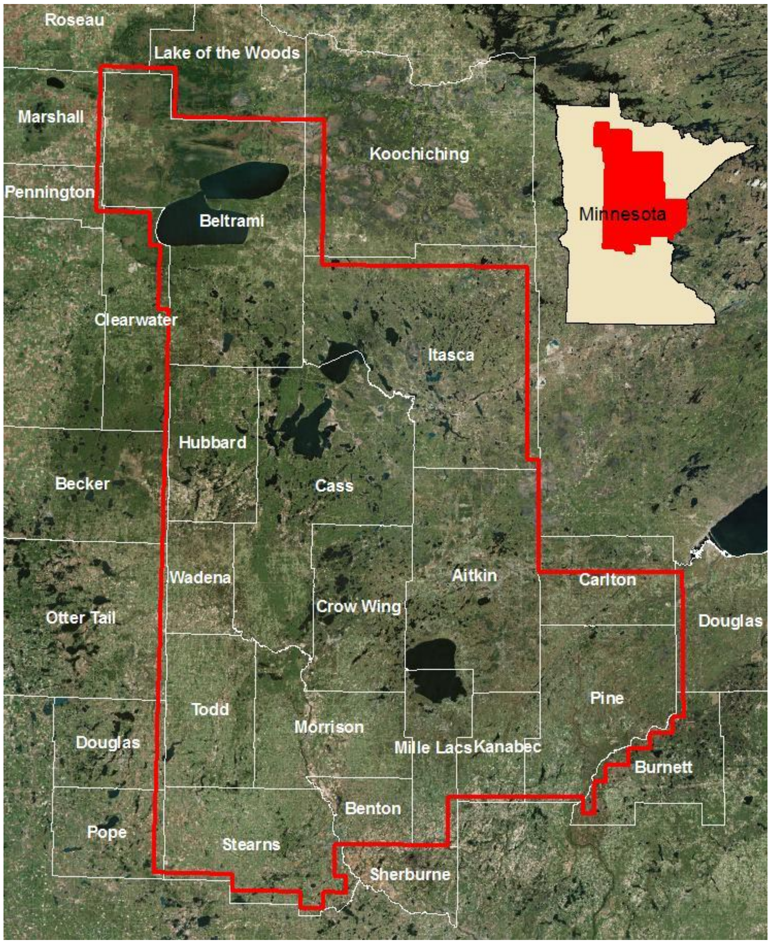
# Technical Procedures for Updating the National Wetland Inventory for Minnesota

## Central Project Area

July 27, 2018




**Ducks Unlimited, Inc.**

1220 Eisenhower Place
Ann Arbor, MI 48108–3281
USA

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# 1.0 PROJECT SPECIFICATIONS

## 1.1 Project Area

The project area includes all or part of the following counties in Minnesota: Aitkin, Becker, Beltrami, Benton, Carlton, Cass, Clearwater, Crow Wing, Douglas, Hubbard, Itasca, Kanabec, Koochiching, Lake of the Woods, Marshall, Mille Lacs, Morrison, Otter Tail, Pennington, Pine, Pope, Roseau, Stearns, Todd and Wadena (Figure 1). A small portion of both Burnett and Douglas Counties of Wisconsin are also included in the Central Minnesota project area. The project area consists of 1,588 USGS quarter quadrangles with an area of approximately 20,300 square miles.

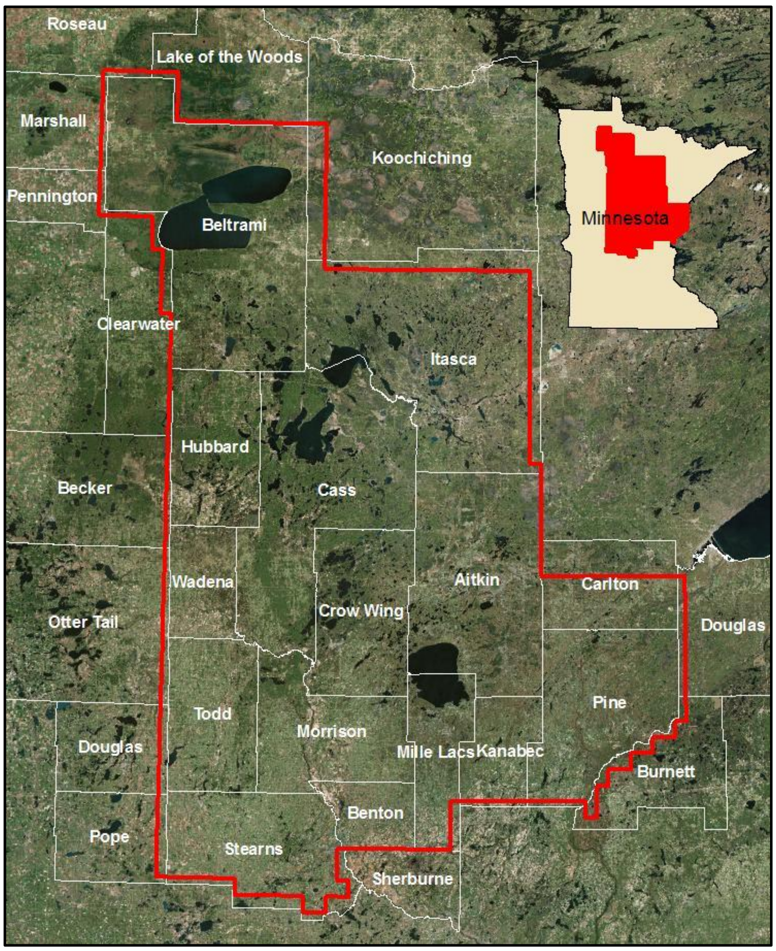



**Figure 1. The Central Minnesota NWI Update project area.**

## 1.2 Project Requirements

### 1.2.1 Deliverables

(1) A preliminary technical procedures document describing standard operating procedures for wetland delineation and classification as well as quality assurance procedures shall be submitted for review and approval prior to initiating work on the wetland inventory update.

(2) A final version of the technical procedures document incorporating any procedural changes that occur during the project shall be submitted upon project completion.

(3) Draft data will be submitted as a GIS data layer using a modified USGS 24k quadrangle tiling scheme (Figure 2).

(4) Two copies of the final data must be submitted in a single seamless GIS data layer with metadata provided on portable hard drives or other such media as deemed acceptable by the State. One copy shall use the Minnesota standard geographic data project (UTM-15N, NAD83, meters) and the second copy shall use the USFWS standard geographic data projection (Albers Equal Area Conic Projection, NAD83, meters).

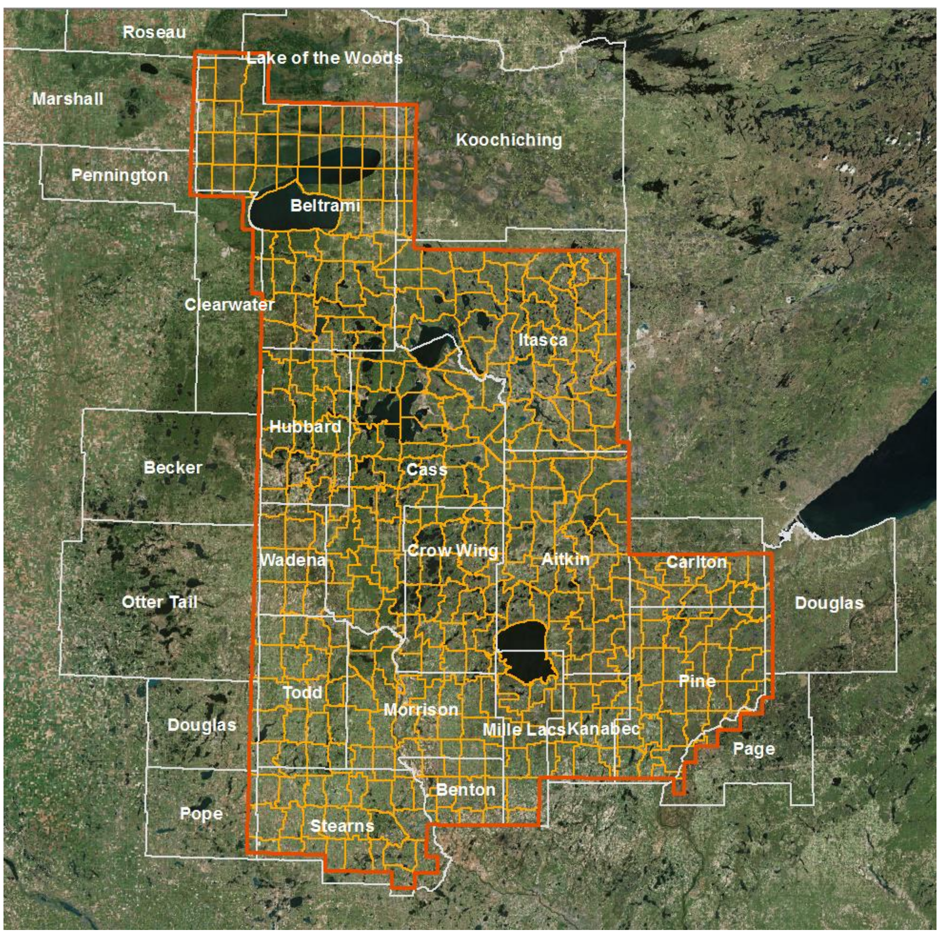



**Figure 2. Map of the** modified USGS 24k quadrangle **tiling scheme.**

### 1.2.2 Data Format

ESRI ArcGIS File Geodatabase, polygons

### 1.2.3 Projection

UTM-15N, NAD83, meters and Albers Equal Area Conic Projection, NAD83, meters

### 1.2.4 Classification

Wetlands will be mapped and classified according to Cowardin et al. (1979) including the system, subsystem, class, sub-class, water regime, and special modifiers. Detailed information on valid codes for the Minnesota NWI is available in a guidance document posted on the DNR ftp server (ftp://ftp.dnr.state.mn.us/pub/eco/nwi/MappingGuidance/).

### 1.2.5 Target Mapping Unit

Wetlands >½-acre in area are subject to the accuracy assessment goals; however, wetlands smaller than ½-acre that are visible at 1:6000-scale will be mapped. Long-narrow wetlands wider than 15-feet are included in the assessment of the target map unit.

### 1.2.6 Quality Assurance and Quality Control (QA/QC)

Ducks Unlimited (DU) will conduct an internal quality control check on all mapped data prior to submission. The data will be checked for completeness, accuracy, logical consistency, edge-matching, and attribute validity. DU will submit a work plan for approval that includes a description of their internal quality control procedures prior to commencing work. This quality control review will include a visual inspection of all data by a senior image analyst (or equivalent). A secondary review of the draft data will be provided by the State with feedback provided to the vendor prior to creation of the final seamless data layer. The USFWS QA tools will be also incorporated into the DU's process (http://www.fws.gov/wetlands/data/Tools-Forms.html). The State will conduct a final validation of the data with an independently acquired dataset to ensure compliance with the performance criteria contained herein.

### 1.2.7 Horizontal Accuracy

Wetland boundaries will be coincident with the base imagery. This means that 95% of well-defined boundaries (e.g. water-land boundaries) shall occur within 20 feet of the boundary position on the base imagery. This requirement is consistent with the National Map Accuracy Standard for a map with a scale of 1:6000.

### 1.2.8 Classification Accuracy

The classification accuracy should meet the goals set forth in the Federal Geographic Data Commission (FGDC) wetland mapping standard. These accuracy goals include a producer's accuracy ≥98% for wetland features (>½-acre) that are visible on the imagery and an overall classification accuracy ≥85% for the Cowardin class level. At a minimum, the final wetland maps will have user's, producer's, and overall accuracies ≥93% for wetland-upland discrimination. Cowardin class-level accuracy will be ≥80%. Accuracy evaluation will be conducted by comparing wetland maps to a set of validation points developed from an independent analysis conducted by the State and the University of Minnesota. Results from this analysis will be included in the final metadata by the State.

### 1.2.9 Cartographic Standards

Features and boundary lines should be represented with a level of detail that is appropriate for the desired use scale of 1:6000. Features smaller than 1/20th of an acre will not be mapped. Features that are smaller than 1/20th of an acre should be incorporated into the predominant adjacent class. Upland features are not mapped. The boundary lines for wetland features should not have an excessive number of vertices or have a jagged, saw-toothed appearance. As a guideline, the average distance between vertices composing the feature boundary will be at least 10 feet (1/50th of an inch at a map scale of 1:6000).

### 1.2.10 Data Verification

The data will be logically consistent and topologically complete. The data will be complete polygons with no overlaps and no gaps between adjacent polygons. The final data will be edge-matched across tile boundaries into a seamless coverage. Boundaries will be edge-matched to data for areas adjacent to the project area. Wetland classification attributes will be checked to ensure that only valid attributes are used.

### 1.2.11 Metadata Information

Metadata for this project shall meet the requirements of the Minnesota Geographic Metadata Guidelines. Metadata information will include a tested classification accuracy statement, an error matrix, a full description of the data lineage, and spatial reference information (http://www.mngeo.state.mn.us/chouse/meta.html).

### 1.2.12 Time Line

Draft data will be submitted as it is developed for the State's review. The State will make every effort to ensure that draft data are reviewed in a timely manner. All deliverables will be complete and delivered for the State's final QA/QC review according to the timeline listed for the deliverables in Section 3.

### 1.2.13 Documentation

DU will fully document its mapping methods and provide the documentation to the State for approval. Any substantial method changes will require an update to the documentation and must be approved by the State.

### 1.2.14 Training

DU will ensure that all personnel working on this project have adequate training and ensure that training records are kept on file for the State to review if necessary. Photo-interpreters will demonstrate proficiency in wetland mapping prior to conducting work on this project. Training will be consistent with "Classification of Wetland and Deepwater Habitats of the United States" (Cowardin et al.1979).

### 1.2.15 Data Management

DU will establish and maintain a system to manage input data, intermediate products, and final wetland maps in a secure manner with provision for data backup.  The input data may be voluminous. DU will maintain a copy of the data for at least one year after the completion of the project.

### 1.2.16 Simplified Plant Community Classification

In addition to the attributes required for the basic NWI update, an additional attribute will be included to describe the wetland plant community based on a modified version of the Eggers and Reed classification system. These attributes are described in a supplemental guidance posted at (ftp://ftp.dnr.state.mn.us/pub/eco/nwi/MappingGuidance/). Most classes in the simplified plant community classification system can be determined directly from the Cowardin classification data, but bog wetlands will require an additional special modifier to complete the cross-walk between the two classification systems.

### 1.2.17 Simplified Hydro-Geomorphic Classification

In addition to the attributes for the basic NWI update, the classification will include an additional set of attributes to describe the hydro-geomorphic setting of wetlands based on a modified version of the LLWW system. The simplified hydro-geomorphic classification system is described in a supplemental guidance document posted here: ftp://ftp.dnr.state.mn.us/pub/eco/nwi/MappingGuidance/.

# 2. PROJECT TASKS

## 2.1 Project Organizational Structure

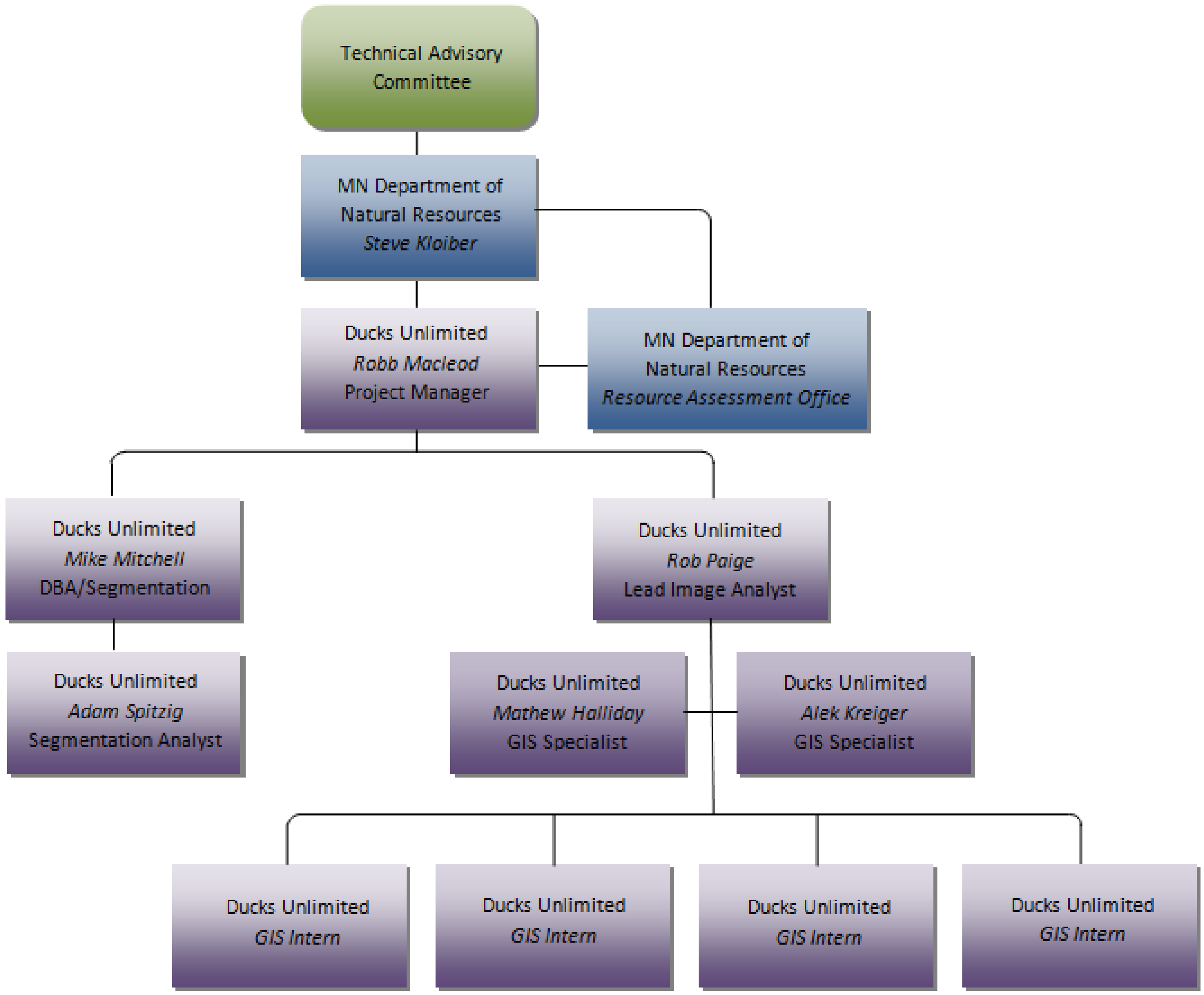



**Figure 3. Hierarchal structure of project organization.**

## 2.1 Technical Documentation and Meeting

DU will prepare a technical document that details the mapping methods and work flow for approval by the MN DNR. In addition, a meeting will be held to review methods, finalize data transfer techniques and data management, and begin project coordination. The technical documentation will be updated periodically throughout the term of the project. Once the NWI update for the Central project area is approved by the MN DNR, a final report will be created detailing the final mapping methods. Metadata compliant with the requirements of the Minnesota Geographic Metadata Guidelines will be created and incorporated into the final geodatabase. Both documents will be submitted to the MN DNR for review.

## 2.2 Data Gathering

All data will be imported into DU's ArcSDE geodatabase for use in the photo interpretation process. Data will be transferred between the MN DNR Resource Assessment Office (RA) and DU through a file transfer protocol (FTP) site, Dropbox (or similar) or the shipping of physical hard drives (depending on the size of the data being transferred). The LiDAR data will be processed by RA and transferred to DU for incorporation into the segmentation process.

### 2.2.1 Primary data layers

The primary data layers will be used in creating the segmentation and the photo interpretation process.

Seamless updated NWI – A seamless NWI geodatabase was created for the east-central and northeastern project areas. This same geodatabase will be utilized to incorporate the final updated NWI for the Central project area.

Spring digital orthophotos – The primary image data set for the Central MN NWI update is the State acquired 0.5-meter or 1-foot resolution digital imagery for the entire Central MN project area in spring 2013 or 2014. The imagery is 4-band, digital ortho quarter quads (DOQQs), spring leaf-off aerial imagery. This imagery is also available in stereo format.

LiDAR data – LiDAR is an active remote sensing technology that operates on the power of laser light to detect and measure surface features on the earth. This data is particularly valuable for representing the topographical variation across a landscape. LiDAR data is available for the entire project area at a spatial resolution of 3 meters.

Lake Bathymetric (DEM) – This layer is not available for all lakes, but will be used when available for the semi-automated delineation of the L1 and L2 wetland boundary within the segmentation process. The bathymetric data is available at https://gisdata.mn.gov/dataset/water-lake-bathymetry.

Lake Bathymetric (contours) – It includes many lakes not contained in the previously described bathymetric DEM dataset but coverage is still not exhaustive. This polyline layer will also be used in the semi-automated process to delineate the L1 and L2 boundary of lakes. (Same data source as lake bathymetric DEM.)

### 2.2.2 Ancillary data layers

The ancillary data layers will be used for creating the training data for assisting with the photo interpretation.

Summer digital orthophotos – State-wide summer aerial photos have been flown by the Farm Service Agency (FSA) National Agriculture Imagery Program (NAIP) in 2008, 2009, 2010, 2013 and 2015. The 2008, 2013 and 2015 imagery is 4-band, ortho-rectified imagery, while the 2009 and 2010 imagery is natural color (3-band), ortho-rectified imagery.

Fall Peak Color aerial photos – The MN DNR has flown fall peak color aerial photos (3-band natural color) for the project area (excluding Stearns County) that may be useful for interpreting forested wetlands.

USGS 1:24,000 DRG – The digital topographic maps from the USGS will be acquired and available for use in the classification process.

Original NWI – The FWS administers a seamless version of the original NWI as part of the National Map in an ArcSDE master geodatabase format. The importance of the original NWI should not be overlooked when making classification decisions. While the base imagery for the original NWI was not ideal for detailed wetland classification, it was accomplished with experienced photo interpreters using stereo pairs. This information can provide valuable historic information regarding the hydrologic regimes, classes and boundaries that can be used to inform the current classification process as long as the interpreter understands the limitations of the dataset.

SSURGO Soils – The Natural Resources Conservation Service (NRCS) produces soils maps in GIS format (SSURGO) from the original soil survey maps. These maps can be very useful in identifying wetlands using various combinations of attributes contained within the SSURGO database. The SSURGO database is available for most of the Central Minnesota project area. http://websoilsurvey.nrcs.usda.gov/DataAvailability/SoilDataAvailabilityMap.pdf

Native Plant Communities – This dataset contains results of the Minnesota Biological Survey (MBS), State Park land cover data, Forestry native plant community data, and Wildlife Management Areas land cover data. The MBS collects information on high-quality, native plant communities. The MBS locates higher quality native plant communities using aerial photo interpretation followed by field survey of selected sites. These native plant communities can be downloads in GIS format from the MN Geospatial Commons at https://gisdata.mn.gov/dataset/biota-dnr-native-plant-comm.

Wetland Restoration Sites – DU has a point file for all of its wetland restoration projects. This layer can be helpful in identifying newly created wetlands and determining wetland class.

Public Waters Inventory (PWI) Watercourse – The PWI is defined by the MN Rule and consists of both natural/naturalized streams and altered channels. Segments contained in the PWI will be included as stream features in the updated NWI for the Central Minnesota project area. See section 2.3.13 for more details.

### 2.2.3 Management data layers

Data layers will be created to help manage the project and inform the partners about the status.

NWI Status – In order to inform MN DNR of the NWI update progress, a boundary layer of the Photo Interpretation areas will be created and posted to an ArcServer web site. The layer will be color coded by update status (in progress, draft and completed).

Online shared documents – In order to track progress between RA and DU staff, a set of cloud based document files that are accessible to all project partners will be used to track the status of individual watersheds in the production workflow and to catalog quality and process control information.

## 2.3 Procedures

### 2.3.1 Overview

The NWI classification process for the Central Minnesota project area will consist of three basic steps: 1) creation of image segments (polygons) and 2) photo interpretation of the classified image segments, and 3) running the Simplified Plant Community Classification (SPCC) and simplified Hydro-Geomorphic classification (HGM) classification scripts. A detailed description of each of the steps is described in the sections below and outlined in Figure 4. The layerstack (multi-band image of the LiDAR, described in more detail below) and spring 4-band imagery are input into eCognition software (Trimble 2015) to create the image segments. Topology is built for the image segments and any issues are corrected. Additional fields (e.g. attribute, comments, field verified) are added to the image segments for the photo interpretation process. Each of the segments is viewed, edited (e.g. merged with neighboring segments of the same class or cut to exclude an area), and assigned a final NWI classification using information from the previously described variety of image and data sources. Once an area is completed, it is run through a quality control process that checks for overlaps, gaps and approved NWI codes. The draft version of the NWI classification for the areas is sent to the MN DNR for review. A final draft version of the NWI is created from the comments and feedback from the MN DNR. The SPCC and HGM scripts are run to populate those classification attributes. The final step is to convert the final NWI geodatabase into the approved US FWS NWI format.

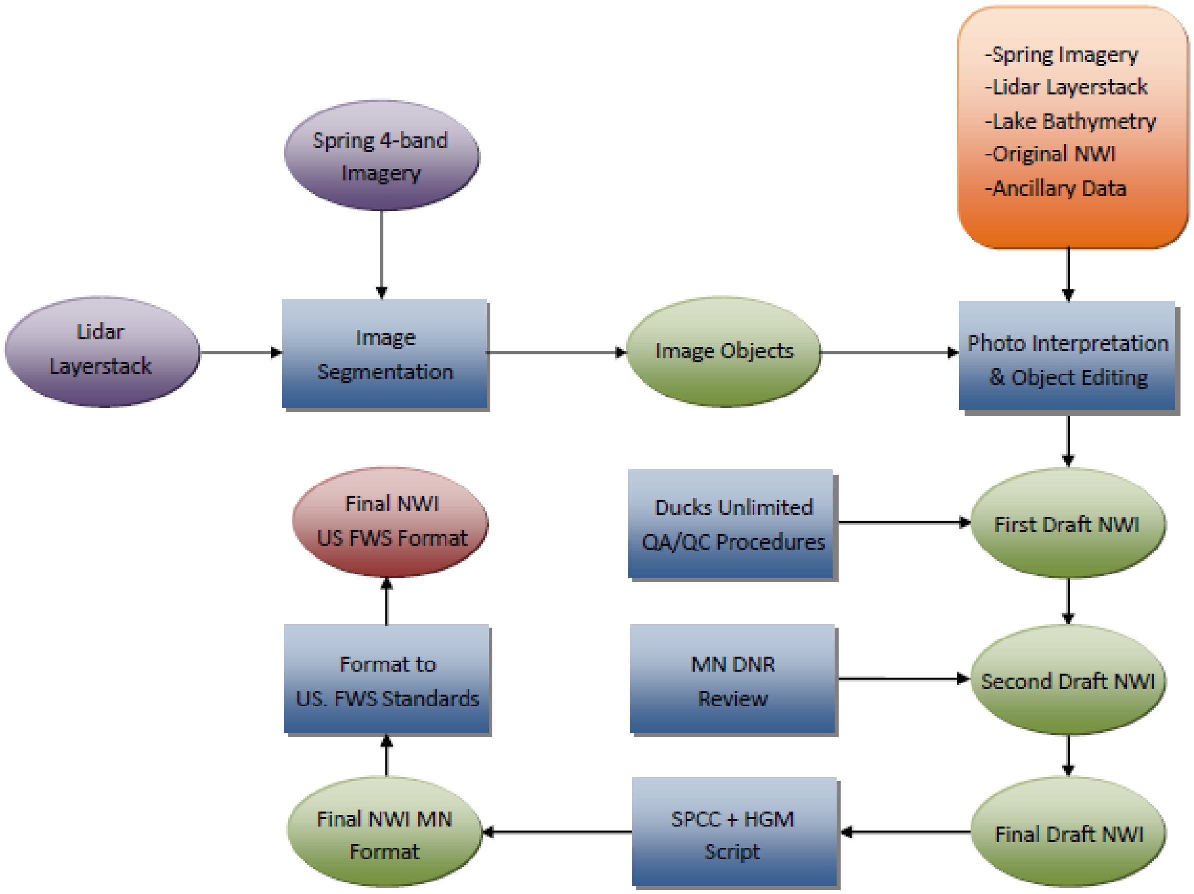



**Figure 4. Data Analysis Workflow.**

## 2.3.2 Data Management

This section describes the technical aspects of the data management for the project. For specifics on tracking the progress and status of the project, please see the project management section.

**Database**

ArcSDE Geodatabase – ArcSDE geodatabase allows the efficient storage and management of geographic information inside a database management system (DBMS). ArcSDE geodatabase leverages the underlying DBMS architecture to provide a centralized data storage, better data security, such as access permission control for individual datasets, distributed file management, backup/recovery capabilities, and data integrity. For this project, ArcSDE geodatabase will serve as the DU NWI master geodatabase (MGD) for primary and ancillary vector data.

Data Backup – Data for this project will be backed up to multiple locations at various stages during the process. After the segments are imported into the geo-database, the data is stored on an IBM storage array network (SAN) which has a snapshot backup feature and is backed up to tape nightly. During the photo interpretation stage the data is stored locally on interpreter's computers. At least once per day interpreter's backup their individual work to the network. When the initial photo interpretation is completed, the data for that completed photo interpretation area is also backed up. After a second interpreter has reviewed the data it is again backed up. After the lead analyst has completed QA/QC on the data it is backed up and appended into the ArcSDE MGD. The MGD has a full backup every weekend and differential backups every night. The MGD also is replicated to a file geodatabase stored on the SAN.

**Data Coordination**

Data coordination is an extremely important part of successfully completing this project within the timeframe allocated. Personal communication is the single most important part of this process. All organizations (RA and DU) that will be contributing to the Central project area have worked together successfully on the NWI update for the East-central and Northeastern project areas. Strong inter-personal communication between the organizations has paved the way for the success of these projects. In addition to the personal communication, an online tracking system will be implemented where the organizations can request processing of specific photo interpretation areas or suggest improvements to the segmentation process.

### 2.3.3 Data Analysis and Preparations for Segmentation

The primary purpose of the data analysis portion of this project is to develop an improved and repeatable methodology for updating NWI for Minnesota that utilizes the best available remotely sensed data and ancillary information. Manual interpretation of aerial photography was the key process used to create the original NWI and continues to be the primary mechanism underpinning current updates of the NWI in states outside of Minnesota (e.g. MI, IL, IN, OH, WI, and IA). Projects related to the NWI including the Status & Trends Program and the Minnesota Restorable Wetlands Inventory (RWI) also rely heavily on manual interpretation of digital aerial photography. In keeping with this tradition our proposed methodology for the MN NWI update project will be primarily based on using trained specialists to interpret the spring and summer digital aerial photography. Our analysis design calls for an analyst to make the final determination of validity for each wetland polygon that will be entered into the NWI update for Minnesota. Also in keeping with the original NWI and current related projects, analyst based interpretation will be the primary mode for all QA/QC operations and accuracy assessment.

It is also important to recognize that the technology and software for automated image analysis and pattern recognition has improved tremendously since the development of the original NWI database. We propose to incorporate several computationally-based image analysis techniques (image segmentation, data integration, machine learning algorithms) into the workflow for this NWI update in a manner that will support rather than supersede analyst based photo interpretation.

**SSURGO Analysis**

An ordinal map based on the predominant soil water regime (SSURGO soil map derivative) will be used as ancillary data in the NWI update for Central Minnesota. The variables included in the analysis to create the soil water regime map are those most likely to be related to wetland water regime (i.e., drainage class, flood frequency for April, pond frequency for April, and pond frequency for August). The drainage class, April flood frequency, April pond frequency, and August pond frequency fields are concatenated and the results sorted on the concatenated field. The resulting table includes water regime classes for all soil components. Map units may contain more than one component. Therefore, the data must be summarized to the map unit level. The water regime field is used as an indicator of wetness intensity from 0 to 8 with higher numbers indicating wetter, more permanent water regimes. This water regime index is used as a guide in the classification and photo interpretation process as the SSURGO soils data does not take into account anthropogenic changes such as tile draining.

### LiDAR Derived Layers

Several topographic metrics or indices can be derived from the LiDAR data. These derived metrics and indices potentially provide a greater ability to discriminate wetland from upland than the DEMs alone. These derivatives are described in the following sections and will be performed by the RA staff.

*Slope* - Slope represents the rate of change of the elevation for each digital elevation model (DEM) cell. Slope is normally output into degree or percent rise. However, the compound topographic index (CTI, as described below) has better results with the slope expressed in radians. Therefore, the slope will be calculated in degrees and converted to radians. Areas with low slope (flat areas) are more likely to be wetlands areas than areas with high slope.

*Topographic Position Index (TPI)* – TPI values provide a simple and powerful means to classify the landscape into morphological classes (Jenness 2005, Tagil and Jenness 2008). TPI is a simplification of the Landscape Position Index described by Fels and Zobel (1995) and developed by Weiss (2001). TPI for each cell is calculated by subtracting the mean elevation of its neighborhood from its own elevation value. A positive value indicates the pixel is higher than its neighbors, while a negative value indicates it is lower. This simple classification is a useful means of mapping topographic depressions. Groups of pixels with negative TPI scores represent such depressions, and are possible wetland locations. A DEM is the only data required to calculate TPI. Selecting appropriate neighborhood settings is an important part of the process. Selecting too small of a neighborhood will result in very fine resolution, which is not adequate for detecting topographic depressions over large areas. Selecting too large of a neighborhood will result in depressions which may encompass upland areas as well. For the central project area, a circular neighborhood with radius of 240 meters will be selected based on the results of the east-central and northeastern project area.

*Compound Topographic Index (CTI)* – CTI is a function of both the slope and the upstream contributing area. CTI can be calculated as: $CTI = \ln (A_s / (\tan(\beta))$, where $A_s$ = contributing area and $\beta$ is the slope expressed in radians. Slope and flow direction can be calculated using the TauDEM tool (Tarboton 2003). Flow direction can be calculated using the D-Infinity (D-inf) algorithm. Flow direction can then be used to derive the contributing drainage area, also using TauDEM. The slope grid and contributing area are then plugged in the equation for CTI.

### Modified USGS 1:24,000 Quadrangle Tiling Scheme

The central Minnesota project area will be divided into easily digestible and trackable parts based on the USGS 1:24,000 quadrangles that will be modified in order to minimize the number of wetlands that occur on the border of adjacent quadrangles (see Figure 2). The USGS 1:24,000 quadrangles will be manually edited so that the boundary of the modified quadrangles overlay roads, ridges, or other areas of high slope. Minimizing the number of wetlands that cross quadrangle borders will allow for more efficient incorporation into the seamless database and ultimately a higher quality product. PIs will interpret one modified quadrangle at a time and the updated NWI will be submitted to the MN DNR for review according to the modified USGS 1:24,000 quadrangle tiling scheme.

### 2.3.4Layerstack Creation

The eCognition segmentation process requires the raster data be clipped to the same extent with the same projection. Therefore a “layerstack” (a tiff image or img file with multiple bands) will be created to contain all of the LiDAR derived products. The process for creating the tiff layerstack is summarized in Figure 5. The final tiff layerstack will consist of the following layers:

1) DEM
2) Slope
3) TPI
4) CTI
5) Maximum Height of 1st Returns
6) Average Intensity of Bare Earth

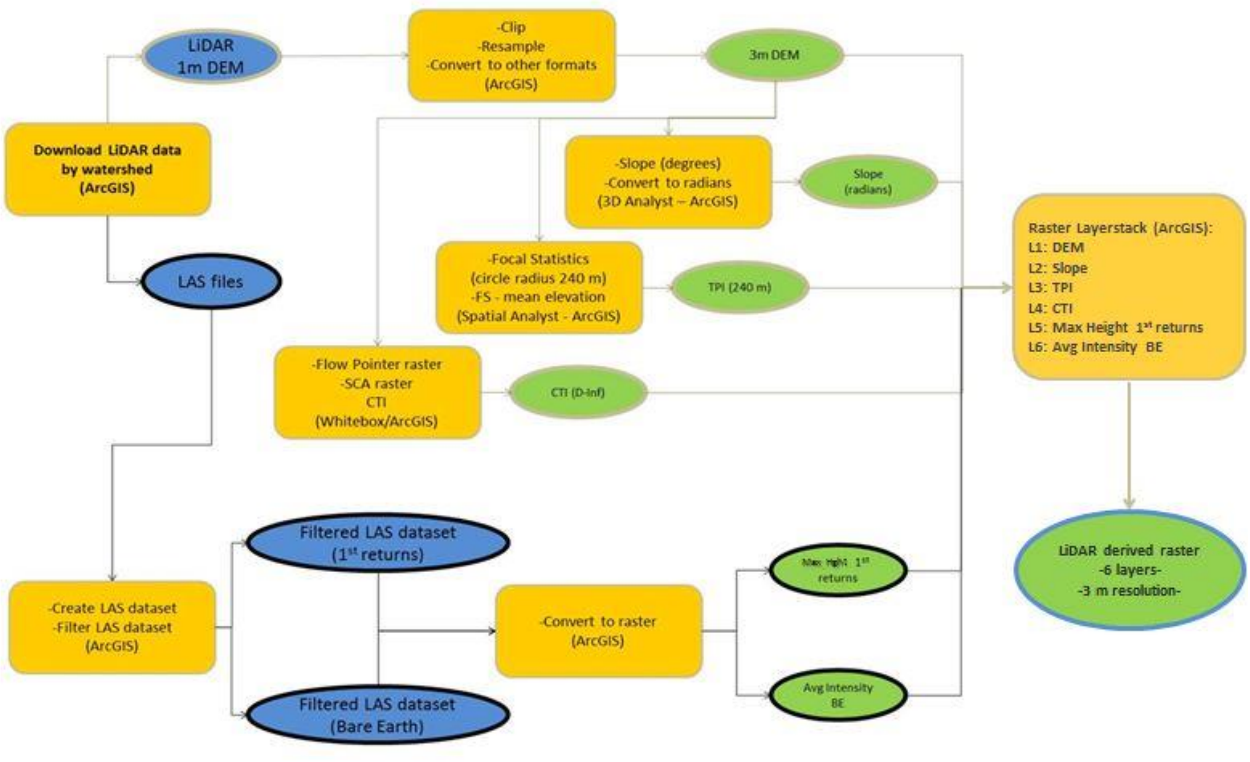



**Figure 5. LiDAR derived products and layerstack creation.**

### 2.3.6 Image Segmentation

The 2013/14 spring 4-band imagery and layerstack (described above) will be imported into eCognition software (Trimble 2015) to create the image segmentation files. The eCognition processing rule-set performs over 250 separate operations designed to reduce the amount of manual editing required from the photo interpreters. These operations include:

1. Initial Quad-tree image segmentation
2. Hierarchical image object aggregation by spectral, topographic, and classification based characteristics
3. Sub-processes to manage edge matching between adjacent tiles
4. Smoothing of all image object boundaries (vertices no closer than 10 feet)
5. Elimination of image objects smaller than the MMU ($1/20^{th}$ of an acre)
6. Export of a final shape file for each tile

Improvements to the rule-set and workflow refinement are continuous throughout the production process. Suggestions and requests to improve the properties of the segmentation will be made by the photo interpretation team and incorporated into subsequent versions of the segmentation process. The ultimate goal is to develop eCognition based segmentation and feature extraction processes that support and complement the work done by the photo interpretation (see Figure 4) team rather than to try to replace human photo interpretation entirely.

The goal of the image segmentation process is to have the photo interpretation team spend the vast majority of their time interpreting wetland classes that are difficult to classify instead of digitizing boundaries. This gain in efficiency allows the photo interpreters to spend more time on difficult classes, which ultimately increases accuracy. Most of the delineation effort will be allocated to making minor edits to existing polygons rather than on manually creating a new polygon for each wetland feature. All subsequent segmentation process development efforts will be directed toward improving the efficiency of the overall workflow in order to further reduce the amount of time required to complete the inventory. Overall efficiency also will improve by optimizing the rule set for efficient batch processing using the production oriented functions provided by eCognition Server software.

### 2.3.7 Limnetic and Littoral Subsystem Delineation

The lake bathymetry data (DEM and contours) are utilized in an iterative semi-automated process to create limnetic (L1) and littoral (L2) features for each lake in the project area. The rasterized data of the DEM will be converted to polygon features where any cell with a depth value of 8.2021 ft (2.5 m) or greater is classified as L1 and any cell with a depth value less than 8.2021 ft is classified as L2. The lakes for which the DEM bathymetry was not available the contour polyline data will be used. The contour data will first be converted to raster data in order to interpolate the depth between contour lines, which are given at a minimum of 5-foot intervals. This conversion is accomplished using the Topo to Raster tool of the 3D Analyst toolbox. Once the contours are rasterized the same process used to create the L1/L2 boundary from the DEM data is utilized.

Since the bathymetric data available could not be used to delineate an accurate boundary for lake shorelines, only the L1 features and those L2 features that are contained within L1 features (that may represent shallow areas surrounding islands, for example) will be selected from the results of the aforementioned process. These selected L1 and L2 features are then "burned" into the segments produced via the eCognition image segmentation process. Shoreline boundaries are delineated as part of the eCognition segmentation process. Littoral zones that occupy the area between the L1 features and the lake shoreline would be manually classified as such. For any lakes that are not included in the available bathymetry datasets the USGS digital topographic maps were consulted and a L1/L2 boundary will be approximated manually.

### 2.3.8 Photo Interpretation Process

A step by step outline of the photo interpretation process is listed below and displayed in Figure 6. The photo interpretation process will follow the protocols outlined in Dahl et al. 2009. The photo interpreters (PI) will start the process by importing the output of the segmentation process. The PI updates the status layer to "in progress" and proceeds to the photo interpretation process. The photo interpretation process consists of reviewing the segments (polygons created from the segmentation process) on a section by section basis with the aerial photos and ancillary data. The wetlands are identified within the section and classified according to the MN NWI classification scheme. The PI continues on a section by section basis until the entire area is completed. A second PI will then review the area for consistency and correct any discrepancies. After this initial review a third PI, a GIS specialist, will perform another review further assuring accurate and consistent classification and ultimately a high quality product. DU and FWS QA/QC tools will be run on the data and the lead image analyst will review the update and import it into the seamless NWI MGD. Upon approval from the lead image analyst, the draft data will be posted on DU's NWI web site for the MN DNR to download and review. Final edits from the MN DNR review and a final QA/QC will be performed on the area before it is checked back into DU's NWI MGD. When the entire project area is completed, the final seamless NWI update will be projected to Albers Equal Area Conic Projection, NAD83, meters. Both the Albers and UTM projected NWI update will be sent to the MN DNR.

**Step by Step Process**

1) Import PI area from segmentation process
2) Update NWI status layer to "in progress"
3) Update NWI layer using segments and primary data sources
4) Review update with ancillary data
5) Cross-validation with different interpreter
6) Second review by experienced GIS specialist
7) Run DU and FWS QA/QC tools
8) Lead image analyst review
9) Merge with seamless master geodatabase
10) Draft data ready for MN DNR to download and review
11) Status layer changed to "draft"
12) Final edits performed based on MI DNR review
13) Final QA/QC and review by lead analyst
14) Status layer changed to "final"
15) Final data sent to MN DNR

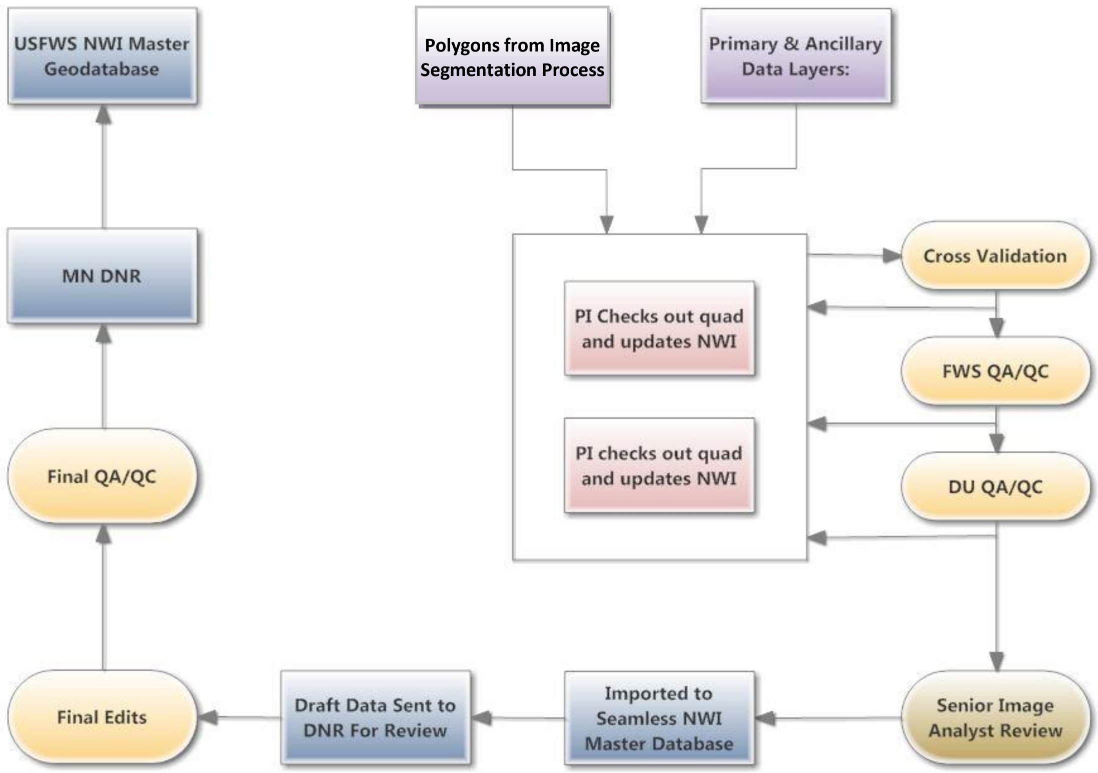



**Figure 6. Proposed NWI work flow.**

### Training

DU stresses consistency within the photo interpretation process so that a wetland class is interpreted the same throughout the project area. To obtain this consistency, DU performs the following management and training activities:

- Creation of a photo interpretation guide with multiple examples of each class
- Monthly staff meetings to review DNR assessments of draft data
- Review of every PI area and NWI attribute by the lead image interpreter

DU utilizes GIS Interns to complete a majority of the photo interpretation. The following steps will be taken to ensure adequate training is provided for the GIS Interns:

- Successful completion of "Wetland Mapping Training" online tutorial by the U.S. Fish and Wildlife Service [http://www.fws.gov/wetlands/_/Wetlands-Mapping-Training/]
- Day long training session describing the process and a field excursion
- Review MN NWI classification scheme and photo interpretation guide for Minnesota
- Dual interpretation for one quadrangle with experienced image interpreter
- Cross validation with different interpreter
- Second cross-validation with GIS specialist
- Full review of PI area by lead image analyst

### Photo Interpretation Guide

A photo interpretation guide has been created for the East-central and Northeastern project areas to assist interpreters and help standardize NWI update methodology. This guide will be expanded based on examples from the Central project area. This guide includes a brief description of the wetland class and is followed by a representative photo taken during the field training data process, as well as aerial imagery for spring and summer in CIR and natural color. These images help the interpreter identify wetland types by viewing ground photos with paired aerial photos for the same wetland type.

### Classification Scheme

The classification scheme will follow the NWI classification for Minnesota as outlined in the document titled "Cowardin Classification System Guidance for the Minnesota National Wetlands Inventory Update." Special attention will be given to the bog special modifier, as it is an important component in the simplified plant community classification system. A complete list of NWI codes allowed in the MN NWI classification will be generated from this document and used in the custom DU QA/QC tools to ensure the codes conform to the official list for Minnesota. Since the list of MN NWI codes is going to be extensive when combining all of the combinations of classes, subclasses, water regimes, and special modifiers, domains will not be set for the NWI code field in the geodatabase. Instead, global variables will be stored in the custom attribute table that will allow the most common codes to be populated in the pick list (please see Custom Object Inspector section below). DU has found this process the most efficient method for updating the NWI because it allows for fast selection of the most common codes and the ability to change attributes quickly for the less common codes. Otherwise, the pick list becomes too long to be efficient, or one would need to add additional attribute fields for the class, subclass, water regime, and special modifier and concatenate them together to get the resulting code. DU's interpreters are efficient at using the NWI codes and any typo or accidental unofficial code will be caught in the QA/QC process.

### Target Mapping Unit

As stated in the request for proposals (RFP), all visible wetlands on the imagery at a scale of 1:6,000 will be mapped. The accuracy of the NWI update will be performed on wetlands greater than ½ acre. This standard will be documented in the mapping methods and metadata for the NWI update.

### Field Verification

The field verification will serve two purposes: 1) train the interpreters though on-the-ground experience and inclusion of site based photos for the photo interpretation guide and 2) provide quality assurance data review. The field verification will occur at three different times: spring 2016, fall 2016, and spring 2017. Staff from DU will assist the RA staff with the field verification in the spring of 2016 so they can gain on-the-ground experience with the wetlands in

Central MN. The RA staff will be responsible for the field work in the fall of 2016 and spring of 2017.

The original NWI will be used to identify wetland types to field visit for the spring of 2016. A stratified sample of the wetland types will be selected based on accessibility and efficiency. The field verification crew will be provided with a laptop with the wetland polygon location. The crew will recording the MN NWI class, subclass, water regime and special modifiers for the site and take a digital photograph of the site. Once the field verification is complete, the field information will be compared to the original NWI classification. A determination of the proper code will be made by a consensus of the image interpreters. In cases of confusion, the MN DNR and FWS NWI coordinator will be consulted. The field verification in the fall of 2016 and spring of 2017 will be performed by the MN DNR Resource Assessment staff. DU will provide the RA staff locations of wetlands that were difficult to determine from the photo interpretation process or unique classes that can be added to the photo interpretation guide.

#### Photo Interpretation Process

The photo interpreters view the segments over the spring 2013-14 imagery to identify wetland segments. The photo interpreters use the spring imagery, professional knowledge, photo interpretation guide, as well as the summer and fall imagery to assign the NWI code. Additional data layers (e.g. USGS DRG, SSURGO soils, DEM and other LiDAR-derived products) are also available to assist with the NWI classification. Adjacent segments of the same class are merged. Segments that have multiple wetland classes or combine wetland and upland classes are cut into separate polygons to conform to the NWI class boundary. Each PI area is interpreted systematically until the entire area had been completed.

### 2.3.9 Quality Control Procedures

The QA/QC process for the NWI update will consist of self-validation tests run by the PI, cross validation by a different PI, a review by a GIS specialist, and final review and approval by a senior image analyst. There are two self-validation tests that the PI runs after completing the NWI update for an area. The first is the FWS QA/QC tool that checks for spatial and attribute errors. Second, DU has a custom QA/QC tools to check against the official MN NWI codes and wetlands in the potential wetlands or local wetlands layer that may have been missed. After the PI has completed the self-validation checks, a different PI reviews the area (cross validation) and runs the QA/QC tools, followed by a third review by a GIS specialist. This process helps maintain consistency between PIs as well as a review for interpreter errors. Finally, the senior image analyst reviews the area before it is considered "Draft" and sent to the MN DNR for review.

#### Self-Validations

FWS QA/QC Tools – The FWS NWI attribute and verification tool checks for NWI attribute errors and spatial errors (Figure 7). The updated NWI data must pass the FWS attribute and verification tool in order for the FWS to accept the update back into the FWS NWI MDG. For more information on the USGS NWI attribute and verification tool, please see http://capp.water.usgs.gov/FWS_web/tools.htm.

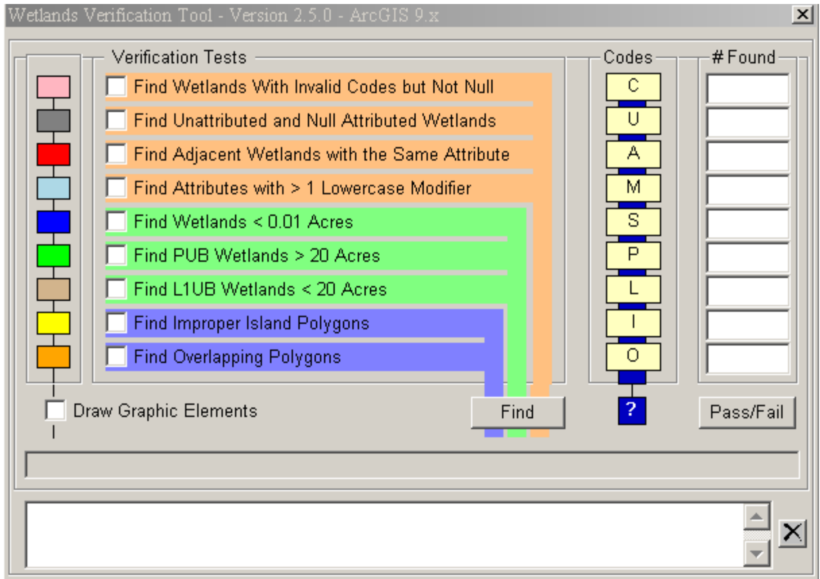



**Figure 7. FWS NWI QA/QC tool.**

<u>DU QA/QC Tools</u> – Tools to check for valid MN NWI codes and missing potential wetlands have been created as part of the MN NWI update project. All NWI codes must conform to the list of codes outlined in the document entitled "Cowardin Classification System Guidance for the Minnesota National Wetlands Inventory Update." A master list of acceptable NWI codes has been created from this document and will be used to compare all of the codes in the MN NWI database. Any code that does not conform to this list will be identified and fixed. The tool will be run until the test is successful. A tool was created that intersects the NWI update with the potential wetland, local wetland layers and wetland restoration sites. Any wetland missing from the NWI update will be reviewed.

### Cross Validation

A different PI is asked to review each NWI update area. The PI visually inspects the entire area for both spatial and attribute errors, making minor corrections as needed. If the reviewing PI finds an unacceptable amount of errors, the area is sent back to the original PI for revision and the QA/QC process begins anew. After the second PI finishes reviewing the interpreted area, a more experienced photo interpreter, a GIS specialist, performs an additional cross validation. This iterative cross validation is important to maintain consistency between PIs.

### Senior Analyst Validation

As the final step in the QA/QC process, a senior image analyst reviews the NWI update. Any changes to the update are reviewed with the PI. The FWS and DU QA/QC tools are performed a second time. A tile is considered "draft" once it successfully passes the Senior Analyst validation.

### Draft versions posted

Once the update NWI area passes the QA/QC process, the senior image analyst appends the area to DU's MGD and the NWI status layer for that area is updated to "Draft." A replica of the database is made available on-line (or sent to the MN DNR) for review.

### Final review

Comments received from the MN DNR on the Draft versions of the NWI tiles will be addressed and a final review and QA/QC will be performed. Once all reviews are accomplished, the areas will be considered final and checked back into DU's NWI MGD. The NWI status layer will be changed to "completed" for that area.

## 2.3.10 Project Management

The following management techniques will be used to ensure timelines and accuracy standards are met:

- Project status geodatabase to track the status of the NWI quads
- Detailed project work plan
- Quarterly progress reports
- Customized QA/QC tools
- PI training and review
- Single lead image analyst to review all NWI data

In order to inform the MN DNR and its partners of the status of the project, DU will modify its MN NWI project status geodatabase to identify which areas are currently being updated, being reviewed by the MN DNR and which ones are completed. This layer can then be used in the MN DNR NWI review application (Figure 8).

<u>Status Layer Definitions</u>

| | |
|---|---|
| **In Progress** – | Quad has been checked out and the update is currently taking place |
| **Draft** – | Quad has been sent to MN DNR for review |
| **Final** – | Quad has been reviewed and checked back into the DU NWI MGD |

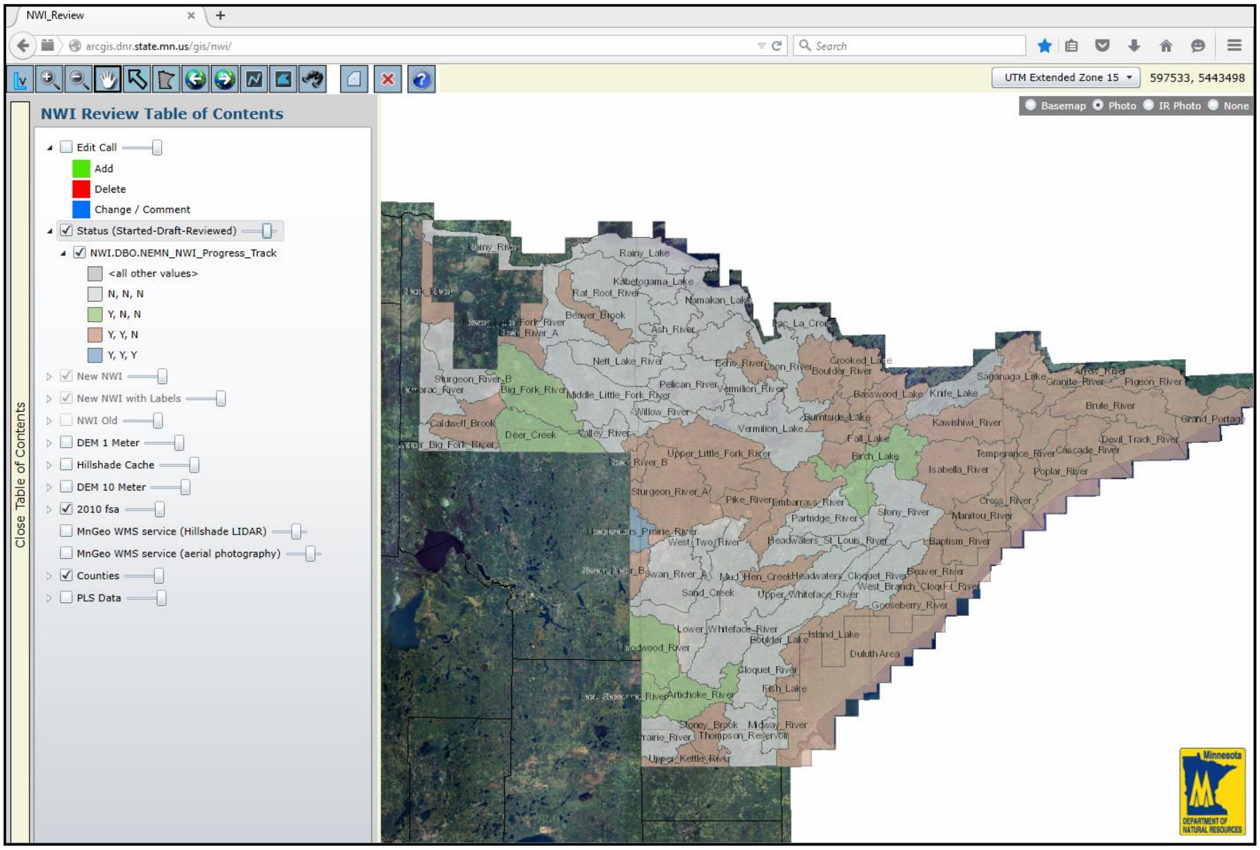



**Figure 8. Example of the NWI status layer and MN DNR review application.**

### 2.3.11 Simplified Plant Community Classification

The Simplified Plant Community Classification (SPCC) will be added to the NWI update for the central project area using the document titled "Simplified Plant Community Classification System for the Minnesota National Wetlands Inventory Update" as listed in the RFP. Most of the SPCC is directly correlated to the FWS NWI codes. The one exception is the bog (q) special modifier. Since the MN NWI codes include the bog special modifier, and it will be included in DU's methodology for the NWI classification, no additional interpretation will be needed to add the SPCC to the NWI geodatabase. A correlation from the NWI code to the SPCC will be created and added to the attributes.

DU will utilize geoprocessing functionalities within ArcGIS to generate a script to populate the SPCC based on the NWI code (Figure 9). There are no additional input data, hardware or software required. The script can be run under any ArcGIS desktop environment and can be easily integrated into the vendor internal QA/QC procedure. The following lists the steps of developing, testing, deploying, and distributing the script.

(1) Write the Python script in Notebook and saved it into a .py file.
(2) Test the script and check the field to see if it's correctly populated.
(3) Import into ArcToolbox as an Arctool with a user-friendly interface.

Recoding.py - Notepad

File Edit Format View Help

```
....

# create an updatecursor...
rows = gp.UpdateCursor(MNNWI)
row = rows.Next()

while row:
    # get value of the COWARDIN field...
    cowardin = row.COWARDIN

    # recoding...
    if cowardin in ("PEM1C", "PEM1F", "PEM2F"):
        plantcommunity = "Shallow Marsh"
    elif cowardin in ("PEM2G", "PEM2H", "PABF", "PABG"):
        plantcommunity = "Deep Marsh"
    ....
    ....

    # update PLANTCOMMUNITY field...
    row.SetValue("PLANTCOMMUNITY", plantcommunity)
    rows.UpdateRow(row)

    ....
    ....
```

**Figure 9. An example of part of the SPCC code.**

## 2.3.12 Simplified Hydro-Geomorphic Classification

A Simplified Hydro-Geomorphic (HGM) Classification will be added to the NWI classification based on a script created for the Northeastern MN project area. We anticipate some slight modifications to the script based on the outcomes of running the script on the Northeastern project area and additional inputs from experts. The methods are as follows:

**Required Datasets:**

(1) Central MN NWI layer with valid NWI codes
(2) MN DNR streams data
(3) Public Water Inventory (PWI) basin layer
(4) Slope layer generated from DEM (Raster format)
(5) Landscape position mask.

**Required 6 Fields for the NWI layer:**

(1) Landscape
(2) Landform
(3) Water flow
(4) Secondary water flow
(4) HGM_NAME
(5) HGM_CODE

**Derived Data:**

Two additional layers are developed from the MN DNR stream data. The first layer is a flooding stream layer that is used later to define the extent of the lotic landscape component. The flooding stream layer is created by deleting all of the drainage ditches, connectors and small streams from the stream layer. Small headwater streams and artificial channels are generally found not to have developed flood inundation areas. A visual review of the flooding stream layer is conducted and any stream without a visible floodplain will be deleted.
The second layer is a stream layer for the water flow path analysis. All streams are used and visually reviewed for accuracy. The visual review of the stream layer digitized any stream that does not completely connect with a lake or any missed stream that would affect the water flow path analysis.

A landscape position mask is created in order to identify the landscape position component of the HGM class. The mask consists of identifying the lentic and lotic landscape positions and the remaining areas are considered terrene. The lentic and lotic landscape position are created from the ordinary high water mark delineation of lakes from the Minnesota Department of Natural Resource's Public Water Inventory (PWI) basin layer and the flooding streams layer as described below.

To identify the lentic landscape position, a lentic layer is derived from the PWI. The PWI basin layer contains both wetlands and open water bodies delineated to the ordinary high water mark. A spatial selection is done between the PWI layer and all lacustrine wetlands within the NWI. A reverse selection is performed to identify any feature within the PWI that is not associated with a lacustrine wetland within the NWI. These features are reviewed for accuracy and deleted. The remaining PWI basins are then used to create a lentic landscape position feature class.

To identify the lotic landscape position, a riparian area layer is derived from the flooding stream layer and the DEM. A slope grid is first calculated on the DEM layer, which is used to create a fractional slope grid (rise over run). The fractional slope grid is used in conjunction with the stream floodplain layer to run a cost-distance analysis, where the flooding stream layer is the source feature and the fractional slope is used as the cost. The results from this analysis provide an approximation of the height above the nearest stream. A threshold classification approach is used to select a height above the nearest stream that corresponds to the extent of the riparian area. This threshold is selected based on visual inspection of the DEM, aerial photos and FEMA floodplain delineation, where available.

A landscape position classification layer is made by combining the lentic and lotic layers. Lentic features are given priority over lotic features when they overlapped. Any areas within the project boundary not covered by either lotic or lentic features are assigned to a terrene class. A final inspection of the lotic feature class is performed to remove any small polygons surrounding the lentic features.

In order to assign slope wetlands to the Landform type, a two percent slope layer is created using the DEM. A percent slope grid is calculated from the DEM and all areas greater than two percent slope were identified. Any cell with a value of two percent slope or less is reclassified with a value of 1. Any cell with a value of greater than two percent is reclassified to a value of 2.

**Classification Process:**

The model inputs are: 1) NWI layer with the following fields: landscape, landform, water flow, secondary water flow, HGM_Name, and HGM_code; 2) landscape position mask; 3) two percent slope layer; 4) stream water flow layer; and 5) lentic layer.
The model is composed of six primary steps: 1) assignment of landscape position, 2) assignment of landform classes within the lentic landscape position, 3) assignment of landform classes within the lotic landscape position, 4) assignment of landform classes within the terrene landscape position, 5) assignment of water flow path, and 6) quality control review and assignment of secondary waterfowl path (Figure 10).

The landscape position mask is used to assign the lentic, lotic and terrene landscape positions to all of the NWI wetlands. A majority rule is used for wetlands intersecting multiple landscape positions within the mask. The lotic position is further sub-divided by using the NWI riverine class (15 feet wide and larger) and assigning those wetlands a lotic river position with any remaining lotic positions being assigned lotic stream. Defining the landscape position restricts the potential landform classes that can be assigned to any given wetland. For example, lentic and lotic landscape positions cannot have slope landforms.

Wetlands within the lentic position are classified into landform types fringe, basin or flat based on NWI water regime. Wetlands with a semi-permanently flooded (F) water regime are assigned the fringe landform type. Wetlands with a seasonally flooded (C) water regime are assigned a basin landform type and any remaining lentic wetlands are assigned the flat landform type.

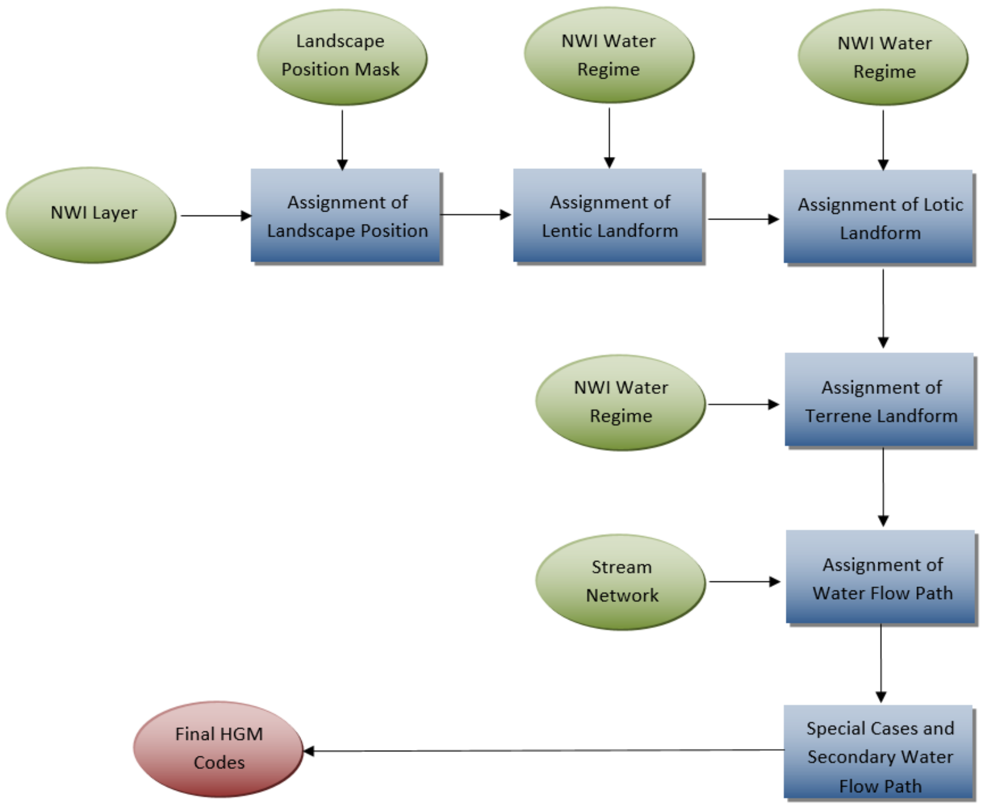



**Figure 10. HGM classification flow chart.**

Wetlands within the lotic position are classified into landform types fringe, floodplain, or reclassified into the terrene landscape position. Wetlands with an unconsolidated shore class or semi-permanently flooded (F) water regime are assigned the fringe landform type. Wetlands with a temporarily flooded (A) or seasonally flooded (C) water regime are assigned the floodplain landform type. All wetlands within the lotic position with a saturated (B) water regime are re-classed to the terrene landscape position. The saturated water regime is characteristic of bog wetlands which are mostly associated with the terrene landscape position.

Wetlands within the terrene position are classified into landform types of fringe, basin, flat or slope based on the water regime or two percent slope layer. Wetlands with a semi-permanently flooded (F) water regime are assigned the fringe landform type. Wetlands with a seasonally flooded (C) water regime are assigned the basin landform type and wetlands with a temporarily flooded (A) water regime are assigned the flat landform type. Wetlands with a slope greater than two percent are assigned the slope landform type (these wetlands should also generally have a saturated (B) water regime).

The water flow path is assigned by determining the location of the wetland in relation to the stream layer. If the stream layer ended at the wetlands, it is assigned an inflow water flow path. If the stream layer started at the wetland or if the wetland is adjacent to a riverine wetland it is assigned an outflow water flow path. If the stream flowed through the wetland, it is assigned a through flow water flow path. All wetlands without stream connection are assigned the vertical flow water flow path. All riverine wetlands are assigned a through flow water flow path.

Finally, the classification process includes a step to address some situations that are not addressed by the above steps. Any wetland that is surrounded by open water or aquatic bed is assigned the island landform type. Peatlands identified through photo-interpretation and assigned the special modifier “q” are also assigned the peatland landform type. Any lacustrine open water wetland is assigned the lake landform type and any palustrine open water wetland is assigned the pond landform type. Any riverine open water wetland is assigned the river landform type. Any slope wetland is assigned an outflow water flow path. Any fringe landform type with either a lentic or terrene landscape position is assigned a bi-directional water flow path and any wetland with a peatland modifier is assigned a terrene landscape position and vertical flow water flow path.

| Landscape Position | | Landform/Waterbody | | Water Flow Path | |
|---|---|---|---|---|---|
| NAME | CODE | NAME | CODE | NAME | CODE |
| Lentic | LE | Island | IL | Inflow | IN |
| Lotic River | LR | Fringe | FR | Outflow | OU |
| Lotic Stream | LS | Floodplain | FP | Throughflow | TH |
| Terrene | TE | Basin | BA | Bi-directional Non-tidal | BI |
| | | Flat | FL | Isolated | IS |
| | | Slope | SL | | |
| | | Lake | LK | | |
| | | River | RV | | |
| | | Pond | PD | | |

**Table 1. HGM description crosswalk to HGM codes.**

### 2.3.13 Extended Mapping of Watercourses

The National Wetland Inventory (NWI) update for central Minnesota will incorporate extended mapping of watercourses. This work will include mapping the stream banks in polygon format for all watercourse features that correspond to the Minnesota DNR's Public Water Inventory (PWI), including the ones below the federal wetland mapping standard of 5 meters. This mapping will be accomplished using on-screen digitizing with pen tablets using the spring 2013-14 imagery and the Lidar-derived layers.

The data should represent the PWI watercourse where possible, but the authoritative source should be interpretation of the existing watercourses as represented in current LiDAR and aerial imagery. The additional features captured as part of this task will be incorporated in a topologically integrated and extended version of the NWI dataset.

Watercourse will be kept continuous, where practical, except where tributaries enter another watercourse, where the stream enters an open water body such as a lake, or where the feature changes from a natural class to an altered natural class. Connecting features will be created where watercourses cross roads. Watercourse will be delineated through wetlands only where the watercourse is visible.

A special modifier (d) will be assigned to the NWI code to indicate features that are interpreted to be altered, channelized, or ditched natural watercourses. All watercourse features corresponding to PWI watercourse should be identified as such in an attribute field.

# 3.0 DELIVERABLES

## 3.1 Kick-Off Meeting and Technical Workshop – No later than 11/31/2015

DU will provide a work plan to meet DNR approval that includes documentation of standard operating procedures for the MN NWI wetland delineation and attend an initial project meeting to review procedures. DU will work with MN DNR to develop and hold a meet with wetland and remote sensing experts to assist with the development of segmentation rules for the wetland delineation.

## 3.2 Technical Procedures Document Approved – No later than 11/31/2015

DU will provide a technical procedures document and photo interpretation guide for approval by the MN DNR.

## 3.3 Field Work – One week between April and June 2016

DU will work with MN DNR to do field visits for one week during the spring (April to June) 2016. DU will select field sites representative of the project area and visit as many of the sites as possible during the week.

## 3.4 Draft Version of NWI Update – 7/31/2017

Once the updated NWI watershed passes the QA/QC process, the Senior Image Analyst updates the NWI status layer for that quad to "Draft". The draft NWI quad will then be posted to the DU NWI web site for the MN DNR to download. The MN DNR will then be notified that a draft quad is ready for review.

## 3.5 Simplified Plant Community Classification– 9/30/2017

DU will utilize geoprocessing functionalities within ArcGIS to generate a script to populate the Simplified Plant Community Classification based on the NWI code. The final version of the updated NWI will contain an attribute field with the Simplified Plan Community Classification. DU will populate an attribute field in the final version of the updated NWI with the simplified Hydro-Geomorphic (HGM) classification. DU will work with the MN DNR and other experts to assess the HGM classification results.

## 3.6 Simplified Hydro-Geomorphic Classification– 9/30/2017

DU will develop the layers necessary to run the HGM script, work with the MN DNR to update the HGM script if necessary and perform any quality control of the final classification.

## 3.7 Seamline/Edge-Matching between Project Areas– 9/30/2017

DU will edge-match the central Minnesota NWI update with the Northeastern, East-Central, and Southern NWI update project areas.

## 3.8 Extended PWI Watercourse Mapping– 9/30/2017

DU will provide polygon delineations of the PWI stream watercourse mapping based on the spring aerial photos.

## 3.9 Final Data Delivery – 9/30/2017

Two copies of the final data submitted in a single seamless GIS data layer with metadata provided on portable hard drives or other such media as deemed acceptable by the State. One copy shall use the Minnesota standard geographic data project (UTM-15N, NAD83, meters) and the second copy shall use the USFWS standard geographic data projection (Albers Equal Area Conic Projection, NAD83, meters). The final Geodatabase will contain attributes for the Simplified Plant Community Classification and Simplified HGM classification.

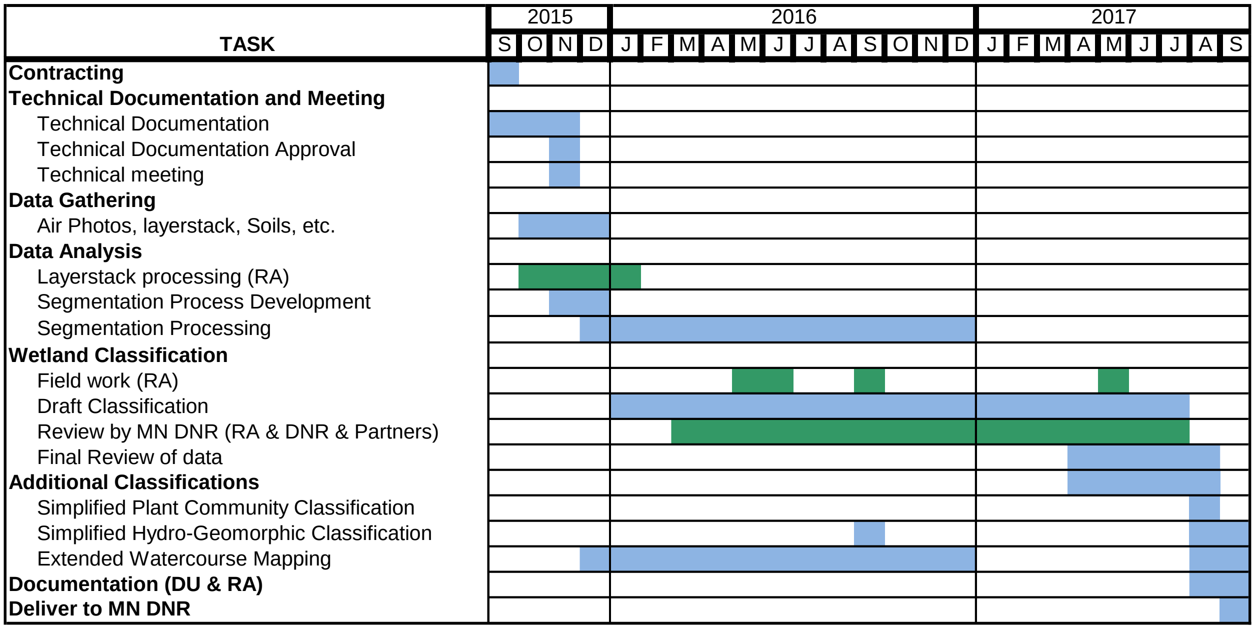
## 3.10 Final Documentation – 9/30/2017

A final report will be created detailing the mapping methods. The final report will be submitted to the MN DNR for review before the final products are generated. Metadata compliant with the requirements of the Minnesota Geographic Metadata Guidelines will be created and incorporated into the final file Geodatabase. The final Geodatabase will contain attributes for the Simplified Plant Community Classification and Simplified HGM classification

# 4.0 TIMELINE

DU anticipates completing the technical documentation and meeting by the end of November, 2015 (Table 1). Data gathering and loading of the imagery and ancillary data will begin in October, 2015 and be completed in December, 2015. The segmentation process will begin in November, 2015 and be complete in January, 2016. The field work will be accomplished in May/June, 2016, September, 2016, and May/June, 2017. The wetland classification will begin in January, 2016 and be completed in July, 2017. The final report and data will be delivered by September 30, 2017.

**Table 1. Timeline for the Central MN NWI Update.**




# 5.0 DEPENDENCIES

The following project tasks will be completed by the MN DNR Resource Assessment (RA) under a separate agreement:

**Field work** **Spring 2016, Fall 2016, Spring 2017**

The field verification will occur at three different times (spring 2016, fall 2016 and spring 2017). Staff from DU will assist the RA staff with the field verification in the spring of 2016 so they can gain on-the-ground experience with the wetlands in central MN. The RA staff will be responsible for the field work in the fall of 2016 and spring of 2017. DU will provide wetlands locations for the RA staff to field verify.

**Layerstack processing** **October 2015 to January 2016**

RA will deliver to DU layerstacks of the Lidar derived products as described above for each of the watersheds within the project area.

**Quality assurance** **March 2016 to December 2017**

RA will provide review comments of the draft data to DU for incorporation into the final data. The review will occur within one month of delivery of the draft data.

**Project documentation** **February 2018**

The RA staff will create the documentation for the LiDAR processing, field verification and quality assurance. In addition, the RA staff will review the entire project documentation and metadata for accuracy and completeness.

# 6.0 WORKS CITED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