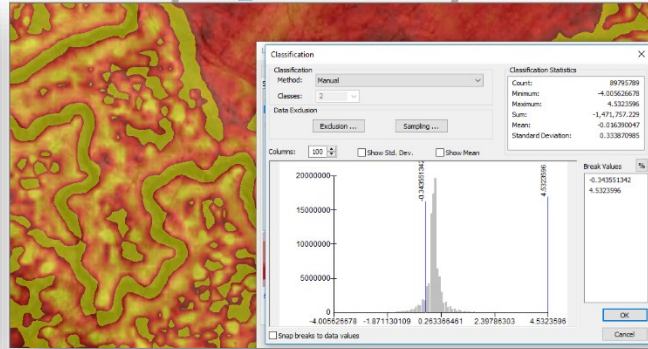


Figure 14

7. Once you have your 2 ranges, copy and paste them to notepad. You can easily do this by double-clicking on the <VALUE> of the raster again and copying the LABEL portion of the ranges and pasting inside the reclassify window. Copy each of them with the dash symbols. We will now extract only those pixels we want and create a new raster.
8. Find the *Reclassify* tool from the ArcToolbox (Found in Spatial Analyst & 3D Analyst, Reclass, Reclassify)
9. Copy and paste the range values you have in Notepad into the Reclassification tables as seen in figure 5. You may have to erase any populated values already in the table by selecting the rows and clicking on Delete Entries.

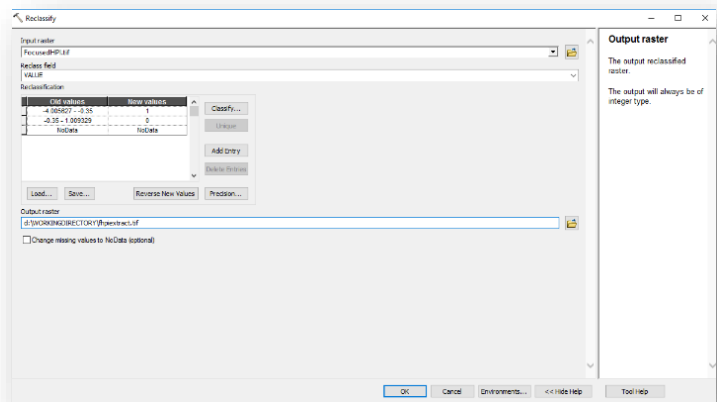


Figure 16 Reclassify to 0 and 1

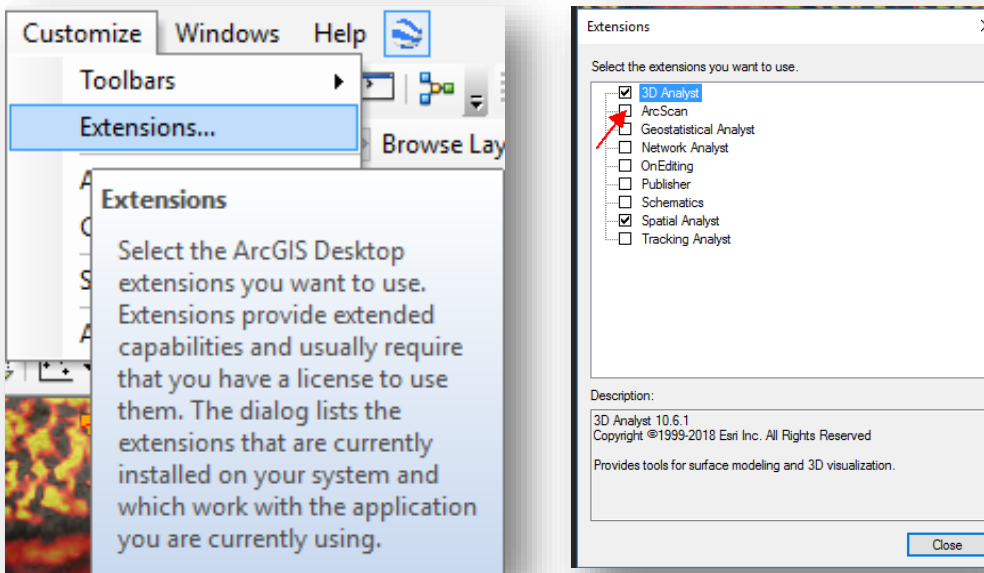
Name the new raster **fhpiextract.tif**.

The next steps will involve probably the most important parts of this whole process.

- Our goal is to select only those raster pixels that make up the stream segments containing visible water and the not-so-visible water features but ARE CLEARLY defined on the fire-red HPI view.
- Our goal for the National Wetland Inventory is to create a polygon feature representing the Riverine environment for intermittent and perennial water features. This may include large ditches as well.
- You will be switching between the image and the HPI view at times.
- You may even want to make your **fhpiextract.tif** raster somewhat transparent if it helps you decipher what you need and don't need.
- You will be grabbing portions of stream raster segments that are disconnected from each other by tree overhang and road gaps, but if you "read" between the lines you can make out the stream course.

- IMPORTANT! You will be using some flavor of high resolution (3in, 6in, 12in) imagery along with your 1m-1.5m digital elevation model as represented by the HPI. THEY WILL NOT OVERLAY PIXEL BY PIXEL PERFECTLY.
- There may be discrepancies in the DEM vs Imagery due to lidar/image flight years. You will have to keep track of the information.
- You will have to stop and skip past farmed areas that have diverted or rerouted flow underground.
- We will not be able to capture everything.

10. Check to see if your ArcScan extension is turned on. Check the box if it is blank.

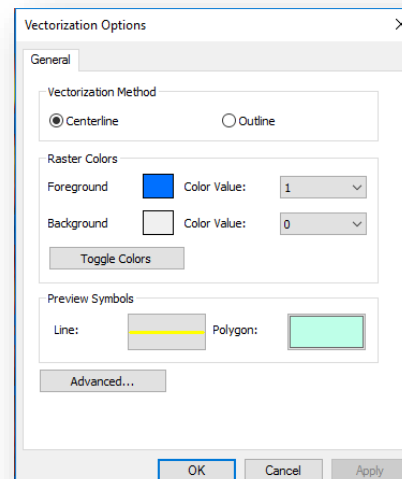


12. You should see the ArcScan toolbar now on your screen.



13. Start an edit session on either your Hydro flowlines or WWI Poly layers. This will activate your ArcScan toolbar. (Portions of the toolbar will no longer be greyed out.)
14. In the Raster dropdown box, make your **fhpiextract.tif** your raster to be edited within ArcScan. (See above.)

15. Click on **Vectorization** from the ArcScan toolbar, select **Options**. This opens up the choice menu to either vectorize the centerline of the raster or outline of your raster. We will choose centerline first. Click on **Centerline**.

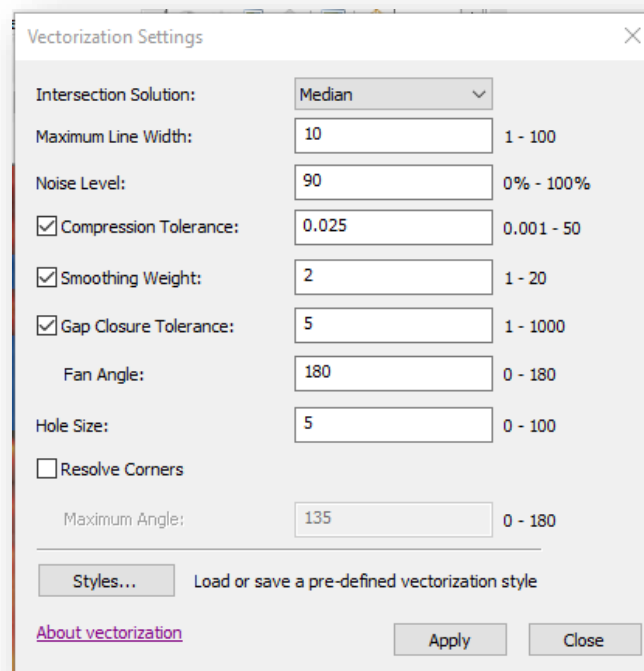


- Change your **Preview Symbol** for Line to a color and thickness that suits you.
- Adjust your foreground color of your **fhpiextract.tif** raster to a color that is pleasing to work with. Turn on 50% transparency for the raster - this allows the stream/water features to show through the raster pixels.
- Make your 0 values for your **fhpiextract.tif** raster No Color to allow the image/HPI layers to be visible.

River Centerline Generation from Raster

We will now use this new raster to locate all the connected and unconnected cells that make up the hydro segments. ArcScan will give you a preview of the centerline as you work your way up the watershed.

16. Zoom into an area of stream that you will be starting with. Do not be too far out as the next steps involve the software doing a great deal of processing to show you the stream centerlines for ALL the raster pixels that fit the vectorization settings.
17. Click on **Vectorization** from the ArcScan toolbar and select **Vectorization Settings**.



18. Change the settings to reflect the above numbers. Use as a guideline.
19. From the **Vectorization** menu, select **Show Preview** – from the Vectorization menu. This will activate the auto-trace preview for the raster and give you a preview.

20. Set Maximum Line Width to about 5 above your average raster line width. If you have fatter parts that are ACTUAL streambed, you will have to make your Line Width setting wider.

- You can use the Raster Width Tool to show you your width. Click on the **Raster Line Width** tool and Click on a portion of your raster and it will tell you the width.



21. Get yourself organized and work your way up the stream sections, going only as far as what fits the goal. Visible water, definite streambed, well defined intermittent flowpaths, drained areas and ditches.

22. When you come to a road crossing and the gap is too large for ArcScan to jump you can edit the raster:

- a. Select **Raster Cleanup**, slide down to **Start Cleanup**.



- b. You can use the eraser to both erase and draw by switching between foreground/background. You don't need the paintbrush.

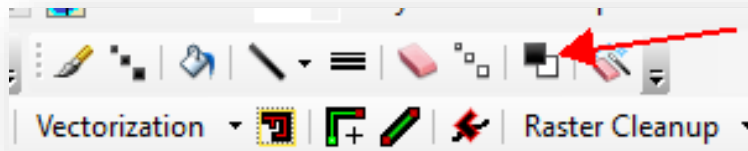
- c. Click on Eraser



- d. Click on proper sized eraser/draw width to use (insert image)



- e. Click on foreground/background until you get the foreground. (You have to click on your raster to see which one you have. There's no other way to tell. You will either erase or paint – erase your added raster if it is noise with CTRL-Z)



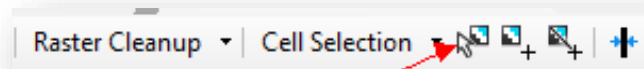
- f. CAREFULLY, paint the road gaps in or areas that were missed. Move fast.
 - g. If you make a mistake, click CTRL-Z.
 - h. If you have to erase pixels, click on the Foreground/background icon again.
 - i. SAVE YOUR RASTER EDITS, Click on **Raster Cleanup**, slide down to **Save**
 - j. Move up the stream and repeat your steps.
 - k. Let ArcScan's Show Preview jump the little gaps that may occur. If you see GLARING issues, fix accordingly.
 - l. Continue until the stream is no longer a visible intermittent and move to next stream channel.
 - m. SAVE YOUR RASTER EDITS, Click on Raster Cleanup, slide down to **Save**
 - n. Once you complete the centerline preview, it's time to do the Raster Outline process
- ONLY use the Raster Cleanup Tool and Raster Painting Toolbar if the settings do not adhere to what you are trying to capture. Do not waste time.
 - Fill in road gaps, walking bridges and anything else that forces ArcScan to stop.
 - The Show Preview will change with any edits you make.

23. Save your raster edits OFTEN, by Clicking on Raster Cleanup, Save.

24. Work your way up the stream course as quickly as you can. DON'T FORGET TO SAVE your raster edits.

- TIP: use a line markup shapefile to make visible cross marks on those stream courses you have finished editing. When you zoom out to the watershed scale, you will not be able to see very well.

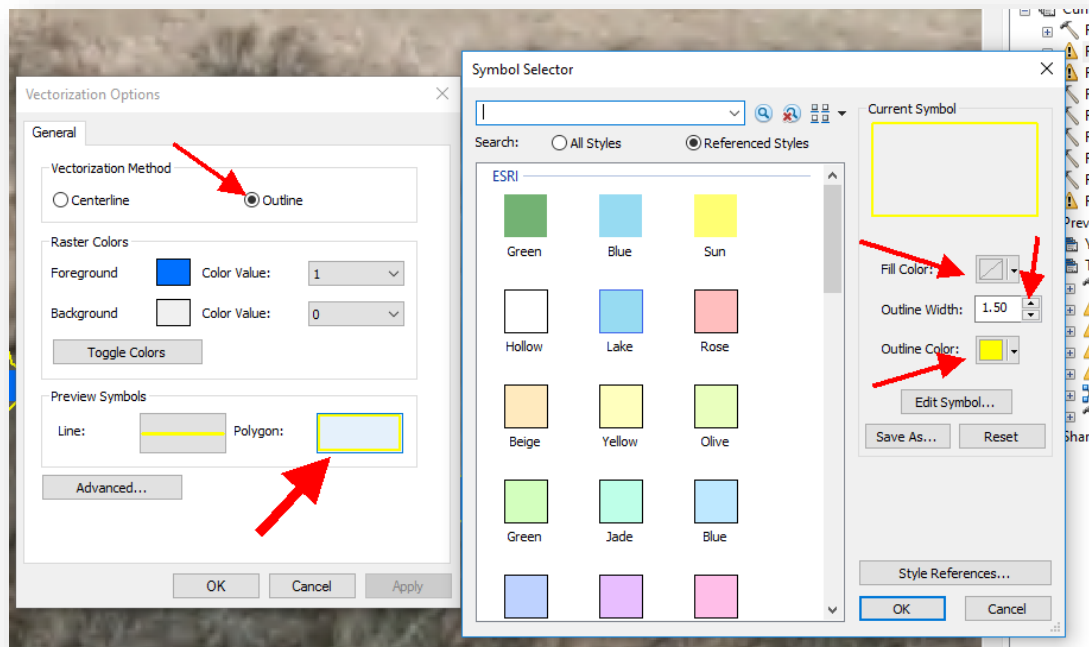
25. Turn off the **Show Preview** from ArcScan toolbar.
26. Move to your starting point for your watershed.
27. Click on **Select Connected Cells** tool from the ArcScan toolbar



28. With the mouse, grab ALL the cells that make up the water features, avoiding all noise (using the shift key to add to your selection).
 - You will find areas that you probably missed. Add them
 - The more breaks you have the more pieces of the puzzle you have to grab – That's ok.
29. **Save your selection, making sure you haven't dropped any by accident, by Clicking on Cell Selection, and sliding down to Save Selection As. Use a temporary filename for now.**
30. **Save often**
31. Once you have all the cells selected, save your connected cells to a new raster called **ConnectedCells.tif**
 - The new raster **ConnectedCells.tif** will most likely have the 0 and 1 cell values flipped. We will have to reclassify.
32. Reclassify **ConnectedCells.tif** raster, resetting 0 to 1 and 1 to 0., saving to a new raster **ConnectedReset.tif**
33. Turn off the unwanted noisy rasters from Table Of Contents and make sure your **ConnectedReset.tif** is now your ArcScan raster in the dropdown window.
34. Click on **Vectorization** and turn on **Show Preview** again. Look at the preview.
35. Follow each section from start to end up the stream/water features. If you are satisfied, let's move to the polygon outline process. This will capture the stream as a polygon to be part of the Riverine NWI layer. Zoom into beginning section of stream raster.

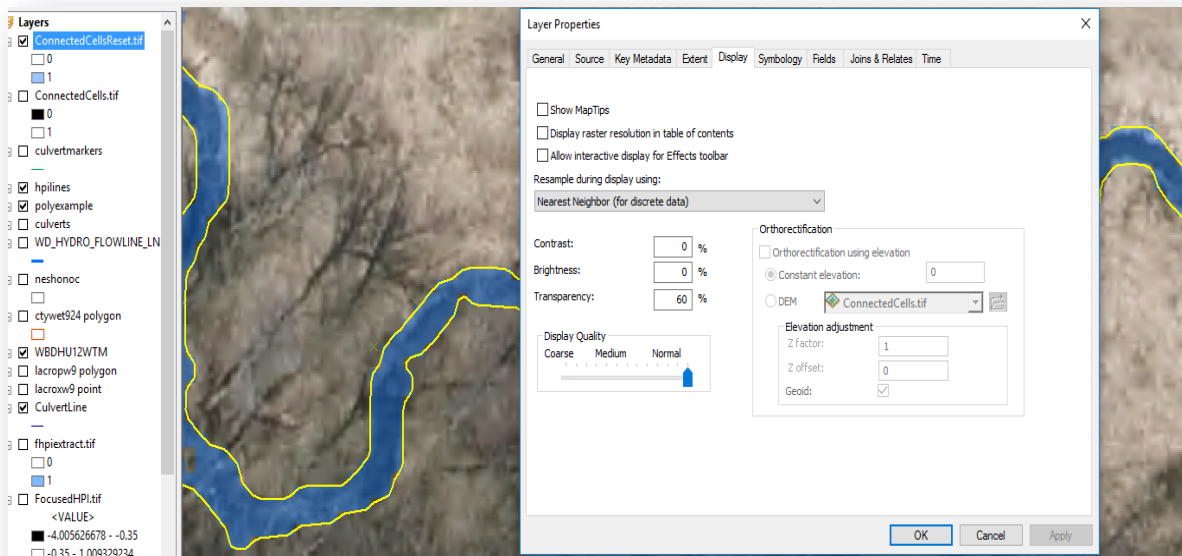
River Outline Generation from Raster

1. Select **Vectorization, Options**, Select the Outline button



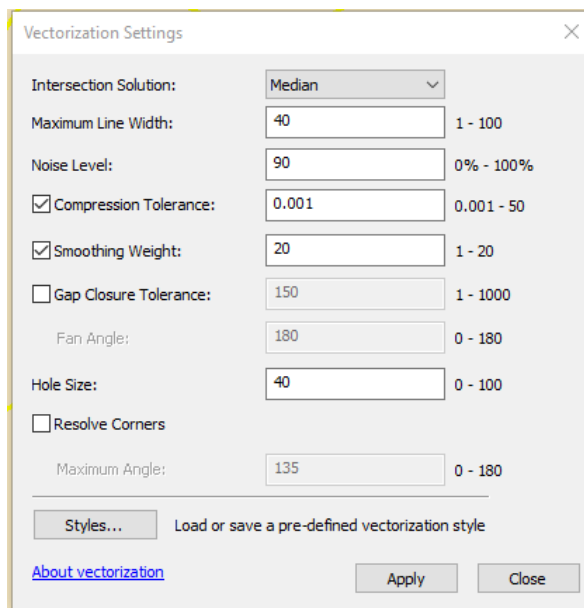
2. Under **Preview Symbols**, Click on **Polygon** color window
3. Change the Fill Color to No Color
4. Change the Outline Color to Yellow, Set the Outline Width to 1.5
5. Click Ok to close Symbol Selector window. Change the display transparency for your **ConnectedReset.tif** raster.

This will allow you to see the stream feature underneath and guide your decisions in this outline process.



6. Select **Vectorization**, and **Show Preview**

7. Select **Vectorization**, **Vectorization Settings**. Use the below image as a guide.



8. When you edit the raster, you change the centerline for the flow, so do so carefully.



9. Move your way across the stream areas checking for areas that can either be fixed by adjusting the Vectorization options automatically, or with the Raster Cleanup process.

10. When you are done with the raster polygon editing, SAVE your ConnectedReset.tif raster.

11. Click on **Vectorization** and turn off **Show Preview**.

12. Click on **Vectorization** again and slide down to **Generate Features**. You will place the polygon feature into your WWI_POLY layer. If you know the stream segment being vectorized, you can assign the proper NWI template for the ATTRIBUTE field.

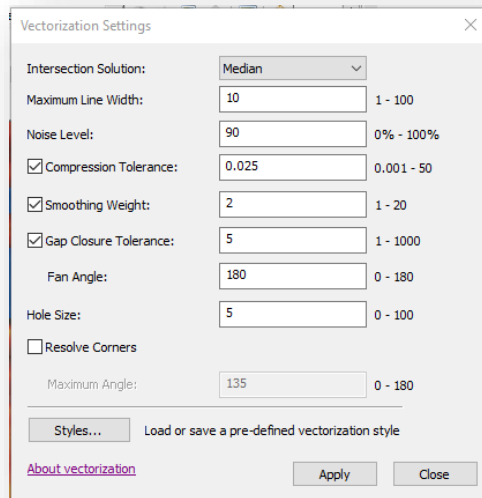


Now, let's get the centerline for the new Hydro flow lines.

Raster Centerline

1. Click on **Vectorization** and slide down to **Options**.
2. Click on the **Centerline** button.

3. **IMPORTANT!** You must change the **Vectorization** settings from what they are currently set for the outline process back to what you had previously before generating the centerline features.



4. Click on **Vectorization** again and slide down to **Generate Features**. You will place the linear features into your HYDRO FlowLines layer. If you know the duration of stream segment being vectorized, you can assign the proper Perennial or Intermittent template for the ATTRIBUTE field.



Appendix B: Wisconsin-Specific Additions to NWI Attribution for Wetland and Waterbody Polygons Produced by the Wisconsin Wetland Inventory (WWI)

Christopher Noll, 7/13/2019

Introduction

From 1979 until 2017, the Wisconsin Wetland Inventory (WWI) produced wetland polygon and point data using hard copy photo drafting and digitization techniques. While drafting and digitization methods were refined and improved over time, the overall workflow and polygon attribution remained consistent as outlined in the Wisconsin Wetland Inventory Classification Guide (PUBL-WZ-WZ023, 1992).

With statewide coverage from orthorectified data recently completed, discontinuation of long-standing base materials (film-based B&W stereo pairs), and advances in state-of-the-art GIS data & availability, the time was ripe to consider major changes to the WWI to continue mapping while remaining relevant to agency and customer needs.

As part of the WDNR's FY2016 EPA Wetland Program Development Grant, funds were designated for a pilot mapping study (hereafter referred to as "the Pilot Study") to "design, test, and evaluate a process to map wetlands and surface waters in tandem from the same data surfaces, to produce a single Integrated Surface Waters and Wetlands GIS Layer." A primary goal of this project was to provide improved, modernized methods and a path forward for the Wisconsin Wetland Inventory (WWI).

During this overhaul process, a major area of consideration has been how to attribute polygons. In part because the WDNR's wetland mapping efforts preceded the NWI, Wisconsin created and maintained its own wetland classification system for decades even as 49 other states adopted the National Wetland Inventory (NWI) standards using the Cowardin Classification System (Cowardin et al. 1979). While the systems were roughly equivalent, they diverged in the WWI's relative lack of hydrologic modifiers versus the NWI's more numerous and descriptive modifiers.

Since an objective of the Pilot Study was to create wetland maps that are fully compatible with NWI standards, by default the WWI needed to attribute wetland polygons using the Cowardin Classification System. This requirement created two possible scenarios for the attribution of wetland polygon data. The first, more complex scenario would require maintaining the WWI and Cowardin classification systems in parallel which would require significant expenditures in time and money to dual-attribute millions of polygons. The second scenario would require only using the Cowardin Classification and abandon WWI classification.

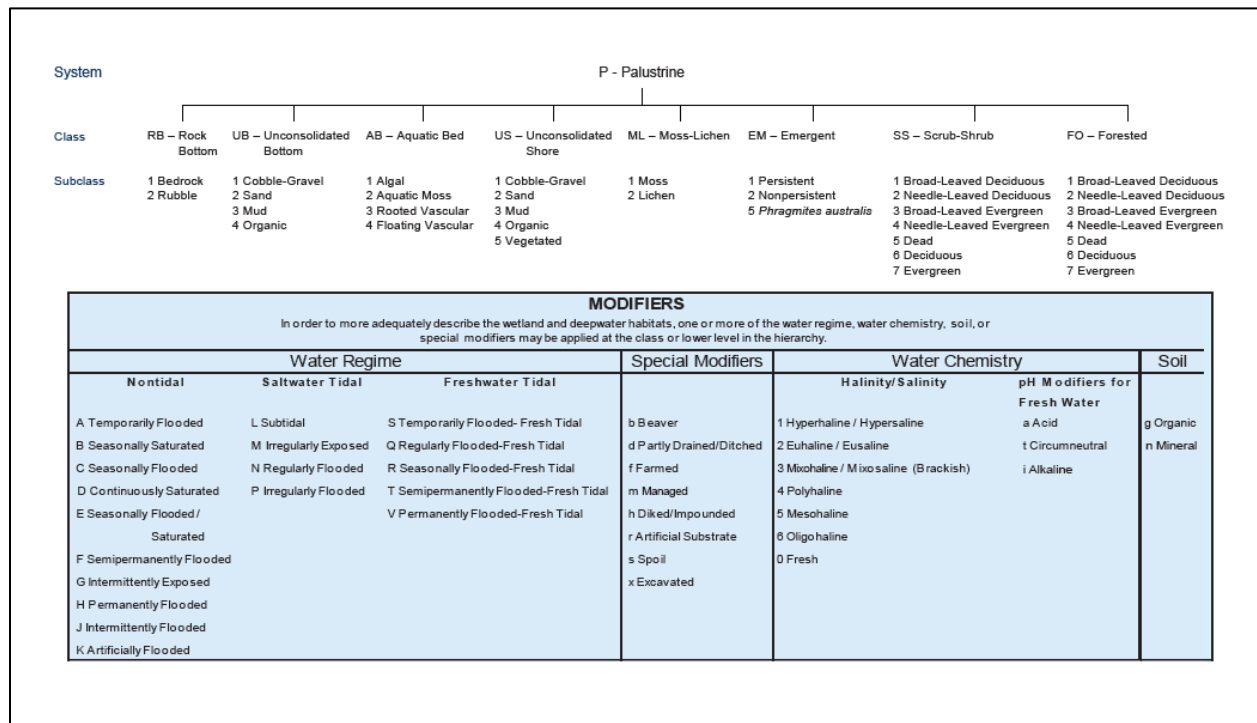
While the second scenario is preferable from a production standpoint, the WWI Classification System has decades of history and use across Wisconsin. As a result, the decision was made to proceed cautiously before abandoning the Wisconsin system. To get a sense of user opinions, in spring 2018 the WWI team surveyed stakeholders about how they interacted with wetland map data. This survey was distributed at the 2018 Wisconsin Wetland Association's Wetland Science Conference in Lake Geneva and at two Critical Methods workshops. Ninety-three responses were tallied. Of these results, only 2% of respondents thought switching to the Cowardin Classification System would have a negative impact. This

overwhelming result provided the support to discontinue use of the WWI Classification System and adopt NWI standards as a base classification system. Additionally, 70% of users reported “frequently” or “occasionally” keying out wetcodes, confirming that classification tools are important and commonly referenced by users of wetland maps.

Enhancing Cowardin to suit Wisconsin’s Needs

The Cowardin Classification System has a hierarchical structure. The most general attribute code represents the *System*. Under this there may be a *Subsystem* if within Lacustrine or Riverine systems, followed by a *Class*. The *Class* describes a general type of land cover – such as forested, shrub, emergent, open water, etc. If applicable, each *Class* is modified by a *Subclass*, followed by a *Water Regime*, and optionally up to one *Special Modifier* to describe land use, soils, and water chemistry.

Sample Diagram - Classification of Wetlands and Deepwater Habitats of the United States, Cowardin *et al.* 1979



As of 2019, the amount of valuable, photo-interpretable detail that can be captured by wetland cartographers has greatly increased with LiDAR data and 6-12” imagery that easily supports 1:1,000 scale viewing. By resuming wetland and surface water mapping within the WDNR, exciting possibilities exist for capturing unprecedented detail about the landscape through photointerpretation and modeling. However, this data can only be captured if there is an efficient system and workflow for doing so. The Cowardin Classification System is nearly 40 years old. While robust, it was developed at a time of restrictive hard-copy methods, coarser imagery, and 1:20,000 mapping scales which limited what could be seen and captured. One way the WWI is seeking to increase the value of its mapping product is through the development of Wisconsin-specific attributes that fit within the Cowardin Classification System and expand its descriptive capabilities.

While it may seem contradictory to abandon a state-specific classification system in favor of a national standard only to re-add a suite of Wisconsin-specific attributes, there are several reasons why this approach makes sense:

1. Wisconsin-specific attributes recognize unique, high-value, local data needs that can be efficiently captured through a standardized mapping workflow. Careful consideration of attribute additions will hopefully increase the WWI's relevance and build support for increased output.
2. If Wisconsin-specific attributes are built *within* the existing Cowardin Classification System framework, there is no risk of incompatibility with NWI standards. For collaboration with the NWI, WWI GIS data can simply be dissolved (a GIS method of data generalization) into the NWI attribute to meet NWI standards.
3. Through Python scripting and custom GIS tool creation, the WWI team is capable of simultaneously dual-attributing wetland polygons with an "enhanced" WWI attribute and a generalized NWI-standard attribute. This minimizes the additional labor needed for creating polygons with enhanced attributes.

Some of the proposed classification additions in the following section may seem overly specific and detailed. However, the precedent for creating plant family and genus-specific subclasses was set by Cowardin (1979) with the inclusion of "broadleaf evergreen shrubs" and "needle leaved deciduous" trees/shrubs representing Heath Family (Ericaceae) and Tamarack (*Larix* sp.) respectively – at least in the upper Midwest. Cowardin classification relied on what was visible in 1970's era photography, and the attributes aim to push the boundaries of ecological descriptiveness further according to what can be interpreted from modern imagery and connected databases. Careful consideration and testing went into only adding new attributes that reliably categorized meaningful ecological data that could not be improvised through existing attributes.

Established and Proposed* Emergent Wetland Subclasses & Attribute Codes

Emergent Class "EM" Overview: "In this wetland Class, emergent plants—i.e., Erect, rooted, herbaceous hydrophytes, excluding mosses and lichens —are the tallest life form with at least 30% areal coverage. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants" (FGDC 2013).

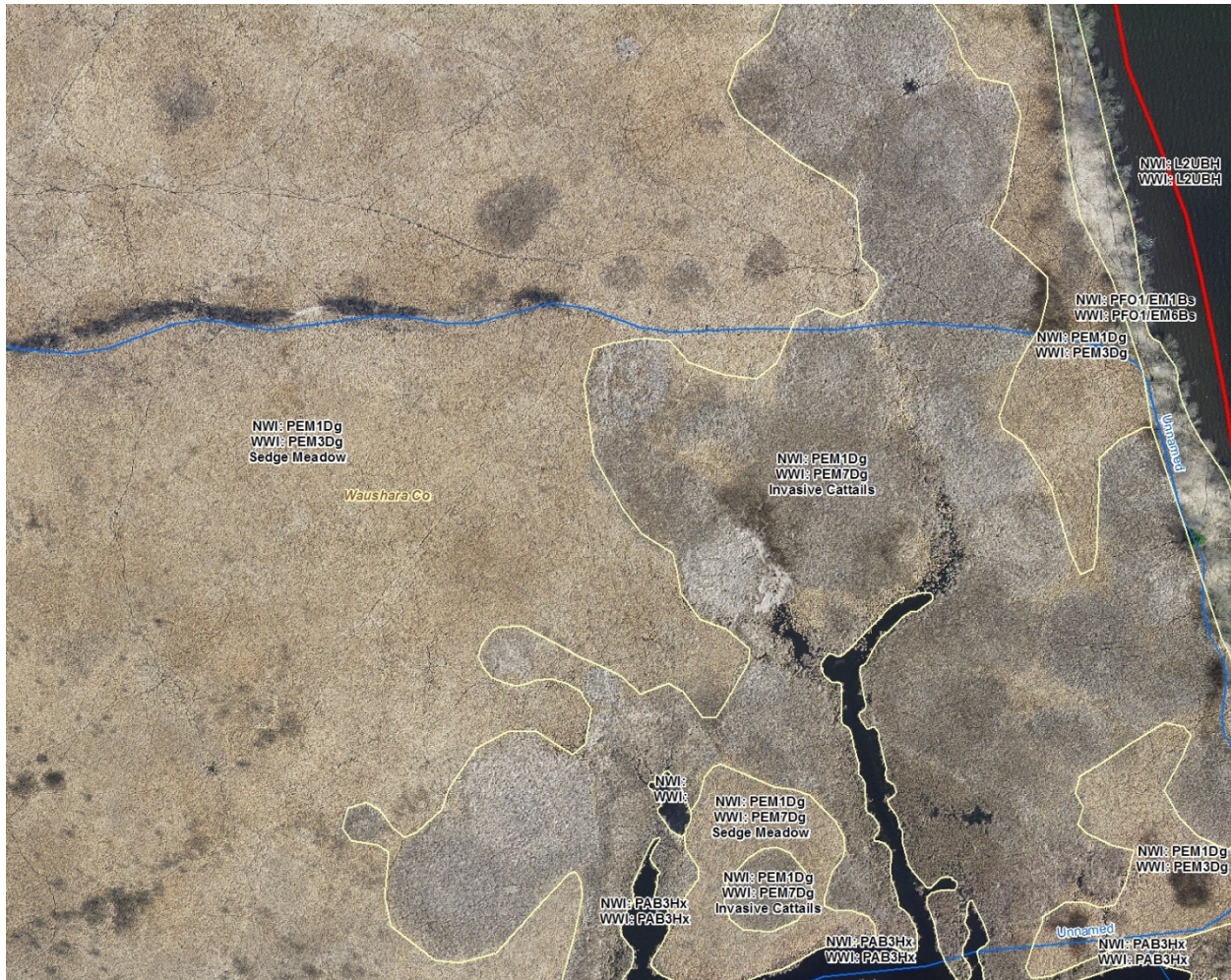
EM1 NWI: Persistent – "Persistent emergents are emergent hydrophytes whose stems and leaves are evident all year above the surface of the water, or above the soil surface if water is absent. Herbaceous wetland vegetation that persists through the winter and into the following growing season" (FGDC 2013)

WWI Refinement – This subclass shall be reserved for situations where no clear dominant emergent vegetation type can be determined. Situations where this may arise include very small wetlands, grazed pastures, early-successional regrowth after plowing, and disturbed wetlands with interspersed patches of dominant cover types.

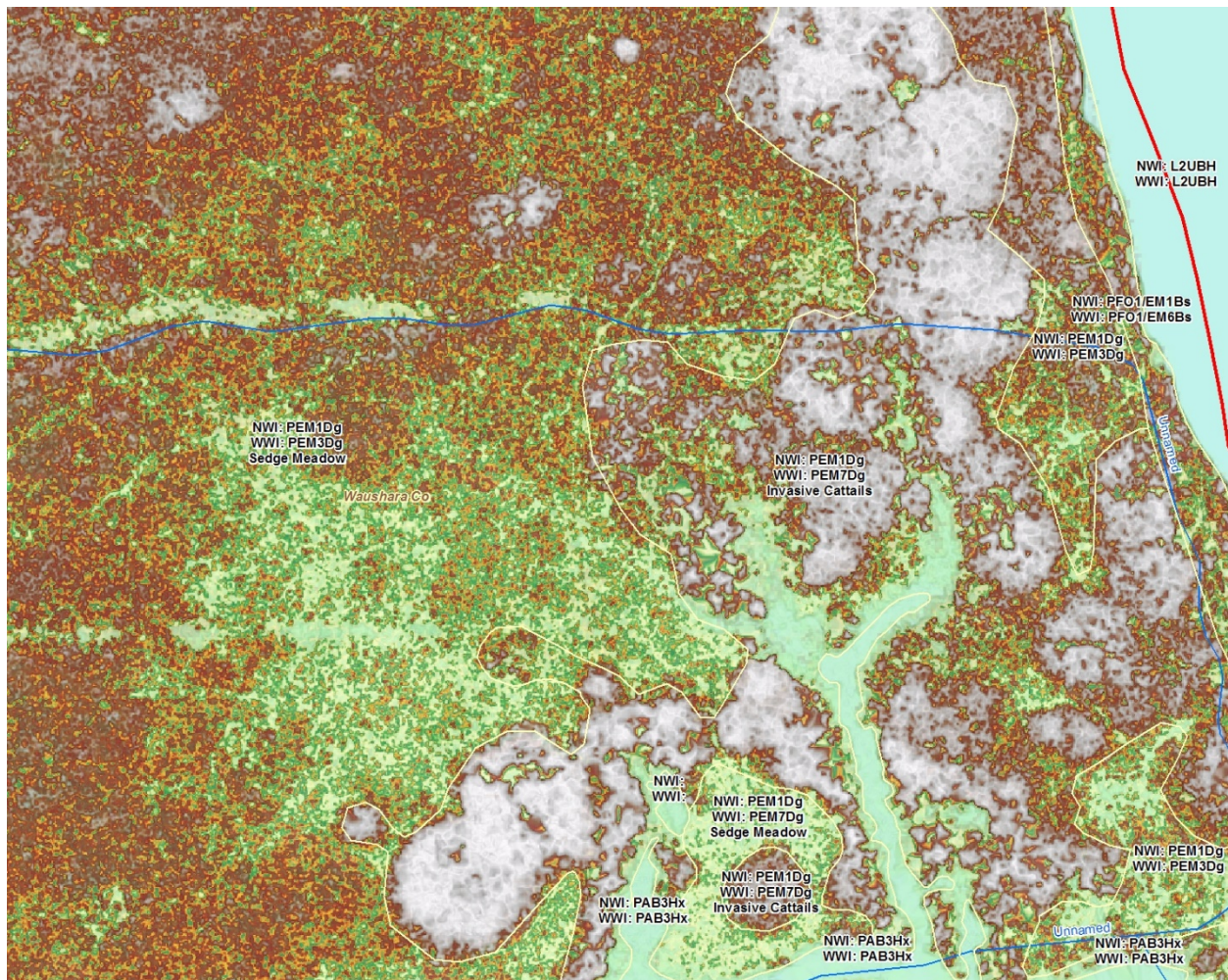
EM2 NWI: Non-persistent – "Nonpersistent emergents are emergent hydrophytes whose stems and leaves are evident above the water surface, or above the soil surface if surface water is absent, only during the growing season or shortly thereafter. During the dormant season, there is no obvious sign of emergent vegetation" (FGDC 2013).

EM3* Cyperaceae Family and Native Grass (WWI Specific)

WWI Definition – Northern and southern sedge meadows, calcareous fens, poor fens, wet mesic prairies are examples of classic natural community types that are dominated by sedges (Cyperaceae Family / *Carex* sp.) and native grasses. Less commonly, riverine wetlands may be dominated by bulrushes (*Bolboshenous* sp.). Collectively, these community types occupy hundreds of thousands of acres across Wisconsin and are often a significant indicator of wetland & water quality. In pure stands within emergent wetlands, sedges and bulrushes can be identified on leaf-off spring by observing fine-textured, straw or tan to light-brown winter-cured foliage. Depending on the community type, these wetlands may be dominated by one or more of the following species: *Carex lacustris*, *C. stricta*, *C. utriculata*, *C. trichocarpa*, *C. aquatilis*, *C. lasiocarpa*, *Scirpus* sp., *Schoenoplectus* sp., and *Bolboschoenus fluviatilis*. Pure stands of native grass are more challenging to discern but can be identified on leaf-off imagery by observing off-white foliage that is similar to Reed Canary (EM5), but differs by having a finer, less ‘lumpy’ texture due to its narrower leaves reflecting less light. This subclass generalizes to “EM1”.



17 Invasive Cattail (EM7) expanding into native sedge meadow (EM3). *Typha*'s grayish, fuzzy appearance contrasts with the more uniform beige sedge meadow, producing a "mold on cheese/bread" visual effect.



18. The same extent as the previous image showing stretched LiDAR data and the "false ground" signal created by dense, elevated invasive cattail litter

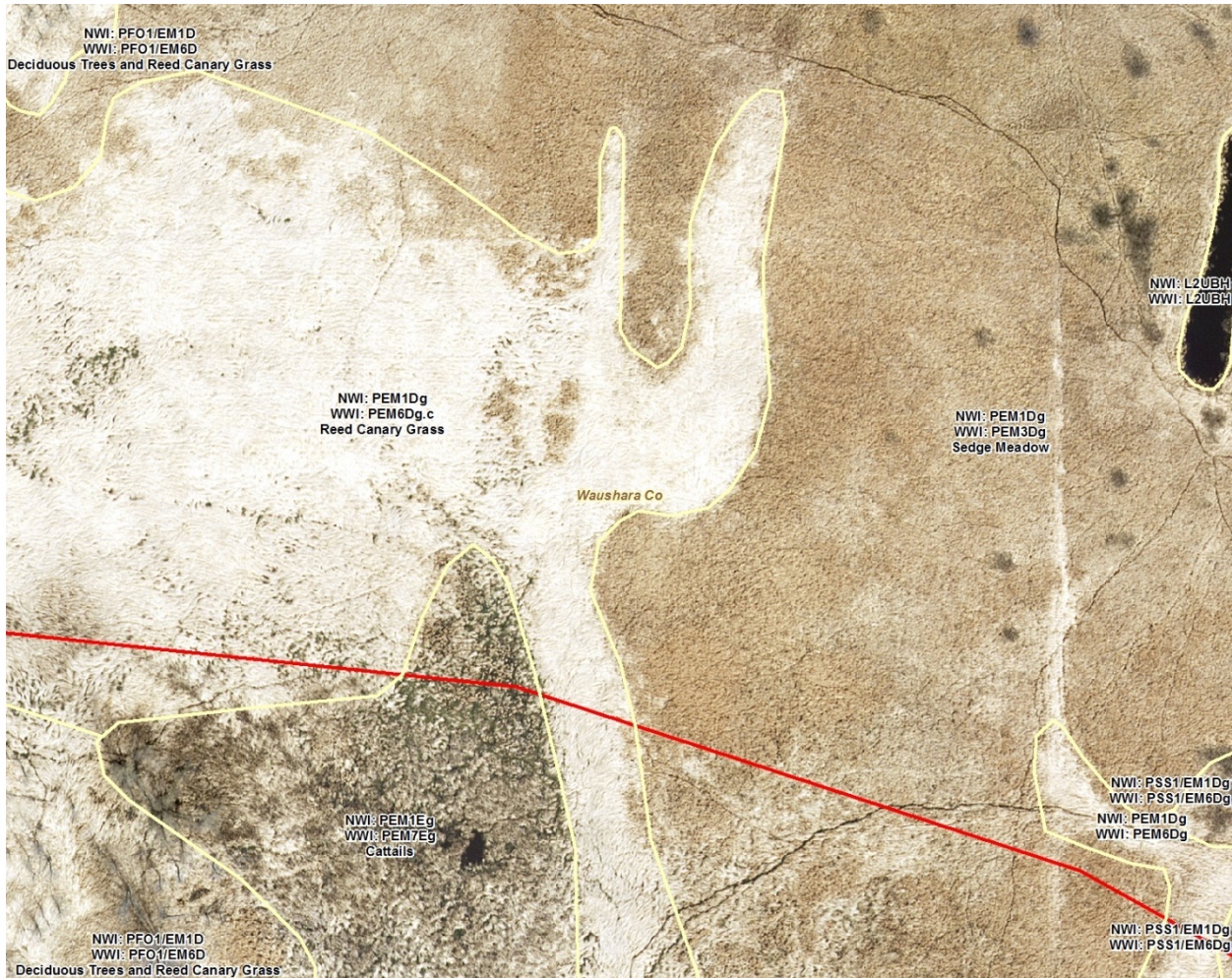
EM 4 Blank

EM5 NWI: Common Reed Grass, *Phragmites australis*

WWI Refinement – This NWI subclass should only apply to dense, tall, near-monotypic stands of non-native common reed grass (*Phragmites australis* subsp. *australis*). Stands of native common reed grass (*Phragmites australis* subsp. *americana*) rarely achieve more than 50% cover in a stand of sedges or cattail and are difficult to discern on even high-resolution aerial imagery.

EM6* **WWI Proposed: Reed Canary, *Phalaris arundinacea*** – *Phalaris arundinacea* is a prolific invasive species that covers hundreds of thousands of acres in Wisconsin (Bernthal and Hatch 2008) and a strong indicator of past or current disturbance. In the reed canary grass subclass, "EM6" polygons are assumed to have reed canary grass covering 50% or more of the upper most layers of foliage. Reed canary grass can be identified on leaf-off imagery by observing areas of bright white, coarse, and often 'lumpy' textured vegetation. The visual signature of sedges, if present, is overwhelmed by the high reflectance of reed canary grass. Reed canary will often be associated with 'partially

drained’, ‘abandoned ag’, and/or ‘grazed’ special modifiers and should not be split with other Emergent Subclasses. This subclass generalizes to “EM1”.



19. Bright white Reed Canary Grass (EM6) winter foliage contrasts with tan Carex foliage. A smaller polygon of cattail (EM7), possibly native as evidenced by a non-clonal appearance, is also visible.

EM7* **WWI Proposed: Invasive cattails, *Typha* species** – Hybrid cattail (*T. x glauca*), along with the myriad back-crosses it forms with parent species narrow-leaf (*Typha angustifolia*) and broad-leaf (*T. latifolia*) cattail, frequently invade sedge (*Carex* sp.) and bulrush (*Schoenoplectus* sp.) dominated emergent wetlands to form dense stands of diminished functional and habitat value. In the invasive cattail mapping subclass, “EM7” polygons are assumed to be dominated by near-monotypic stands of hybrid or narrow-leaf cattail where the cover of current years’ growth and standing dead vegetation exceeds 66%. At lower densities, as in the case when native cattails are interspersed with sedges, it is not practical to discern native vs invasive cattails aerially. Invasive cattails can be identified on leaf-off imagery by observing grayish, “fungal” or fuzzy-looking, circular patches of vegetation that increase in diameter from year to year until individual clones coalesce into a dense, near-monotypic stand. On LiDAR DEM’s, these stands are often so dense that they create a false ground signal and appear as elevated circles within shorter-statured sedge and grass-dominated wetlands (see figure 18). Within a watershed, invasive cattails are commonly associated with

nutrient inputs, road rights-of-way, impoundments, excavations, wetland fills, and hydrologic alteration from a pre-settlement regime. This subclass generalizes to “EM1” in NWI.

EM8* **NWI Proposed: Giant Reed Grass, *Glyceria maxima*** – *Glyceria maxima* is a recent invasive species that is rapidly expanding along drainage ditches, streams, and river corridors in southeast Wisconsin. Able to expand into and replace stands of reed canary grass (*Phalaris arundinacea*) and extend rhizomes that span across narrow streams and ditches, giant reed grass poses a serious threat to wetlands wherever it is found. Giant reed grass leaves often remain green throughout winter and can be identified on leaf-off or leaf-on imagery by observing patches of yellow-green (leaf-off) to bright emerald-green (leaf-on) grassy vegetation. In this subclass, “EM8” polygons are assumed to have *Glyceria maxima* covering 75% or more of the upper most layers of foliage. Already-mapped populations of this species will aid in photointerpretation. This subclass generalizes to “EM1” in NWI.

Established and Proposed* Scrub-Shrub Wetland Subclasses & Attribute Codes

Scrub-Shrub “SS” Class Overview “In Scrub-Shrub Wetlands, woody plants less than 6 m (20 ft) tall are the dominant life form—i.e., the tallest life form with at least 30 percent areal coverage” (FGDC 2013). This includes tree saplings in recently logged areas.

- SS1** **NWI: Broad-leaved deciduous** – “In this Subclass, broad-leaved deciduous species have the greatest areal coverage within the shrub layer” (FGDC 2013). Any deciduous wetland shrub. Includes willows (*Salix* sp.), dogwoods (*Cornus* sp.), Alder (*Alnus* sp.), and several others.
- SS2** **NWI: Needle-leaved Deciduous** – “In this Subclass, needle-leaved deciduous species have the greatest areal coverage within the shrub layer. Dominance Types include young or stunted tamarack and southern bald-cypress” (FGDC 2013). In Wisconsin, this subclass is limited to young or stunted tamarack trees (*Larix laricina*) less than 6 m tall.
- SS3** **NWI: Broad-Leaved Evergreen** – “In the Palustrine System, the broadleaved evergreen species are typically found on organic soils. Northern representatives are labrador tea (*Ledum groenlandicum*), bog rosemary (*Andromeda polifolia* L.), bog laurel (*Kalmia polifolia*), and the semi-evergreen, leatherleaf (*Chamaedaphne calyculata*)” (FGDC 2013).
- SS4** **NWI: Needle-leaved Evergreen** – “In this Subclass, needle-leaved evergreen species have the greatest areal coverage within the shrub layer. Examples of Dominance Types include young or stunted black spruce (*Picea mariana*) and pond pine (*Pinus serotina*)” (FGDC 2013).
- SS5** **NWI: Dead** – “This Subclass includes stands of dead woody plants less than 6 m tall, regardless of their density, with less than 30 percent cover of living vegetation. If living vegetation equals or exceeds 30 percent in such stands, the Class and Subclass are based on the dominant life form of the living plants” (FGDC 2013).
- SS6** **NWI: Deciduous** - Not typically used, equivalent to SS1.
- SS7*** **NWI: Evergreen** - Redundant with “SS4”, not used

WWI Proposed Replacement: Mixed needle-leaved evergreen & deciduous conifers - In split-subclass shrub-dominated wetlands - especially muskegs - there are often significant proportions of both deciduous conifers (tamarack), evergreen conifers, and broadleaf evergreens present. This subclass improves descriptive accuracy by recognizing the co-dominance of stunted tamarack and evergreen conifers set within a matrix of broadleaf ericaceous shrubs or emergents. This subclass is used if estimated coverage of tamarack or needle-leaved conifers exceeds 10%, with a combined total of at least 30%. This subclass generalizes to “SS2” or “SS4” depending on which subclass appears to cover more basal area, however the default generalization is “SS4”.

- SS8*** **WWI Proposed: Alder (or “Tag” Alder), *Alnus incana*** – *Alnus incana* occurs with increasingly frequency north of the tension zone, where large alder thickets form in association with minerotrophic hydrology. This subclass is used where alder (*Alnus incana*) is assumed to comprise at least 30% of the shrub layer. Alder may be co-dominant with other forest, shrub-scrub, or emergent subclasses, but should not be combined with “SS1” due to the unreliability of distinguishing mixed stands of alder and other deciduous shrubs. Reliable photointerpretation of this subclass requires high-quality uncompressed 6” leaf-off imagery where its characteristic dark bark and upright growth form can be seen. This subclass generalizes to “SS1”.
- SS9*** **WWI Proposed: Buckthorn Thicket, *Rhamnus cathartica* and *Frangula alnus*** – Buckthorn thickets have only recently been recognized as a widespread, growing disturbance community. In this subclass, common buckthorn (*Rhamnus cathartica*) and glossy buckthorn (*Frangula alnus*) comprise at least 30% coverage of the shrub strata. Practically speaking, buckthorn needs to be present in higher percent covers to be photo interpretable. In dense thickets, there is often exposed, oxidizing muck from the lack of undergrowth, which combined with dark-barked shrubs creates a distinct aerial signature on leaf-off imagery. This subclass generalizes to “SS1”.

Established and Proposed* Forested Wetland Subclasses & Attribute Codes

Forested “FO” Class overview “In Forested Wetlands, trees are the dominant life form—i.e., the tallest life form with at least 30 percent areal coverage. Trees are defined as woody plants at least 6 m (20 ft) in height” (FGDC 2013).

- FO1** **NWI: Broad-leaved deciduous** – “In this Subclass, broad-leaved deciduous species have the greatest areal coverage in the tree layer. Broad-leaved Deciduous Forested Wetlands, which are represented throughout the United States, are most common in the South and East. Common Dominance Types include red maple, American elm (*Ulmus americana*), ashes (*Fraxinus pennsylvanica* and *F. nigra*), black gum (*Nyssa sylvatica*), tupelo gum (*N. aquatica*), swamp white oak (*Quercus bicolor*), overcup oak (*Q. lyrata*), and swamp chestnut oak (*Q. michauxii*). Wetlands in this Subclass generally occur on mineral soils or highly decomposed organic soils (FGDC 2013).”
- FO2** **NWI: Needle Leaved Deciduous** – In this Subclass, needle-leaved deciduous species have the greatest areal coverage in the tree layer...Tamarack is characteristic of the Boreal Forest Region, where it occurs as a dominant on organic soils. Relatively few other species are included in this Subclass” (FGDC 2013)
- FO3** **NWI: Broad-Leaved Evergreen** – *No broad-leaved evergreen trees grow in Wisconsin.*

- FO4 NWI: Needle-leaved Evergreen** – “In this Subclass, needle-leaved evergreen species have the greatest areal coverage in the tree layer. Black spruce, growing on nutrient-poor organic soils, represents a major dominant of the Needle-leaved Evergreen Subclass in the North. Eastern arborvitae (*Thuja occidentalis*) dominates northern wetlands on more nutrient rich sites” (FGDC 2013).
- FO5 NWI: Dead** – “This Subclass includes stands of dead woody plants at least 6 m tall, regardless of their density, with less than 30 percent cover of living vegetation. If living vegetation equals or exceeds 30 percent in such stands, the Class and Subclass are based on the dominant life form of the living plants. Dead Forested Wetlands usually are produced by a prolonged rise in the water level resulting from impoundment by humans or beavers” (FGDC 2013).
- FO6 NWI: Deciduous** (Standard NWI) - *Redundant with FO1, not used.*
- FO7* NWI: Evergreen** – *Redundant with “FO4”, not normally used*

WWI Proposed Replacement: Mixed needle-leaved evergreen & deciduous conifers

WWI Definition - In forested wetlands split between emergent or scrub-shrub classes, significant proportions of both deciduous conifers (tamarack) and evergreen conifers may be present. This subclass improves descriptive accuracy by recognizing the co-dominance of tamarack and evergreen conifers set within a matrix of broadleaf ericaceous shrubs or emergents. Use this subclass if estimated coverage of tamarack or needle-leaved conifers ranges from 30-70%, with individual proportions of at least 15%. This subclass generalizes to “FO2” or “FO4” depending on which subclass appears to cover more basal area. An additional attribute number is required to make this generalization.

- FO8* WWI Proposed: White Cedar (*Thuja occidentalis*)** – White Cedars, when present in well-developed stands with areal coverage above 30%, are indicators of ecologically distinct wetland communities fed by calcareous soils and/or groundwater. White cedars dominate a small fraction of Wisconsin’s total wetland area but provide habitat for many species of concern. This indication of conservation value and ecological distinctness merits separation from the black spruce and pine dominated communities that they would otherwise be lumped under which tend to form under acidic conditions. This subclass generalizes to “FO4”.X

Established and Proposed* Special Modifiers & Attribute Codes

All proposed WWI Special Modifiers are stored after a period in the attribute string and are stripped from the NWI attribute. A handful of proposed WWI modifiers are carry-overs from the WWI Classification System, while the remainder are new additions.

- a Acid** – Water pH <5.5. This special modifier should be used on lakes and ponds that are surrounded by sphagnum bogs, black spruce, and/or tamarack swamps.
- b Beaver** – “These wetlands have been created or modified by beaver (*Castor canadensis*). Dam building by beaver may increase the size of existing wetlands or create small impoundments that are easily identified on aerial imagery. Such flooding frequently creates Dead Forested or Dead

Scrub-Shrub Wetland initially, followed in a few years by Aquatic Bed and Emergent Wetland” (FGDC 2013).

- c*** **Abandoned Ag Land - WWI Definition** – Areas which appear to have been cultivated in the past, but which have since been abandoned from cultivation and have reverted to wetland vegetation.
- d** **Partially Drained/Ditched** – “A partly drained wetland has been altered hydrologically, but soil moisture is still sufficient to support hydrophytes. Drained areas that can no longer support hydrophytes are not considered wetland. This Modifier is also used to identify wetlands containing, or connected to, ditches. The Partly Drained/Ditched Modifier can be applied even if the ditches are too small to delineate. The Excavated Modifier should be used to identify ditches that are large enough to delineate as separate features; however, the Partly Drained/Ditched Modifier also should be applied to the wetland area affected by the ditching” (FGDC 2013).
- e*** **Ephemeral Pond - WWI Definition** – Applies to small, closed, seasonally-flooded depressional wetlands with standing water observed in one or more years of photography. Requires "C" Hydro modifier.
- f** **Farmed** – “Farmed wetlands occur where the soil surface has been mechanically or physically altered for production of crops, but where hydrophytes would become reestablished if the farming were discontinued. Farmed wetlands should be classified as Palustrine-Farmed. Cultivated cranberry bogs may be classified Palustrine-Farmed or Palustrine Scrub-Shrub Wetland-Farmed” (FGDC 2013).
- g** **Organic Soils** – “A soil is classified as an organic soil (Histosols) if more than half of the upper 80 cm (32 inches) of the soil is organic or if organic soil material of any thickness rests on rock or on fragmental material having interstices filled with organic matter” (Soil Survey Staff 1999).
- h** **Diked/Impounded** – “These wetlands have been created or modified by a man-made barrier or dam that obstructs the inflow or outflow of water” (FGDC 2013).
- i*** **Alkaline** – pH > 7.4. This special modifier should primarily be used on hard-water lakes where water chemistry data is known.

***WWI Refined Definition** – This modifier may also be applied to sedge (“EM3”) and shrub-dominated communities where calcareous fens are known to exist. In this case, place the attribute after the NWI special modifier (most likely “g”) in the “WWI” special modifier place.
- j*** **Reconstructed Wetland - WWI Definition** – Used to indicate areas where hydric conditions have been restored to previously fully-drained former wetlands.
- k*** **Restored Wetland – WWI Definition** – Used to indicate where previously extant, partially drained or fully impounded wetlands have been restored in a manner that re-approximates the pre-settlement hydrology under which they formed. This could apply to wetlands where ditch fills were performed, cultivated cranberry bogs are reclaimed, or dikes and water control structures are removed. This special modifier does not apply to areas that have been diked/impounded (“h”) to create open water within formerly emergent wetlands, nor does it apply to artificial (“r”) or Reconstructed (“j”) wetlands.

- l*** **Channelized Streams and Rivers - WWI Definition** – Used to indicate streams and rivers that naturally existed on the landscape historically but were excavated and straightened by human activity. This modifier stands in contrast to excavated drainage ditches (“x”) which have no natural, historic analog.
- m** **Managed** – “This modifier is used to identify wetlands where water inputs are controlled to achieve a specific water regime or habitat type. Water control structures in combination with dikes and impoundments are common” (FGDC 2013).
- n** **Mineral Soil** – Any soil that falls below the organic content criterion outlined for organic soil, “g”.
- o*** **Artificial Wetland - WWI Definition** – Used to indicate wetlands which appear to be constructed/engineered in areas that lack wetland presence prior to 1991 and hydrophytic vegetation may be present as the result of human modification to the landscape. These wetlands are likely, but not guaranteed, to fall under the scope of Section 21 281.36(4n) in Act 183 exemption for “artificial wetlands”.
- p*** **Pastured/Grazed - WWI Definition** – Wetlands which are used for pasturing domesticated animals.
- q*** **Ruderal Vegetation - WWI Definition** – Wetlands dominated by one or more species of non-native plants which do not fit within any described subclass or where any one dominant exotic species subclass fails to reach 30% cover. May apply to vegetated classes within the palustrine or lacustrine systems. Dominant plant species in ruderal communities include non-native tree willows, boxelder, common buckthorn and glossy buckthorn, honeysuckle, giant ragweed, purple loosestrife, and stinging nettle. Ruderal wetlands tend to receive frequent disturbance from various sources and/or have experienced intense historic disturbance.
- r** **Artificial Substrate** – “This Modifier describes concrete-lined drainageways, as well as Rock Bottom, Unconsolidated Bottom, Rocky Shore and Unconsolidated Shore where the substrate material has been emplaced by humans. Jetties and breakwaters are examples of Artificial Rocky Shores” (FGDC 2013). Farmed cranberry is another common example of Artificial Substrate.
- s** **Spoil** – “The Spoil Modifier is used to describe wetlands where deposition of spoil material forms the primary substrate type. By definition, spoil is material that has been excavated and emplaced by humans. Ancillary data may be needed to accurately identify spoil in areas such as reclaimed strip mines that have become revegetated” (FGDC 2013).
- t** **Circumneutral** – pH 5.5-7.4. This special attribute is typically not applied except for very limited special applications where lake water chemistry data is known.
- u*** **Ridge and Swale Complex - WWI Definition** – “This landform occurs mainly along the Lake Michigan coast, where narrow beach ridges (strand lines) were formed parallel to the shore as the water in lake Michigan receded during post-glacial times. Depressions (swales) between the beach ridges contain wetland vegetation, but the ridge themselves are dry. This complex is used to indicate areas where the swales are too small to delineate individually.” This attribute also indicates a type of “Rare and high-quality wetland.”

- v*** **Vegetation Recently Removed - WWI Definition** – Used to indicate areas where the vegetation has been recently totally or partially removed by clearing, shearing, logging or other means.
- w*** **Floodplain Complex - WWI Definition** – This modifier describes the floodplains of rivers and streams which are composed of small areas of seasonally flooded wetlands, wet meanders scars, oxbow lakes, and or small inclusions of upland, all of which are too small to delineate individually.
- x** **Excavated** – “This Modifier is used to identify wetland basins or channels that were excavated by humans” (FGDC 2013). This modifier may apply to open water and aquatic bed classes as well as the emergent class where vegetation has grown over the excavated area.
- y*** **Glacial Lake Plain Complex – WWI Definition** – This modifier is reserved for complex, extremely difficult-to-map former glacial lake plains where estimated wetland coverage is greater than 75% and upland inclusions are less than 1/10th of an acre. In these cases, subtle topography makes delineation of wetlands and upland inclusions extremely challenging and impractical.

Proposed Non-wetland Standalone Special Modifiers & Attribute Codes

These modifiers are used to attribute non-wetland features that are created for maintaining spatial and hydrologic relationships between connected and formerly connected wetlands on the landscape.

- \$** **Filled Wetland - WWI Definition** – Used to indicate areas where wetlands were filled due to roadbuilding, building construction, or other human activities - historically or recently. These features will be dropped completely from NWI maps and may be retained for internal use.
- &** **Fully Drained Wetland (special use only) - WWI Definition** – Used to indicate areas of formerly hydric soils which are now fully drained as to no longer support hydric vegetation or qualify as a wetland under most commonly accepted definitions. While not practical for inclusion in routine statewide mapping, this symbol is reserved for special applications like watershed modeling, manual interpretation of potentially restorable wetlands, long-term trend assessment, and others where it may be important to account for the lost services and spatial relationships of fully drained wetlands within the landscape.

Appendix C: Strategy for Assessing the Feasibility of Producing a Statewide Combined Wetland and Surface Water GIS Layer

Christopher Noll, last updated 7/1/2020

Background: The WWI's FY2016 EPA Wetland Program Development Grant designated funds for a pilot mapping study to "design, test, and evaluate a process to map wetlands and surface waters in tandem from the same data surfaces, to produce a single Integrated Surface Waters and Wetlands GIS Layer." Part of the evaluation process required a feasibility assessment for resources required to remap the entire state.

Study Area

The study area encompasses all counties within Wisconsin that have usable (typically 2010 onward) lidar data.

Spatial Unit of Assessment

The base unit area of assessment consists of PLSS sections (generally consistent 1 sq mile squares). The target population was all PLSS sections within Wisconsin that intersect at least one wetland polygon from the current NWI 2.0 geodatabase. The choice was made to use NWI 2.0 over the current WWI dataset because it better approximates the intended final product by combining existing WWI polygons, points, and hydrography features into an all-polygon layer.

Sampling Strategy

Because Wetland density varies widely across Wisconsin's landscapes, and wetland-dense areas tend to take longer to map than drier areas, the whole spectrum from dry to wet needed to be accounted for to create accurate time and cost estimates. Because of this, we stratified our sample according to the following percent cover of wetland area to ensure even coverage along the density spectrum.

Low Density Sections = 0-21.3% wetland cover

Medium Density Sections = 21.4 – 58.8% wetland cover

High Density Sections = over 58.9% wetland Cover

To create these categories, PLSS Sections were intersected with NWI 2.0 wetland and surface water polygons, and for each section a percent cover was tabulated. Sections with 0% cover were excluded. The remaining sections on list were sorted by increasing percent cover, then divided equally into low, medium, or high.

From each low, medium, and high category, 51 sections were drawn at random. Of these 51 sections, three cartographers (Cal Lawrence, Chris Noll, and Chris Smith) were assigned 17 sections at random. Each cartographer was responsible for completing GIS data production in at least 10 of these sections. Each cartographer worked their way sequentially through the list of sections for each density category. If a section happened to be surrounded by a lake or deviated in area more than 10% from one square mile, that section was dropped and the next one on the list taken.

Metrics of Performance

Each cartographer drafted GIS data using a geodatabase that enabled time tracking of polygon feature creation and editing from start to finish by automatically populating two fields - “First Edit Time” and “Last Edit Time”- on each feature created. Additionally, time was manually tracked through an excel based spreadsheet recorded as total minutes. Each section started will be finished before moving on to the next one to ensure a consistent measure of time.

Preliminary Results

Several analyses using regression plots normalized to existing NWI 2.0 data will be ready by the time of the final grant delivery to create more accurate projections for the resources needed for remapping the state with integrated surface waters and wetlands. In the meantime, the following values can be used to summarize the results.

Across 113 square miles of Wisconsin and three mappers working independently to draft new maps using the updated methodology, the average amount of time taken to remap a PLSS Section was 114 minutes per square mile. The average wetland density of the re-mapped area was 36.4%.

If all variables held steady and were extrapolated to remapping the entire state (65,556 sq miles), roughly 124,556 hours of labor would be required to remap Wisconsin’s wetlands and surface waters. Assuming a rough figure of \$45/hour total labor cost, this would bring the cost of the total effort to \$5.6 million.

It must be noted that this is likely a high-end estimate which does not consider a number of confounding factors such as improvements in cartographer skill level over time, efficiency gained through further refinements in methodology, and technological advances in GIS tools like AI-based image classification that are just beginning to reach the GIS world. However, the data captured also did not account for productivity lost to essential tasks such as administrative tasks, obtaining data, running full QA/QC, and coordination & outreach with partners. A more in-depth analysis of the feasibility data will be included in the grant deliverables for the EPA in late fall of 2020.

Appendix D: WWI 2K Geodatabase Fields

WWI_ATTRIBUTE

Alias: None

Type: Text

Description: : The Wisconsin Wetland Inventory (WWI) attribution schema for all new wetland mapping is largely defined in the National Wetland Inventory ([NWI](#)) "[Classification of Wetlands and Deepwater Habitats of the United States](#)" ([FGDC 2013](#)), an updated version of the document originally published by Cowardin et. al 1979.

In addition to terms and conventions outlined by the FGDC (2013), the WWI **has defined** state-specific subclasses and special modifiers to improve separation of dominant vegetation cover types and land uses to add extra value to WDNR-produced WWI data. These added classifications are defined in "Appendix B" of the [WWI SOP](#) document and are designed to fit within the Cowardin framework.

To ensure compatibility with base NWI Cowardin Classification, two attribute columns are maintained.

"WWI_ATTRIBUTE" may contain WWI-specific attributes while "NWI_ATTRIBUTE" adheres to the rules and definitions set by the National Wetland Inventory , for the generalized NWI polygon attributes. Whether an enhanced set of WWI Attributes were applied during map production is indicated in the "**ENHANCED_WWI_ATTRIBUTION**" field.

Often, WWI and NWI attributes are identical, but sometimes appear differently where certain subclass special modifiers are concerned. WWI-specific attributes are stripped from data before submitting to the NWI to maintain compatibility with the national standard.

WETLAND_TYPE

Alias: None

Type: Text

Description Simplistic description of wetland polygon based on the [Wetlands and Deepwater Habitats Classification diagram and Wisconsin-specific attribution](#). Describes System, Subsystem, Class, Subclass, Water Regime, and any special modifiers like water chemistry, soil makeup and/or land use.

NWI_ATTRIBUTE

Alias: None

Type: Text

Description: Wetland classification defined by the National Wetland Inventory

ACRES

Alias: None

Type: Double Precision Numeric

Description: Represents polygon size in acres.

ENHANCED_WWI_ATTRIBUTION

Alias: *ENHANCED_WWI*

Type: Text

Format: All capitalized

Domain: FULL, PARTIAL, NONE

Description: This field describes to what degree the map producer applied enhanced, WWI-specific attribution to newly drafted features. "FULL" assumes all Wisconsin specific subclasses and sub modifiers described in the WWI SOP were applied. "Partial" implies that a subset of these sub modifiers was used, and more information can be found in the metadata for the project area. "NONE" indicates that no Wisconsin specific attributes were used, and all fields will be equivalent to the NWI attribute.

METADATA_LINK

Alias: None

Type: Text

Format: URL text link

Description: URL link to PDF file containing pertinent metadata for the Wisconsin Wetland Inventory mapping project area.

ORIG_HRZ_COLL_NAME

Alias: *CARTOGRAPHER*

Type: Text

Format: All capitalized

Description: User-Id(s) of Wisconsin DNR personnel or acronym of external entity who created the GIS data.

ORIG_HRZ_COLL_DATE

Alias: *ORIG_MAPPING_DATE*

Type: Date

Format: MO/DY/YEAR

Description: Date in which the wetland polygon was created.

ORIG_HRZ_SRC_YEAR_LIDAR

Alias: *LIDAR_YEAR*

Type: Long Integer

Description: Year of LiDAR collection. This is the source dataset used to create the bare earth digital elevation model used for mapping.

ORIG_HRZ_IMG_RSLN_AMT_DEM

Alias: *DEM_CELL_SIZE*

Type: Short Integer

Description: Raster pixel size of LiDAR derived bare earth digital elevation model used for vectorization.

ORIG_HRZ_IMG_RSLN_UNITS_DEM

Alias: *DEM_UNITS*

Type: Text

Format: All capitalized

Domain: FT (Feet), MT (Meters), CM (Centimeters)

Description: Units of LiDAR derived bare earth digital elevation model used for vectorization.

ORIG_HRZ_SRC_YEAR_DOP

Alias: *DOP_YEAR*

Type: Long Integer

Description: Year that the source leaf-off digital imagery from which the feature's horizontal location was originally collected, was created, published, updated, revised, flown, etc.

ORIG_HRZ_IMG_RSLN_AMT_DOP

Alias: *DOP_RESOLUTION*

Type: Short Integer

Description: Pixel size of digital orthophotography.

ORIG_HRZ_IMG_RSLN_UNITS_DOP

Alias: *DOP_UNITS*

Type: Text

Format: All uppercase

Domain: IN (Inch), FT (Feet), MT (Meters), CM (Centimeters)

Description: Units of digital orthophotography

ORIG_HRZ_SRC_DNOM_AMT

Alias: *NOMINAL_MAPPING_SCALE*

Type: Long Integer

Description: Nominal scale denominator at which wetland features were mapped. Example: 2000 for 1:2000 scale. NWI standards are 1:5000.

LAST_UPDATE_EDITOR

Alias: *LAST_EDITOR*

Type: Text

Format: All uppercase

Description: User-Id of Wisconsin DNR personnel or acronym of external entity who last altered wetland polygon.

LAST_UPDATE_DATE

Alias: None

Type: Date

Format: MO/DY/YEAR

Description: Date in which the wetland polygon was last altered.

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